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IWPE - 109

Materials Characterization - II

(June, 6, 1994 -)

N. Sridhar 4/28/94

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N. Sridhar; Yi-Ming Pan; Darrell Dunn

6/8/94 Characterization of Precipitates Formed during Aging of Alloy 825. - INITIAL ENTRY

Objectives

1. Determine the types of precipitates that form at the grain boundaries of alloy 825 upon aging in the temperature regime of 600 to 750 C after solution annealing.

2. Determine the changes in concentration profiles near the grain boundaries as a result of precipitation.

Approach

Selected specimens will be examined by transmission electron microscope with an energy dispersive X-ray attachment to determine the type of precipitates formed (carbides, sigma phase or other intermetallics) and concentration profiles of Cr and Mo near the grain boundaries. Initially, one aging treatment (solution annealed at 1200 C/10 minutes/water quenched + Aged at 750 C/15 hours/air cooled) will be studied.

The effect of this heat treatment on corrosion has been recorded in CNWRA Scientific Notebook 032 and reported in CNWRA Report 93-003). The optical microstructures have been recorded in CNWRA Scientific Notebook 009.

Specimen Treatment

Alloy 825, Heat No. HH4371FG, 0.5" plate, supplied by Inco Alloys International. Specimens from this plate were solution annealed in Lindberg Model 51333 muffle furnace, Serial No. : 909172 at 1200 C for 10 minutes at temperature and water quenched. The temperature was monitored using a calibrated thermocouple (TC#1, CNWRA Scientific Notebook 032, page 7) and meter (Omega Model DP465, Serial No.: 3130900; Cal due date: 9/8/94). Subsequently, the specimen was aged at 750 C using the same furnace and monitoring equipment as above for 15 hours at temperature and still-air cooled. It was then cut into cylindrical specimens for corrosion testing and microscopy. The specimens were pickled ultrasonically in a mixture of 20% nitric + 6% HF (by weight) to remove the heat-treatment scale.

N. Sridhar dt 6/7/94

N. Sridhar 6/7/94

8/2/94

TEM Thin Foils Preparation From 760°C/15hr Aged Specimen

Slices of about 1,000 μm thick were cut from the cylindrical specimen and mechanically polished down to approximately 40 μm using a 6 μm diamond paste. Disc specimens 3 mm in diameter were then punched out and further thinned to perforation by jet polishing.

Two batches of TEM samples were prepared using two typical electrolytes and operation conditions as follows.

a) Batch 1 (Sample #1 & 2)

electrolyte:	Conditions:
300 ml methanol	19 V
180 ml ethylene glycol	6 ma
30 ml perchloric acid	-43°C

b) Batch 2 (sample #3 & 4)

electrolyte:	Conditions:
15% sulfuric acid in methanol	21 V
	65--75 ma
	-35°C

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8/2/94

8/3/94

TEM Observation of Specimens # 2 & 4

Thin foil specimens prepared by 8/2/94 were analyzed using a Philips EM 420 scanning transmission electron microscope (STEM), serial No.: D616. Grain boundary precipitates and their diffraction patterns were recorded in the following.

Sample #4

Negative No.	Magnification	Remark
8403	3,300	
8404	8,200	
8405	60,000	
8406	135,000	
8407	-	Diffraction patterns with a camera length of 350 mm
8408	-	
8409	135,000	
8410	60,000	
8411	-	Diffraction pattern with a camera length of 660 mm.

Sample # 2

8412	60,000
8413	300,000
8414	8,200

TEM examination indicated that, while grain boundary precipitates were seen, the electron transparent thin area was limited due to the electrolytes and conditions used for thin foils preparation. Another electrolytes to produce a larger thin area is necessary.

Ying Pan
8/3/94

Review of Electrolytes for Nickel-Based Alloys

Hastelloy B (~68 Ni - 28 Mo - 0.9 Fe - 0.002 C)

a) 30 vol% HNO_3 ; balance methanol
-30 °C

Grain-boundary Ni-Mo δ phase

Ref: H. M. Tawancy, Precipitation of Ni4Mo in a Ni-Mo base alloy, J. Mater. Sci., 15 (1980) 2597-2604.

b) One part HNO_3 + 3 parts methanol
-30 °C
Ref. H.M. Tawancy, Identification of eta-carbide in a commercial Ni-Mo alloy (Hastelloy® alloy B-2), J. Mater. Sci. letters, 16 (1981) 1117-8.

c) 640 ml H_3PO_4, 150 ml H_2SO_4, 35 ml HCl and 210 ml water
12 °C
25-30 volts
0.8-1.2 A
Ref. K. Vasudevan & E.E. Stansbury, Influence of Chromium on ordering of Ni4Mo, Scripta Metallurgica, 19 (1985) 1101-1106.

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Hastelloy C (66 Ni - 17 Cr - 17 Mo - 0.12 C)

a) C-4, C22, C276 / G.B. precipitation of P, μ, σ and MC carbide phases

10% Perchloric acid in methanol
-65 °C

Followed by ion milling to increase the amount of thin area and to remove any residue electrolyte

Ref. M.J. Cieslak, T.J. Headley and A.D. Romig, The Welding Metallurgy of Hastelloy alloys C-4, C-22, and C-276, Metall. Trans., 17A (1986) 2035-2047.

Incoloy alloy 825 (42 Ni - 30 Fe - 21.5 Cr)

a) 5% HCl in methanol for extraction-replica samples

10% HCl in methanol for X-ray samples by electrolytically dissolving.

Ref. E.L. Raymond, Mechanisms of sensitization and stabilization of Incoloy Ni-Fe-Cr alloy 825, Corrosion-NACE, 24 (1968) 180-188.

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8/14/94

8/5/94 TEM Photomicrographs of G.B. Precipitates (Sample #4)

TEM photomicrographs of G.B. precipitates from Samples #2 and #4 recorded on page 5 were documented below.

a) Sample 4

No. 8404 8,200X

Yuy Pan 8/5/94

No. 8405 60,000X

TEM micrographs of Alloy 825 aged at 750°C for 1000 hours showing particulate type precipitates in grain boundary.

Yuy Pan 8/5/94

b) Sample 2

No. 8414 8,200 X

TEM micrograph showing particulate type G.B. precipitates but different morphology compared to those in sample 4.

Yingpan
8/5/94

No. 8412 60,000 X

TEM micrograph showing film type G.B. precipitates.

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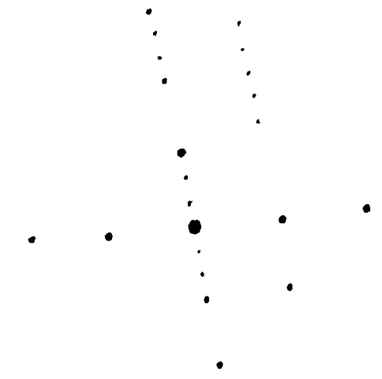
8/5/94

8/8/94 Diffraction Pattern Analysis

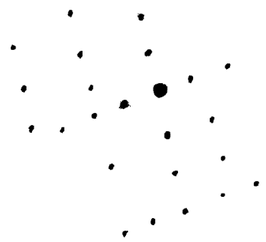
1. Selected diffraction patterns from specimen #4 recorded on page 5 were duplicated below.



NEG. No. 8411

L = 660 mm

where L = camera length



NEG. No. 8407

L = 350 mm

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2. Crystal structure information of chromium carbide ($Cr_{23}C_6$) was obtained from the PDF database published by the International Centre for Diffraction Data (ICDD) below.

35-783 JCPDS-ICDD Copyright (c) 1993 PDF-2 Sets 1-43 database Quality: *

Cr C
23 6

Chromium Carbide

Rad: CuKa1 Lambda: 1.540598 Filter: Mono. d-sp: Diff.
Cutoff: Int: Diffractometer I/Icor:
Ref: Natl. Bur. Stand. (U.S.) Monogr. 25, 21 62 (1984)

Sys: Cubic S.G.: Fm3m (225)
a: 10.6599(5) b: c: A: C:
A: B: C: Z: 4 mp:
Ref: Ibid.

Dx: 6.953 Dm: SS/FOM: F28=70(.011,38)

ea: nwB: ey: Sign: 2V:
Ref:

Color: Gray
Peak height intensities. The mean temperature of data collection was 24.0 C.
The sample was obtained from CERAC, Incorporated, Milwaukee, Wisconsin, USA.
CAS no.: 12105-81-6. Spectrographic analysis (wt.%, CERAC, Incorporated): Al, Fe, Si 0.1; Mo 0.08; Mg 0.07; V 0.01; Ti 0.008; Ni 0.003; Ca, Cu 0.002.
sigma(Iobs)=+/-1. C6Cr23 type. Si used as internal standard. PSC: cF116. To replace 14-407. Structure reference: Westgren, A., Jernkontorets Ann., 17 501 (1933). Mwt: 1267.97. Volume[CD]: 1211.32.

d A	Int.	h k l	d A	Int.	h k l	d A	Int.	h k l
6.148	1	1 1 1						
3.214	1	3 1 1						
3.077	1	2 2 2						
2.666	4	4 0 0						
2.445	1	3 3 1						
2.383	23	4 2 0						
2.176	24	4 2 2						
2.0520	100	5 1 1						
1.8840	20	4 4 0						
1.8016	22	5 3 1						
1.7767	12	6 0 0						
1.6857	2	6 2 0						
1.6261	2	5 3 3						
1.6067	6	6 2 2						
1.4930	<1	5 5 1						
1.4788	<1	6 4 0						
1.3327	2	8 0 0						
1.2928	2	8 2 0						
1.2560	12	8 2 2						
1.2308	6	7 5 1						
1.2227	15	6 6 2						
1.1920	2	8 4 0						
1.1698	4	9 1 1						
1.1174	1	9 3 1						
1.0879	6	8 4 4						
1.0712	3	7 7 1						
1.0453	<1	10 2 0						
1.0259	1	10 2 2						

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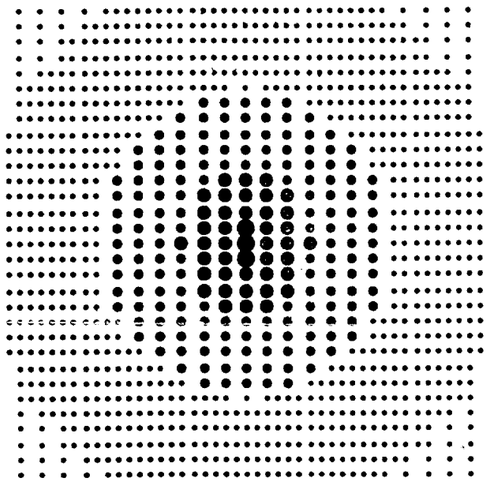
3. Determination of selected diffraction patterns

The crystallographic data were analyzed using the Diffract program distributed by Microdev Software. It is based upon the concept of the unit cell including the lattice parameters, the atomic positions, and the atom type occupying each atomic position.

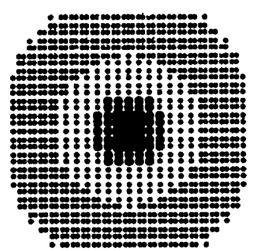
The selected diffraction patterns from the $Cr_{23}C_6$ crystal were determined and plotted.

$\lambda = 0.0371$ Å, $L = 660$ mm



[011] zone axis

$L = 350$ mm



[011] zone axis

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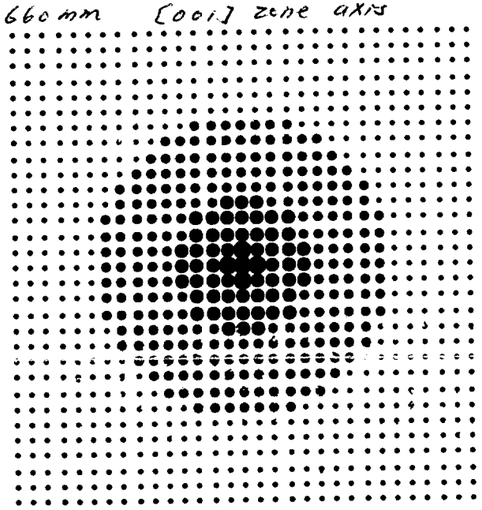
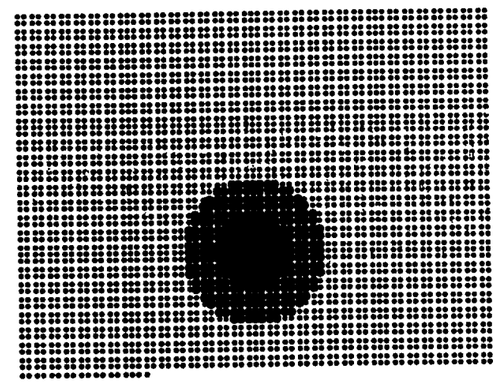
$L = 660$ mm [001] zone axis



$L = 350$ mm [001] zone axis



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8/15/94

A comparison between the selected area diffraction patterns from simulation and those by experiments indicate that the $Cr_{23}C_6$ crystal has diffraction spots with larger spacings. Additional diffraction pattern analysis and experimental work are needed using a double-tilt sample holder.

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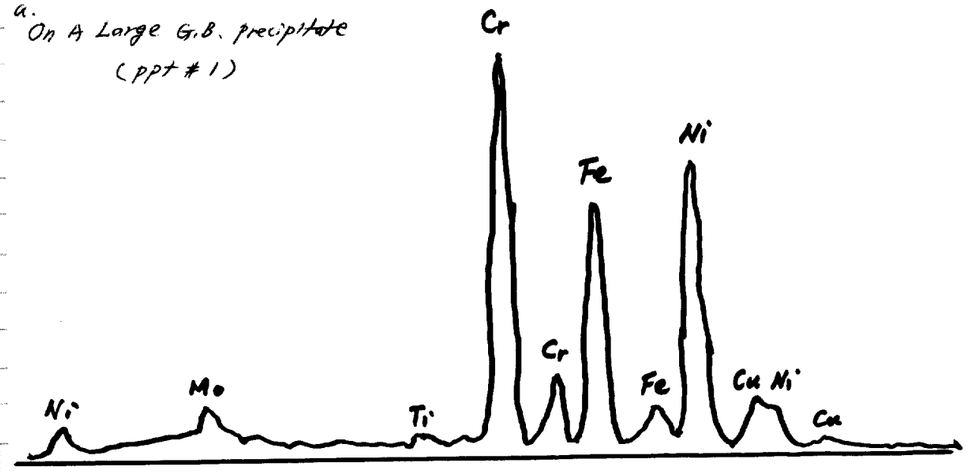
8/19/94

Chemical Analysis of the G.B. precipitates in Sample 4

Microchemical analyses of the precipitates and grain boundary region were conducted using a focused electron probe of about 20 nm diameter. The x-ray intensities were recorded with an energy dispersive x-ray (EDS) detector attached to the TEM instrument. Due to the instrument limitation, the EDS spectra were not able to be printed out. The spectra were then manually drawn from the screen for comparison purposes.

a. The first EDS analysis was performed on a large G.B. precipitate. (see the upper-right large particle in Photo No. 8405, p 9 ppt # 1). The spectrum was recorded for a duration of 150 sec. The vertical full scale (VFS) of the spectrum is 2,048 counts.

a. On A Large G.B. precipitate (ppt # 1)



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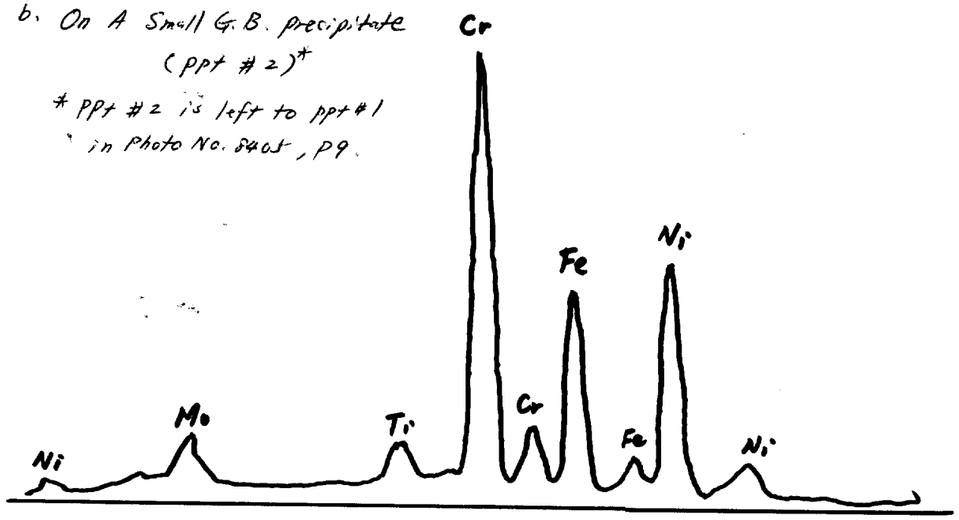
b. On A Small G.B. precipitate (ppt #2)*

* ppt #2 is left to ppt #1 in Photo No. 8403, P9.



X-Ray Energy →

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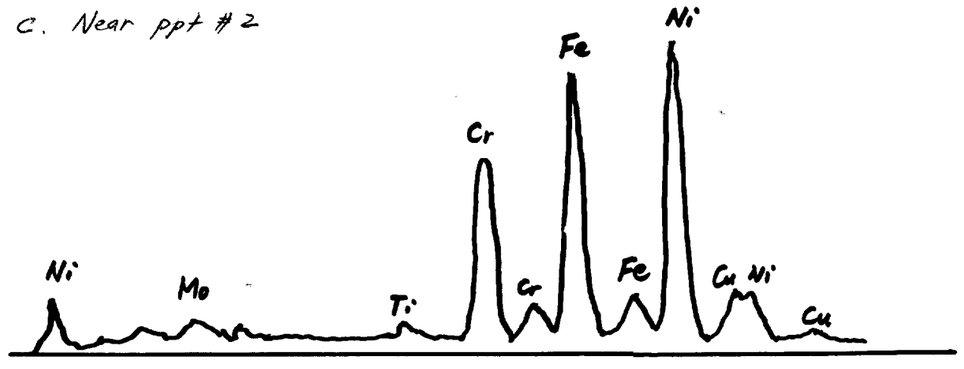
c. Near ppt #2

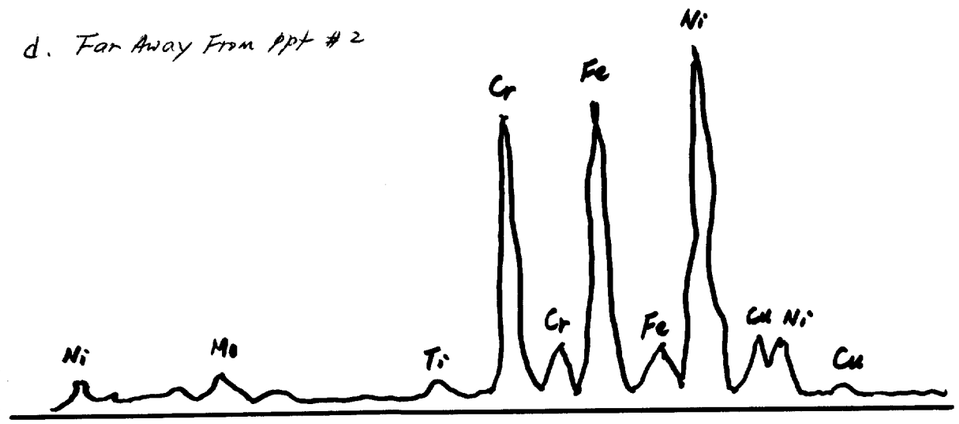


X-Ray Energy →

Yiqing Pan 8/15/94

Yiqing Pan 8/15/94

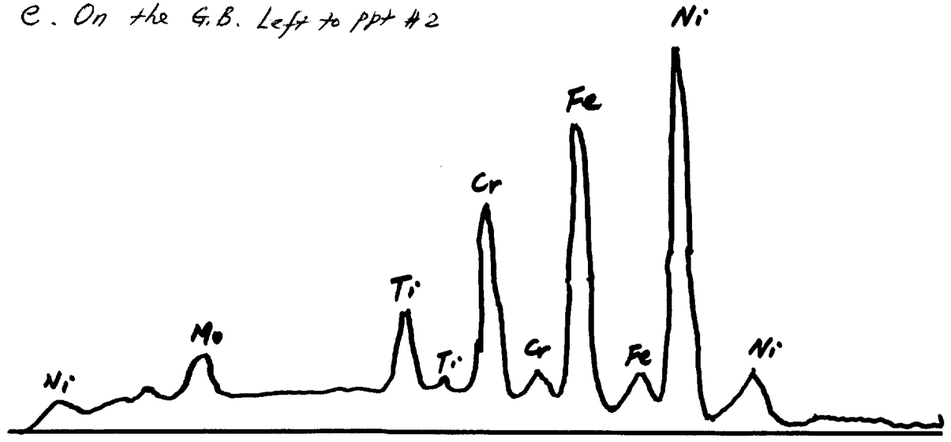
d. Far Away From ppt #2



X-Ray Energy →

Yiqing Pan 8/15/94

e. On the G.B. Left to ppt #2



X-Ray Energy →

Yiqing Pan 8/15/94

Yiqing Pan 8/15/94

The EDS spectra obviously indicate that, while the grain boundary precipitates are Cr-rich, the near grain boundary region is Cr-deficit. This is consistent with the observation of the depletion of Cr by formation of Cr-rich $M_{23}C_6$ precipitates at the grain boundaries reported in the literature.

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8/15/94

8/16/94

Quantitative EDS Analysis of Thin Specimens

Quantitation of the resulting x-ray intensities was accomplished using the Cliff-Lorimer method.* It has been shown for thin specimens:

$$\frac{C_A}{C_B} = k_{AB}\frac{I_A}{I_B}$$

where I_A and I_B are the measured characteristic x-ray intensities, and C_A and C_B are the atomic fractions of any two elements A and B in the specimen. The scaling factor k_{AB} is independent of the specimen thickness and composition, and varies only with the operating conditions of the microscope.

In this analysis, the k values were evaluated by measuring matrix (or bulk) compositions far from grain boundaries and comparing these value to the known bulk compositions from SEM/EDS data provided by Dr. Sridhar. It is more convenient to measure k for all the elements in combination with a single element, nickel in the case, i.e. $k_{x,Ni}$. Therefore, the above equation can be replaced by:

$$\frac{C_x}{C_{Ni}} = k_{x,Ni}\frac{I_x}{I_{Ni}}$$

* G. Cliff and G.W. Lorimer, J. Microscope, V.103, p 203-207, 1975.

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8/16/94

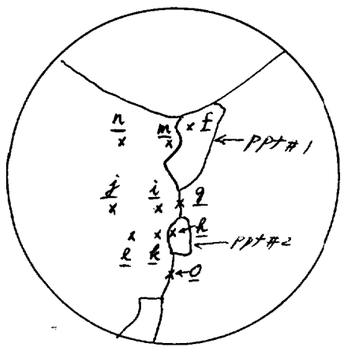
8/17/94 Chemical Analysis of Grain Boundary Region in Sample 2

Microchemical analysis was performed on several grain boundary regions and precipitates in Sample 2, as specified in the following sketch. Quantitative analysis was then done according to the method described in page 21. The results are presented below. ~~which are consistent with~~ YP 8/19/94

Photo 8412
Location P

I	1391.00	1536.00	1731.00	85.00	267.00	228.00	115.00
C(rat)	1.00	0.74	0.64	0.05	0.04	0.03	0.02
C(%)	39.74	29.49	25.52	1.90	1.46	1.02	0.88

Photo 8414 @ 60,000 X



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See p. 23

C_{Ni} (at any point) $= \frac{1}{[1 + \Sigma C(rat)]}$

Yij Pan 8/19/94

12/20/94

$$\frac{C_x}{C_{Ni}} = k_{x,Ni} \frac{I_x}{I_{Ni}}$$

	Ni	Fe	Cr	Mo	Cu	Ti	Si
k(x,Ni)	1.00	0.67	0.52	0.78	0.19	0.16	0.27
Photo 8414 (Sample #2)							
Loc. N&J	40.35	29.26	24.60	1.86	1.37	1.08	1.08
Location F							
I	3002.00	3541.00	5523.00	170.00	529.00	451.00	450.00
C(rat)	1.00	0.79	0.95	0.04	0.03	0.02	0.04
C(%) at.	34.68	27.49	32.92	1.54	1.17	0.82	1.39
Location M							
I	1924.00	2232.00	2366.00	137.00	385.00	351.00	190.00
C(rat)	1.00	0.78	0.63	0.06	0.04	0.03	0.03
C(%)	39.02	30.42	24.76	2.18	1.49	1.12	1.03
Location G							
I	3090.00	3212.00	3485.00	130.00	538.00	459.00	265.00
C(rat)	1.00	0.70	0.58	0.03	0.03	0.02	0.02
C(%)	41.79	29.19	24.32	1.38	1.39	0.97	0.96
Location I							
I	1963.00	2111.00	2322.00	118.00	349.00	323.00	205.00
C(rat)	1.00	0.72	0.61	0.05	0.03	0.03	0.03
C(%)	40.52	29.28	24.73	1.91	1.38	1.05	1.13
Location H							
I	3127.00	3400.00	4307.00	200.00	572.00	600.00	295.00
C(rat)	1.00	0.73	0.71	0.05	0.03	0.03	0.03
C(%)	38.73	28.30	27.53	1.94	1.35	1.17	0.98
Location K							
I	2633.00	2753.00	3015.00	182.00	476.00	506.00	248.00
C(rat)	1.00	0.70	0.59	0.05	0.03	0.03	0.03
C(%)	41.03	28.83	24.24	2.22	1.42	1.24	1.03
Location L							
I	2940.00	3087.00	3256.00	181.00	472.00	468.00	221.00
C(rat)	1.00	0.71	0.57	0.05	0.03	0.02	0.02
C(%)	41.65	29.39	23.80	2.01	1.28	1.04	0.84
Location O							
I	3420.00	3535.00	3743.00	175.00	603.00	516.00	275.00
C(rat)	1.00	0.69	0.56	0.04	0.03	0.02	0.02
C(%)	42.05	29.21	23.75	1.68	1.42	1.00	0.90

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It is interesting to point out the chemical concentration changes in this grain boundary region. Considering the changes in Cr concentration, while the precipitates do shows much higher Cr concentration, there is no depleted zone that can be identified in this region. Further concentration profiles needed to be determined, as well as the type of precipitates by electron diffraction method.

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Concentration Profiles of Grain Boundary Region in Sample 4

Chemical concentration profiles along the grain boundary region in sample 4 were measured using microprobe techniques with a focused electron probe of about 20 nm diameter. The chemical concentration results for each location are presented in the following. The change of Cr concentration across the grain boundary is clearly shown in a plot of Cr-content vs Distance From Grain Boundary. The Cr-depleted zone is approximately 250nm wide. In contrast, the Mo plot in a similar way doesn't show variation in the grain boundary region.

Sample 4	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
I(T-15)	592.00	559.00	488.00	16.00	38.00	80.00	72.00	46.00
k	1.00	0.77	0.74	1.71	0.53	0.20	0.22	0.12
I(T-20)	440.00	431.00	359.00	15.00	38.00	72.00	60.00	44.00
k	1.00	0.74	0.75	1.35	0.39	0.16	0.20	0.09
k(ave)	1.00	0.75	0.74	1.53	0.46	0.18	0.21	0.11
GB-1								
I	1292.00	981.00	662.00	20.00	88.00	114.00	84.00	62.00
C(rat)	1.00	0.57	0.38	0.02	0.03	0.02	0.01	0.01
C(at%)	48.94	28.02	18.64	1.16	1.54	0.78	0.66	0.25
GB-2								
I	1241.00	1025.00	685.00	21.00	100.00	135.00	83.00	64.00
C(rat)	1.00	0.62	0.41	0.03	0.04	0.02	0.01	0.01
C(at%)	46.83	29.17	19.22	1.21	1.74	0.92	0.65	0.26
GB-3								
I	1332.00	1113.00	685.00	18.00	113.00	136.00	85.00	74.00
C(rat)	1.00	0.63	0.38	0.02	0.04	0.02	0.01	0.01
C(at%)	47.39	29.86	18.12	0.98	1.85	0.87	0.63	0.28
GB-4								
I	1221.00	985.00	678.00	25.00	113.00	160.00	90.00	71.00
C(rat)	1.00	0.61	0.41	0.03	0.04	0.02	0.02	0.01
C(at%)	46.72	28.42	19.29	1.46	1.99	1.11	0.72	0.29
BG-5								
I	818.00	619.00	416.00	17.00	78.00	142.00	101.00	59.00
C(rat)	1.00	0.57	0.38	0.03	0.04	0.03	0.03	0.01
C(at%)	47.86	27.31	18.09	1.52	2.10	1.50	1.23	0.37

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T-1								
I	927.00	752.00	487.00	23.00	75.00	135.00	68.00	52.00
C(rat)	1.00	0.61	0.39	0.04	0.04	0.03	0.02	0.01
C(at%)	47.05	28.78	18.38	1.78	1.76	1.24	0.72	0.28
T-2								
I	873.00	729.00	544.00	14.00	85.00	104.00	76.00	51.00
C(rat)	1.00	0.63	0.46	0.02	0.04	0.02	0.02	0.01
C(at%)	45.28	28.85	21.23	1.12	2.06	0.99	0.83	0.29
T-3								
I	926.00	778.00	547.00	22.00	83.00	111.00	73.00	66.00
C(rat)	1.00	0.63	0.44	0.04	0.04	0.02	0.02	0.01
C(at%)	45.53	28.85	19.99	1.65	1.88	0.99	0.75	0.35
T-4								
I	1015.00	912.00	597.00	20.00	76.00	108.00	82.00	59.00
C(rat)	1.00	0.68	0.44	0.03	0.03	0.02	0.02	0.01
C(at%)	45.01	30.50	19.68	1.36	1.55	0.87	0.76	0.28
T-5								
I	949.00	787.00	575.00	15.00	77.00	107.00	81.00	58.00
C(rat)	1.00	0.63	0.45	0.02	0.04	0.02	0.02	0.01
C(at%)	45.83	28.66	20.64	1.11	1.71	0.93	0.81	0.30
T-6								
I	831.00	712.00	562.00	14.00	89.00	97.00	76.00	51.00
C(rat)	1.00	0.65	0.50	0.03	0.05	0.02	0.02	0.01
C(at%)	44.04	27.54	19.84	1.06	1.65	0.90	0.78	0.29
T-7								
I	725.00	652.00	505.00	13.00	64.00	83.00	77.00	56.00
C(rat)	1.00	0.68	0.52	0.03	0.04	0.02	0.02	0.01
C(at%)	43.19	29.29	22.36	1.18	1.76	0.89	0.95	0.36
T-8								
I	702.00	606.00	542.00	20.00	47.00	96.00	73.00	50.00
C(rat)	1.00	0.65	0.57	0.04	0.03	0.02	0.02	0.01
C(at%)	42.49	27.66	24.39	1.85	1.31	1.05	0.92	0.33
T-9								
I	640.00	538.00	459.00	11.00	57.00	81.00	65.00	54.00
C(rat)	1.00	0.63	0.53	0.03	0.04	0.02	0.02	0.01
C(at%)	43.71	27.71	23.30	1.15	1.79	1.00	0.92	0.40
T-10								
I	587.00	523.00	446.00	15.00	46.00	72.00	63.00	45.00
C(rat)	1.00	0.67	0.56	0.04	0.04	0.02	0.02	0.01
C(at%)	42.29	28.42	23.89	1.65	1.53	0.94	0.94	0.35
T-13								
I	682.00	596.00	507.00	16.00	58.00	78.00	89.00	59.00
C(rat)	1.00	0.66	0.55	0.04	0.04	0.02	0.03	0.01
C(at%)	42.66	28.11	23.58	1.53	1.67	0.88	1.16	0.40

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T-15								
I	592.00	559.00	488.00	16.00	38.00	80.00	72.00	46.00
C(rat)	1.00	0.71	0.61	0.04	0.03	0.02	0.03	0.01
C(at%)	40.75	29.02	24.97	1.68	1.21	1.00	1.03	0.34
T-20								
I	440.00	431.00	359.00	15.00	38.00	72.00	60.00	44.00
C(rat)	1.00	0.74	0.61	0.05	0.04	0.03	0.03	0.01
C(at%)	39.91	29.48	24.21	2.08	1.59	1.18	1.13	0.43
T-25								
I	538.00	508.00	418.00	18.00	50.00	94.00	66.00	45.00
C(rat)	1.00	0.71	0.58	0.05	0.04	0.03	0.03	0.01
C(at%)	40.82	29.07	23.58	2.09	1.75	1.29	1.04	0.37
B-1								
I	730.00	560.00	397.00	14.00	61.00	82.00	90.00	59.00
C(rat)	1.00	0.58	0.40	0.03	0.04	0.02	0.03	0.01
C(at%)	47.50	27.48	19.20	1.39	1.83	0.96	1.22	0.41
B-2								
I	644.00	544.00	359.00	15.00	59.00	83.00	71.00	47.00
C(rat)	1.00	0.64	0.41	0.04	0.04	0.02	0.02	0.01
C(at%)	45.80	29.18	18.98	1.63	1.93	1.07	1.05	0.36
B-3								
I	739.00	613.00	470.00	16.00	58.00	93.00	87.00	52.00
C(rat)	1.00	0.63	0.47	0.03	0.04	0.02	0.02	0.01
C(at%)	44.99	28.14	21.27	1.49	1.63	1.02	1.10	0.34
B-4								
I	705.00	614.00	433.00	14.00	56.00	81.00	75.00	51.00
C(rat)	1.00	0.66	0.46	0.03	0.04	0.02	0.02	0.01
C(at%)	44.82	29.44	20.46	1.36	1.64	0.93	0.99	0.35
B-5								
I	484.00	417.00	362.00	13.00	39.00	68.00	50.00	44.00
C(rat)	1.00	0.65	0.56	0.04	0.04	0.03	0.02	0.01
C(at%)	42.72	27.76	23.75	1.75	1.59	1.09	0.92	0.42
B-6								
I	407.00	350.00	288.00	12.00	32.00	58.00	49.00	42.00
C(rat)	1.00	0.65	0.53	0.05	0.04	0.03	0.03	0.01
C(at%)	43.14	27.98	22.69	1.94	1.56	1.11	1.08	0.48
B-7								
I	247.00	222.00	212.00	6.00	31.00	36.00	40.00	32.00
C(rat)	1.00	0.68	0.64	0.04	0.06	0.03	0.03	0.01
C(at%)	40.24	27.27	25.68	1.49	2.33	1.06	1.36	0.56
B-8								
I	179.00	156.00	138.00	7.00	20.00	26.00	27.00	19.00
C(rat)	1.00	0.66	0.57	0.06	0.05	0.03	0.03	0.01
C(at%)	41.48	27.26	23.77	2.48	2.14	1.09	1.30	0.47
B-9								
I	67.00	65.00	54.00	4.00	9.00	12.00	15.00	13.00
C(rat)	1.00	0.73	0.60	0.09	0.06	0.03	0.05	0.02
C(at%)	38.70	28.31	23.19	3.53	2.40	1.25	1.80	0.81

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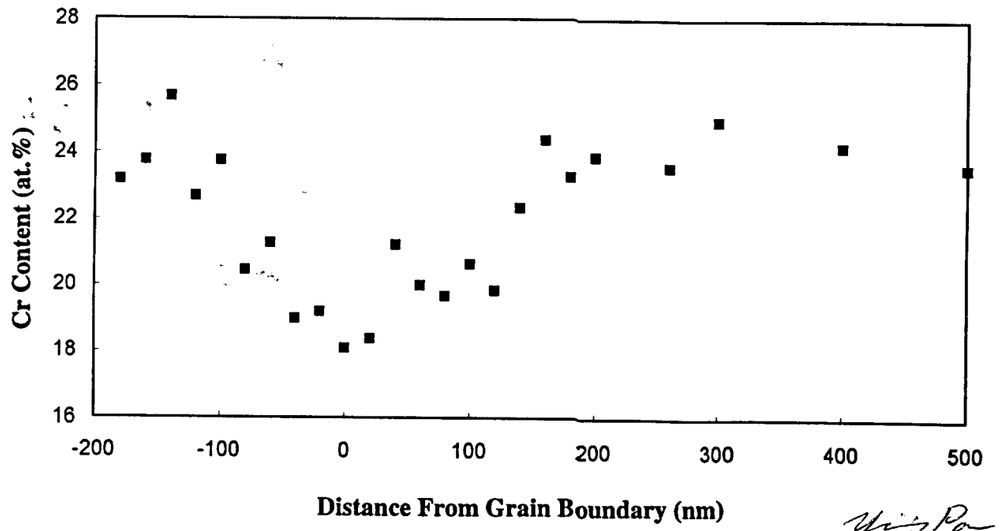
Cr Concentration Plot



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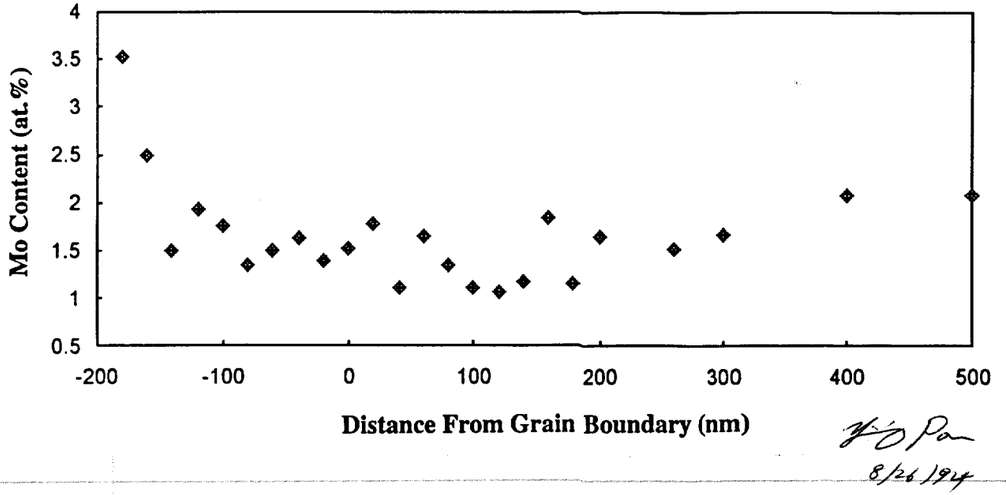
Mo Concentration Plot



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Nanoprobe Chemical Analysis

Philips EM420 scanning transmission electron microscope is also capable of running nanoprobe chemical analysis with a focused electron probe size down to 1 nm. Nanoprobe chemical analysis was performed on the alloy 82S thin foil. Although the probe can be focused down to 1 nm, it is hard to distinguish the location of analysis with confidence, probably due to magnetic influence from the TEM sample. A strong residual force was found after removing the specimen. This focus problem was eliminated once I switched to a standard calibration sample of Al crystal.

A literature review on chemical analysis of $M_{23}C_6$ grain boundary precipitates reveals that most of the chemical analysis under TEM was conducted with a probe size of about 20 nm. even though the instruments are allowed for smaller probe sizes. This may reflect the focus problem we observed above.

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TEM Thin Foil Preparation From 700°C/101hr Aged Specimen

1. A rod alloy 825 specimen was received for TEM analysis
   Heat No. NN4371 F6
   Solution annealed at 1200°C/10min
   Aged at 700°C/101 hr.

2. TEM samples were prepared in a similar way reported on page 4. Owing to limited thin area was observed in previous samples, a different electrolyte of 15% nitric acid in methanol was selected from a literature survey.

3. A third batch of TEM samples was prepared from the previous cylindrical specimen, Heat No. HH4371 FG., aged at 750°C/15hr. The operating conditions were recorded:

Sample ID.	Voltage (V)	Current (ma)	Time (sec)
31	9	35	90 sec
32	6	16	185
33	9	22	128
34	14	44	158
35	14	28	109
36	14	28	93

4. TEM samples were also prepared from the rod specimen using 15% nitric acid electrolyte.

Sample ID.	Voltage (V)	Current (ma)	Time (sec)
R1	14	36	143
R2	14	30	90
R3	14	28	124
R4	14	28	123

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TEM Analysis of Specimens 36 & R4

Preliminary TEM observation and chemical analysis was performed on specimens 36 & R4.

1. Grain boundary precipitates observation

Sample # 36

Negative No.	Magnification	Remark
8418	8,200	particulate precipitates at grain boundary
8419	8,200	
8420	23,000	
8421	60,000	
8422	3,800	Film type precipitates
8423	8,200	
8424	60,000	
8425	8,200	

Sample R4

Negative No.	Magnification	Remark
8426	3,300	Film type precipitates
8427	8,200	
8428	23,000	
8429	8,200	particulate precipitates
8430	23,000	
8431	60,000	

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2. Grain boundary chemistry analysis

Sample 36 :

Sample36	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
I(T-15)	592.00	559.00	488.00	16.00	38.00	80.00	72.00	46.00
k	1.00	0.77	0.74	1.71	0.53	0.20	0.22	0.12
I(T-20)	440.00	431.00	359.00	15.00	38.00	72.00	60.00	44.00
k	1.00	0.74	0.75	1.35	0.39	0.16	0.20	0.09
k(ave)	1.00	0.75	0.74	1.53	0.46	0.18	0.21	0.11
Particle ppt								
I	4569	5224	11223	363	4132	812	607	284
C(rat)	1.00	0.86	1.83	0.12	0.42	0.03	0.03	0.01
C(at%)	23.29	20.08	42.53	2.83	9.71	0.75	0.64	0.16
Near ppt								
I	6087	5949	7247	267	3730	874	492	321
C(rat)	1.00	0.74	0.89	0.07	0.28	0.03	0.02	0.01
C(at%)	33.11	24.40	29.30	2.22	9.35	0.86	0.56	0.19
Away ppt								
I	4280	4470	5977	205	2890	692	384	259
C(rat)	1.00	0.79	1.04	0.07	0.31	0.03	0.02	0.01
C(at%)	30.63	24.12	31.80	2.24	9.54	0.90	0.57	0.20
Layer ppt								
I	278	257	294	10	479	145	99	61
C(rat)	1.00	0.70	0.79	0.05	0.79	0.09	0.07	0.02
C(at%)	28.37	19.78	22.30	1.56	22.54	2.68	2.10	0.67

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Sample R4 :

Sample R4								
Particle ppt								
I	15029	17211	25709	1356	4293	1573	1587	701
C(rat)	1.00	0.86	1.27	0.14	0.13	0.02	0.02	0.01
C(at%)	28.98	25.03	36.85	4.00	3.82	0.55	0.64	0.15
Near ppt								
I	10970	11687	13291	769	2848	1053	886	417
C(rat)	1.00	0.80	0.90	0.11	0.12	0.02	0.02	0.00
C(at%)	33.68	27.06	30.34	3.61	4.03	0.58	0.57	0.14
Away ppt								
I	15569	16140	18219	1030	3667	1361	1139	586
C(rat)	1.00	0.78	0.87	0.10	0.11	0.02	0.02	0.00
C(at%)	34.52	26.99	30.03	3.49	3.75	0.55	0.53	0.14
Film ppt								
I	717	811	931	53	180	116	56	42
C(rat)	1.00	0.85	0.97	0.11	0.12	0.03	0.02	0.01
C(at%)	32.27	27.53	31.15	3.65	3.74	0.94	0.52	0.20
Away ppt								
I	460	520	608	39	124	89	41	24
C(rat)	1.00	0.85	0.98	0.13	0.12	0.03	0.02	0.01
C(at%)	31.76	27.08	31.21	4.12	3.95	1.11	0.59	0.18

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The above chemical composition results were calculated using the scaling factor, k, from sample 4 (see page 25), which deviate from the bulk composition of the alloy. A scaling factor calibrated from each sample is needed. However, high Cr content has been measured for particulate-type precipitate from both samples, which is consistent with that observed in samples 2 and 4. For the chemical composition of the film-type precipitate, its Cr content is comparable to that of the matrix in Sample R4, but substantially lower in Sample 36.

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Recalculated Chemical Composition for Samples 36 and R4

Chemical composition results reported on pages 32,33 were recalculated using a scaling factor calibrated for each matrix composition and intensity, k(36) for sample 36 and k(R4) for Sample R4. These results are consistent with previous measurements.

Sample 36 :

Sample 36	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
I(T-15)	592.00	559.00	488.00	16.00	38.00	80.00	72.00	46.00
k	1.00	0.77	0.74	1.71	0.53	0.20	0.22	0.12
I(T-20)	440.00	431.00	359.00	15.00	38.00	72.00	60.00	44.00
k	1.00	0.74	0.75	1.35	0.39	0.16	0.20	0.09
k(ave)	1.00	0.75	0.74	1.53	0.46	0.18	0.21	0.11
Sample 36								
Away ppt								
I	4280	4470	5977	205	2890	692	384	259
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(36)	1.00	0.69	0.44	0.96	0.05	0.17	0.30	0.16
Particle ppt								
I	4569	5224	11223	363	4132	812	607	284
C(rat)	1.00	0.79	1.07	0.08	0.05	0.03	0.04	0.01
C(at%)	32.61	25.89	34.97	2.49	1.48	0.96	1.29	0.32
Near ppt								
I	6087	5949	7247	267	3730	874	492	321
C(rat)	1.00	0.68	0.52	0.04	0.03	0.02	0.02	0.01
C(at%)	42.97	29.16	22.33	1.81	1.32	1.02	1.04	0.35
Layer ppt								
I	278	257	294	10	479	145	99	61
C(rat)	1.00	0.64	0.46	0.03	0.09	0.09	0.11	0.03
C(at%)	40.79	26.18	18.83	1.41	3.53	3.52	4.33	1.39

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Sample R4

Sample R4								
Away ppt								
I	15569	16140	18219	1030	3667	1361	1139	586
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(R4)	1.00	0.70	0.52	0.70	0.14	0.31	0.37	0.25
Particle ppt								
I	15029	17211	25709	1356	4293	1573	1587	701
C(rat)	1.00	0.80	0.89	0.06	0.04	0.03	0.04	0.01
C(at%)	34.74	29.68	33.02	2.33	1.53	1.19	1.43	0.43
Near ppt								
I	10970	11687	13291	769	2848	1053	886	417
C(rat)	1.01	0.75	0.63	0.05	0.04	0.03	0.03	0.01
C(at%)	39.28	29.44	24.94	1.93	1.48	1.16	1.17	0.38
Film ppt								
I	717	811	931	53	180	116	56	42
C(rat)	1.00	0.79	0.68	0.05	0.04	0.05	0.03	0.01
C(at%)	37.76	29.88	25.54	1.94	1.37	1.87	1.08	0.55
Away ppt								
I	460	520	608	39	124	89	41	24
C(rat)	1.00	0.79	0.69	0.06	0.04	0.06	0.03	0.01
C(at%)	37.28	29.48	25.67	2.20	1.45	2.21	1.22	0.49

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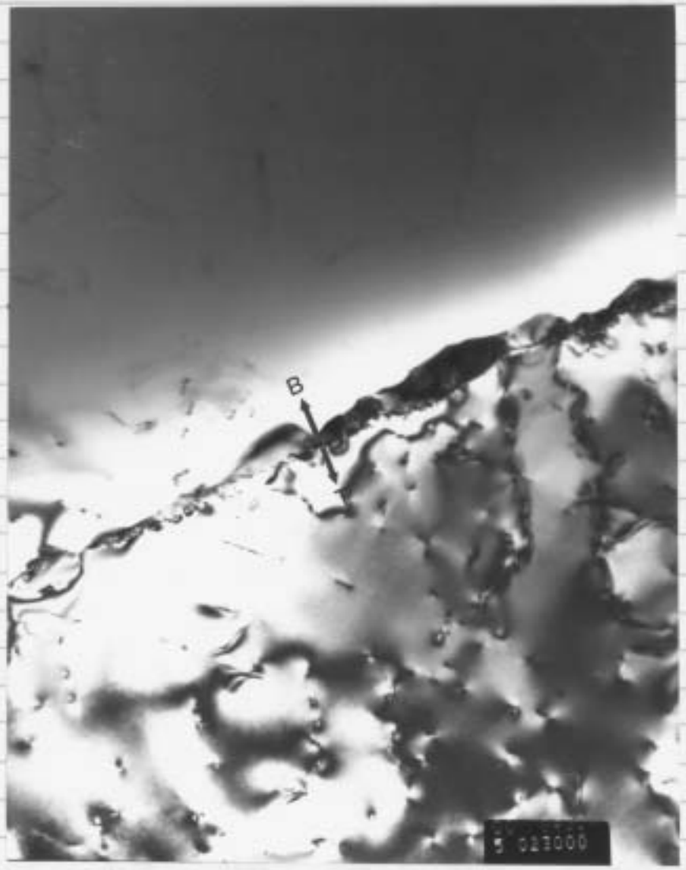
9/7/94 TEM Photomicrographs of G.B. Precipitates (Samples 36 & R4)

TEM photomicrographs of the G.B. precipitates, both particulate- and film-type, from Samples 36 & R4 were documented below.

a) Sample R4

Particulate-type ppt



No. ~~8428~~ 8430 ymp 9/7/94 36,000X

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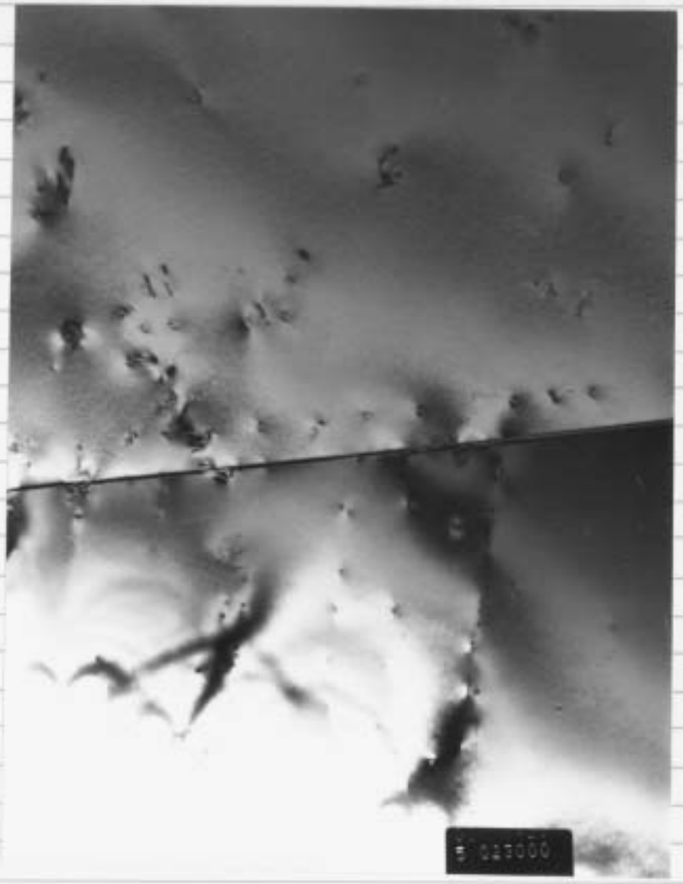
Film-type ppt



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(b) Sample 36
Particulated-type ppt

No. 8421

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Chemical Profile of GB Region in Sample R4 (Particulate-type)

Chemical concentration profiles were measured using microprobe techniques with a focused probe of about 20 nm diameter. TEM/EDS spectra were recorded across a grain boundary region, as marked in Photo No. 8434 on page 36. The results are listed in the following table and the Cr and Mo profiles are plotted in the figures of chemical content vs. distance from precipitate.

Sample R4	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
T 75								
I	935	1037	1226	94	260	180	79	59
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T75)	1.00	0.65	0.46	0.46	0.12	0.14	0.32	0.15
T 85								
I	898	980	1152	69	246	168	79	69
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T85)	1.00	0.66	0.48	0.60	0.12	0.14	0.30	0.12
PPT 1								
I	1286	1410	2322	123	407	256	158	83
C(rat)	1.00	0.73	0.86	0.06	0.04	0.03	0.04	0.01
C(at%)	36.27	26.42	31.12	2.08	1.42	1.03	1.36	0.29
PPT 2								
I	1230	1321	2230	110	359	280	145	96
C(rat)	1.00	0.71	0.86	0.05	0.04	0.03	0.04	0.01
C(at%)	36.46	26.02	31.41	1.96	1.32	1.19	1.31	0.35
PPT 3								
I	1310	1390	2095	121	380	248	144	85
C(rat)	1.00	0.71	0.76	0.06	0.04	0.03	0.03	0.01
C(at%)	38.10	26.86	28.96	2.11	1.37	1.03	1.27	0.30
T 1								
I	823	913	1009	68	235	157	79	51
C(rat)	1.00	0.74	0.58	0.05	0.04	0.03	0.03	0.01
C(at%)	40.50	29.85	23.60	2.01	1.43	1.11	1.18	0.31
T 2								
I	778	883	946	61	226	156	80	48
C(rat)	1.00	0.75	0.58	0.05	0.04	0.03	0.03	0.01
C(at%)	40.28	30.38	23.28	1.89	1.45	1.16	1.26	0.30
T 3								
I	781	881	1058	71	221	156	84	52
C(rat)	1.00	0.75	0.64	0.05	0.04	0.03	0.03	0.01
C(at%)	39.18	29.37	25.22	2.14	1.37	1.12	1.28	0.32

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T 4								
I	692	823	883	58	221	153	65	53
C(rat)	1.00	0.79	0.61	0.05	0.04	0.03	0.03	0.01
C(at%)	39.12	30.92	23.72	1.97	1.55	1.24	1.12	0.37
T 5								
I	719	788	913	53	207	147	71	37
C(rat)	1.00	0.73	0.60	0.04	0.04	0.03	0.03	0.01
C(at%)	40.37	29.40	24.36	1.79	1.44	1.18	1.21	0.25
T 6								
I	1093	1170	1302	77	301	199	94	67
C(rat)	1.00	0.71	0.57	0.04	0.03	0.03	0.03	0.01
C(at%)	41.43	29.47	23.45	1.75	1.41	1.08	1.08	0.31
T 7								
I	1212	1307	1506	106	301	226	109	76
C(rat)	1.00	0.72	0.59	0.05	0.03	0.03	0.03	0.01
C(at%)	40.78	29.22	24.08	2.14	1.26	1.09	1.12	0.31
T 8								
I	1236	1337	1615	102	367	214	113	74
C(rat)	1.00	0.72	0.62	0.05	0.04	0.02	0.03	0.01
C(at%)	40.23	28.92	24.98	1.99	1.48	1.00	1.12	0.30
T 9								
I	1351	1427	1645	112	356	230	123	75
C(rat)	1.00	0.70	0.58	0.05	0.03	0.02	0.03	0.01
C(at%)	41.29	28.98	23.89	2.05	1.35	1.01	1.14	0.28
T 10								
I	1388	1485	1680	107	337	248	127	80
C(rat)	1.00	0.71	0.58	0.05	0.03	0.03	0.03	0.01
C(at%)	41.27	29.34	23.74	1.91	1.24	1.05	1.15	0.29
T 15								
I	1358	1415	1560	99	361	237	106	77
C(rat)	1.00	0.69	0.55	0.04	0.03	0.02	0.02	0.01
C(at%)	42.18	29.20	23.03	1.84	1.39	1.05	1.00	0.29
T 20								
I	1207	1318	1530	92	330	216	125	66
C(rat)	1.00	0.73	0.60	0.05	0.03	0.03	0.03	0.01
C(at%)	40.46	29.36	24.37	1.85	1.37	1.04	1.27	0.27

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T 25								
I	1175	1298	1517	95	313	235	109	67
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.11	29.44	24.61	1.95	1.32	1.15	1.13	0.28
T 30								
I	1221	1325	1480	87	300	226	103	73
C(rat)	1.00	0.72	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	41.16	29.68	23.71	1.76	1.25	1.09	1.06	0.30
T 35								
I	1071	1235	1381	78	282	190	108	61
C(rat)	1.00	0.77	0.61	0.04	0.03	0.03	0.03	0.01
C(at%)	39.71	30.43	24.33	1.74	1.30	1.01	1.22	0.28
T 40								
I	1082	1204	1377	83	282	210	88	58
C(rat)	1.00	0.74	0.60	0.05	0.03	0.03	0.02	0.01
C(at%)	40.30	29.80	24.02	1.83	1.28	1.10	0.98	0.26
T 45								
I	1065	1135	1394	76	300	183	97	57
C(rat)	1.00	0.71	0.62	0.04	0.03	0.02	0.03	0.01
C(at%)	40.54	28.71	25.22	1.74	1.42	1.00	1.12	0.27
T 55								
I	1024	1121	1358	83	286	191	93	61
C(rat)	1.00	0.73	0.63	0.05	0.03	0.03	0.03	0.01
C(at%)	39.96	29.07	25.18	1.94	1.38	1.07	1.10	0.29
T 65								
I	965	1087	1254	79	280	178	98	64
C(rat)	1.00	0.75	0.62	0.05	0.04	0.03	0.03	0.01
C(at%)	39.74	29.74	24.54	1.95	1.43	1.05	1.23	0.32
T 105								
I	855	950	1146	71	229	157	70	52
C(rat)	1.00	0.74	0.64	0.05	0.03	0.03	0.02	0.01
C(at%)	39.73	29.33	25.31	1.98	1.32	1.04	0.99	0.30
T 125								
I	885	956	1121	68	246	177	74	59
C(rat)	1.00	0.72	0.60	0.05	0.03	0.03	0.03	0.01
C(at%)	40.61	29.15	24.45	1.87	1.40	1.16	1.03	0.33

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B 60								
I	2192	2205	2508	133	466	346	183	109
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(B60)	1.00	0.72	0.53	0.76	0.16	0.17	0.32	0.19
B60(k85)								
I	2192	2205	2508	133	466	346	183	109
C(rat)	1.00	0.67	0.54	0.04	0.03	0.02	0.03	0.01
C(at%)	42.94	28.70	23.35	1.56	1.13	0.97	1.09	0.26
k(T85)	1.00	0.66	0.48	0.60	0.12	0.14	0.30	0.12
B 1								
I	1621	1678	1830	116	436	270	150	91
C(rat)	1.00	0.75	0.60	0.05	0.04	0.03	0.03	0.01
C(at%)	39.78	29.68	23.93	2.16	1.71	1.12	1.18	0.42
B 2								
I	1472	1608	1811	114	400	241	152	76
C(rat)	1.00	0.79	0.66	0.06	0.04	0.03	0.03	0.01
C(at%)	38.23	30.11	25.06	2.25	1.66	1.06	1.27	0.37
B 3								
I	1537	1636	1876	115	403	249	132	87
C(rat)	1.00	0.77	0.65	0.06	0.04	0.03	0.03	0.01
C(at%)	38.73	29.72	25.19	2.20	1.62	1.06	1.07	0.42
B 4								
I	1551	1758	1986	116	438	267	145	89
C(rat)	1.00	0.82	0.68	0.06	0.05	0.03	0.03	0.01
C(at%)	37.43	30.58	25.54	2.13	1.69	1.09	1.12	0.41
B 5								
I	1621	1777	1959	113	458	288	149	98
C(rat)	1.00	0.79	0.64	0.05	0.05	0.03	0.03	0.01
C(at%)	38.41	30.35	24.73	2.03	1.73	1.16	1.13	0.44
B 6								
I	1730	1891	2043	117	442	313	163	107
C(rat)	1.00	0.79	0.63	0.05	0.04	0.03	0.03	0.01
C(at%)	38.73	30.52	24.37	1.99	1.58	1.19	1.17	0.45
B 7								
I	1825	1878	2203	115	446	307	162	98
C(rat)	1.00	0.74	0.64	0.05	0.04	0.03	0.03	0.01
C(at%)	39.38	29.21	25.33	1.89	1.54	1.12	1.12	0.40

H'D Pan
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B 8								
I	1954	2000	2301	117	455	315	172	112
C(rat)	1.00	0.74	0.63	0.05	0.04	0.03	0.03	0.01
C(at%)	39.77	29.34	24.95	1.81	1.48	1.09	1.12	0.43
B 9								
I	2002	1990	2248	136	462	305	147	99
C(rat)	1.00	0.72	0.60	0.05	0.04	0.03	0.02	0.01
C(at%)	40.62	29.11	24.30	2.10	1.50	1.05	0.96	0.38
B 10								
I	2178	2204	2530	162	531	364	182	124
C(rat)	1.00	0.73	0.62	0.06	0.04	0.03	0.03	0.01
C(at%)	39.84	29.06	24.66	2.25	1.55	1.13	1.07	0.43
B 15								
I	2301	2326	2672	156	539	344	181	116
C(rat)	1.00	0.73	0.62	0.05	0.04	0.03	0.03	0.01
C(at%)	40.06	29.19	24.79	2.06	1.50	1.02	1.01	0.38
B 20								
I	2276	2302	2640	134	509	356	173	117
C(rat)	1.00	0.73	0.62	0.04	0.04	0.03	0.02	0.01
C(at%)	40.19	29.30	24.84	1.80	1.44	1.07	0.98	0.39
B 30								
I	2191	2275	2551	128	511	349	182	116
C(rat)	1.00	0.75	0.62	0.04	0.04	0.03	0.03	0.01
C(at%)	39.77	29.77	24.67	1.77	1.48	1.07	1.06	0.40
B 40								
I	2304	2232	2494	142	507	320	189	114
C(rat)	1.00	0.70	0.58	0.05	0.04	0.02	0.03	0.01
C(at%)	41.39	28.90	23.87	1.94	1.45	0.97	1.09	0.39
B 100								
I	2453	2488	2710	140	491	361	193	128
C(rat)	1.00	0.73	0.59	0.04	0.03	0.02	0.03	0.01
C(at%)	40.73	29.78	23.98	1.77	1.30	1.02	1.03	0.40
B 80								
I	2071	2308	2463	125	476	345	181	116
C(rat)	1.00	0.80	0.63	0.05	0.04	0.03	0.03	0.01
C(at%)	38.66	31.06	24.50	1.77	1.42	1.09	1.08	0.41

H'D Pan
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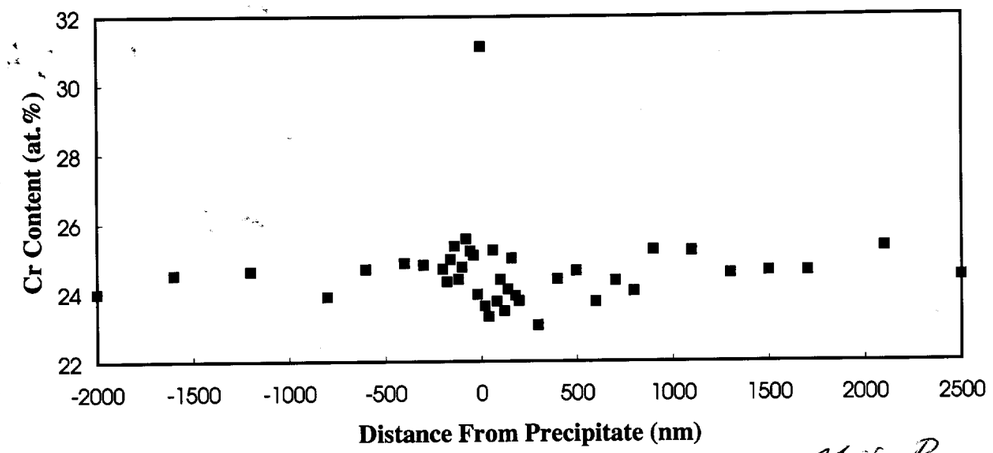
Cr Concentration Profile



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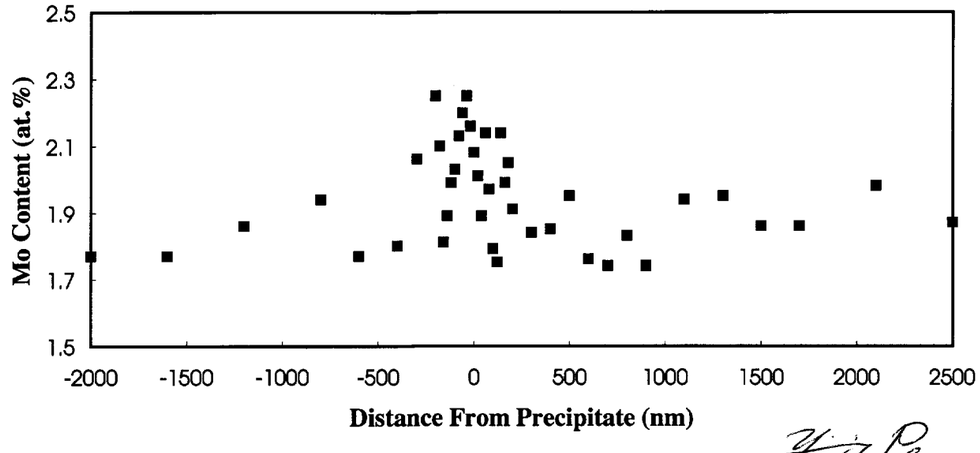
Mo Concentration Profile



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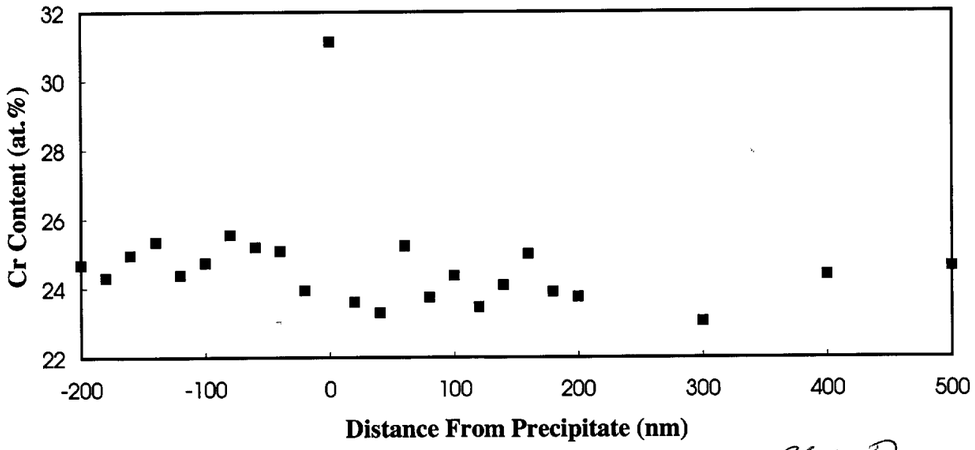

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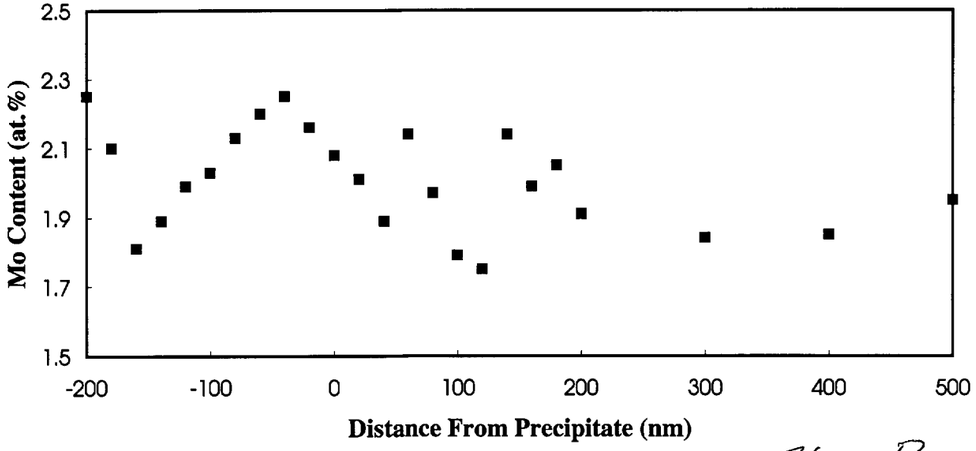

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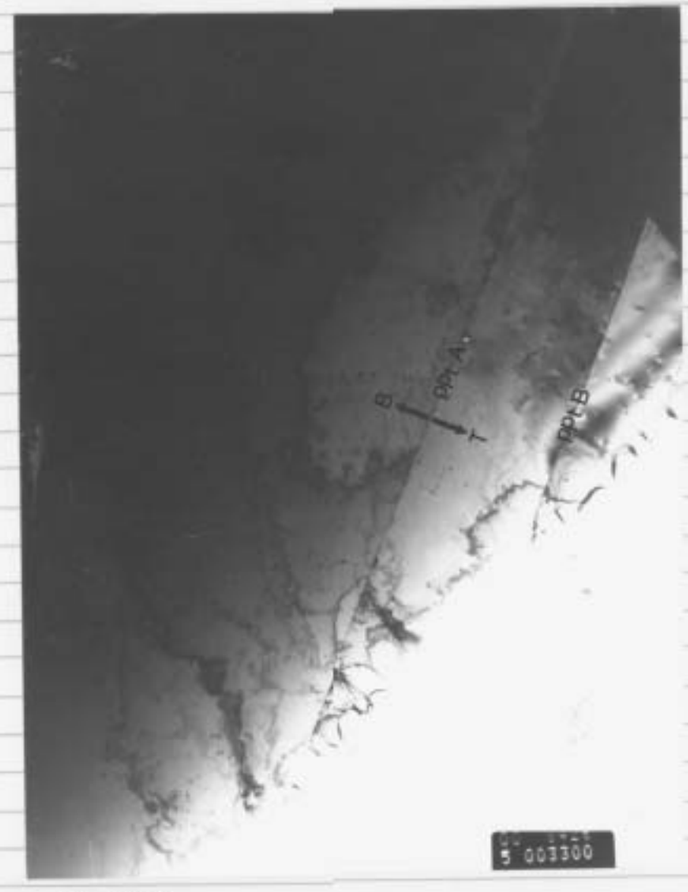
9/14/94 Chemical Profile of G.B. Region Around Film-Type Precipitate

Chemical concentration profiles were also measured across a grain boundary region around the film-type precipitates in specimen R4. The selected grain boundary region is shown in the TEM photo below. As can be seen in the TEM micrograph that two film-type precipitates, ppt A and ppt B, have been crossed along the chemical profile analysis.



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Sample R4	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Particulate Precipitate								
T115								
I	1460	1570	1779	96	336	289	129	78
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T75)	1.00	0.67	0.50	0.70	0.15	0.14	0.30	0.18
T 85								
I	898	980	1152	69	246	168	79	69
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T85)	1.00	0.66	0.48	0.60	0.12	0.14	0.30	0.12
Film Precipitate(k-T85)								
PPT A-1								
I	2397	2605	2856	151	558	283	223	100
C(rat)	1.00	0.72	0.57	0.04	0.03	0.02	0.03	0.01
C(at%)	41.57	30.02	23.54	1.57	1.20	0.70	1.18	0.21
PPT A-2								
I	2095	2182	2458	132	461	304	184	104
C(rat)	1.00	0.69	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	42.22	29.22	23.54	1.60	1.15	0.88	1.13	0.26
PPT A-3								
I	1996	2149	2417	131	427	305	174	125
C(rat)	1.00	0.72	0.58	0.04	0.03	0.02	0.03	0.01
C(at%)	41.44	29.65	23.85	1.63	1.10	0.91	1.10	0.32
T 1								
I	1966	1999	2244	125	399	301	186	109
C(rat)	1.00	0.68	0.54	0.04	0.03	0.02	0.03	0.01
C(at%)	42.76	28.89	23.19	1.63	1.08	0.94	1.23	0.29
T 2								
I	2082	2150	2360	116	420	307	168	119
C(rat)	1.00	0.69	0.54	0.03	0.03	0.02	0.02	0.01
C(at%)	42.81	29.38	23.06	1.43	1.07	0.90	1.05	0.30
T 3								
I	1386	1477	1630	85	310	232	120	86
C(rat)	1.00	0.71	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	41.85	29.63	23.39	1.54	1.16	1.00	1.10	0.32
T 4								
I	1295	1425	1573	72	296	253	109	81
C(rat)	1.00	0.73	0.58	0.03	0.03	0.03	0.03	0.01
C(at%)	41.13	30.07	23.74	1.37	1.17	1.15	1.05	0.32
T 5								
I	1274	1442	1546	87	261	222	127	68
C(rat)	1.00	0.75	0.58	0.04	0.03	0.02	0.03	0.01
C(at%)	40.70	30.61	23.47	1.67	1.03	1.01	1.23	0.27
T 7								
I	1283	1387	1564	86	292	220	119	83
C(rat)	1.00	0.72	0.58	0.04	0.03	0.02	0.03	0.01
C(at%)	41.21	29.60	23.87	1.66	1.16	1.01	1.16	0.33

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T 10								
I	1286	1403	1582	90	279	227	113	76
C(rat)	1.00	0.72	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	41.02	29.74	23.98	1.72	1.10	1.04	1.10	0.30
T 20								
I	1487	1670	1847	90	322	252	141	99
C(rat)	1.00	0.75	0.59	0.04	0.03	0.02	0.03	0.01
C(at%)	40.63	30.32	23.98	1.48	1.09	0.99	1.17	0.33
T 30								
I	1791	1944	2155	109	395	294	144	104
C(rat)	1.00	0.72	0.57	0.04	0.03	0.02	0.02	0.01
C(at%)	41.46	29.69	23.54	1.50	1.13	0.97	1.01	0.29
T 50								
I	1696	1876	2101	124	366	280	151	114
C(rat)	1.00	0.74	0.59	0.04	0.03	0.02	0.03	0.01
C(at%)	40.76	29.96	24.00	1.79	1.09	0.96	1.10	0.34
T 100								
I	1385	1473	1655	98	301	238	111	76
C(rat)	1.00	0.71	0.57	0.04	0.03	0.02	0.02	0.01
C(at%)	41.67	29.45	23.66	1.77	1.12	1.02	1.02	0.28
T 115								
I	1460	1570	1779	96	336	289	129	78
C(rat)	1.00	0.71	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	41.27	29.49	23.90	1.63	1.18	1.17	1.11	0.27
T 125								
I	1250	1356	1554	84	293	218	112	76
C(rat)	1.00	0.72	0.59	0.04	0.03	0.02	0.03	0.01
C(at%)	40.97	29.53	24.21	1.65	1.19	1.02	1.12	0.31
T 130								
I	1219	1357	1501	83	280	200	88	76
C(rat)	1.00	0.74	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	40.86	30.22	23.91	1.67	1.16	0.96	0.90	0.31
T 132								
I	1156	1270	1502	99	281	217	113	92
C(rat)	1.00	0.73	0.62	0.05	0.03	0.03	0.03	0.01
C(at%)	40.07	29.25	24.74	2.06	1.21	1.08	1.19	0.39
T 134								
I	1143	1235	1477	91	289	214	94	65
C(rat)	1.00	0.72	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.49	29.07	24.87	1.93	1.27	1.08	1.01	0.28
T 135 (PPT B)								
I	1030	1114	1344	86	248	184	89	62
C(rat)	1.00	0.72	0.62	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.01	25.03	2.02	1.20	1.03	1.06	0.30
T 136								
I	789	875	987	62	193	151	78	46
C(rat)	1.00	0.74	0.59	0.05	0.03	0.03	0.03	0.01
C(at%)	40.43	29.79	24.04	1.91	1.23	1.11	1.22	0.29

Yi Pan
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<Continued>

T 138								
I	669	706	865	60	174	128	66	47
C(rat)	1.00	0.70	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.52	28.41	24.90	2.18	1.31	1.11	1.22	0.35
T 140								
I	544	678	783	45	160	120	54	33
C(rat)	1.00	0.83	0.68	0.05	0.04	0.03	0.03	0.01
C(at%)	37.49	31.05	25.64	1.86	1.37	1.18	1.13	0.28
T 145								
I	727	806	993	59	182	158	85	44
C(rat)	1.00	0.74	0.65	0.05	0.03	0.03	0.04	0.01
C(at%)	39.38	29.01	25.56	1.92	1.22	1.22	1.40	0.29
T150								
I	709	847	949	61	209	146	74	45
C(rat)	1.00	0.79	0.64	0.05	0.04	0.03	0.03	0.01
C(at%)	38.65	30.68	24.59	1.99	1.41	1.14	1.23	0.30
B 1								
I	1094	1118	1280	78	233	180	99	74
C(rat)	1.00	0.68	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	42.31	28.73	23.53	1.81	1.12	1.00	1.16	0.35
B 2								
I	1052	1077	1217	68	213	181	82	58
C(rat)	1.00	0.68	0.55	0.04	0.03	0.02	0.02	0.01
C(at%)	42.57	28.96	23.40	1.65	1.07	1.05	1.01	0.29
B 3								
I	908	999	1074	70	195	171	84	55
C(rat)	1.00	0.73	0.56	0.05	0.03	0.03	0.03	0.01
C(at%)	41.18	30.11	23.15	1.90	1.10	1.11	1.16	0.31
B 4								
I	838	851	986	65	174	163	85	48
C(rat)	1.00	0.67	0.56	0.05	0.03	0.03	0.03	0.01
C(at%)	42.16	28.45	23.57	1.96	1.08	1.17	1.30	0.30
B 5								
I	813	896	980	57	174	172	83	50
C(rat)	1.00	0.73	0.57	0.04	0.03	0.03	0.03	0.01
C(at%)	40.94	29.98	23.45	1.72	1.09	1.24	1.27	0.31
B 8								
I	846	888	992	56	182	157	91	56
C(rat)	1.00	0.70	0.56	0.04	0.03	0.03	0.03	0.01
C(at%)	41.87	29.20	23.33	1.66	1.12	1.11	1.37	0.34
B 10								
I	1093	1137	1287	78	238	211	119	79
C(rat)	1.00	0.69	0.56	0.04	0.03	0.03	0.03	0.01
C(at%)	41.84	28.92	23.41	1.79	1.13	1.16	1.39	0.37
B 15								
I	1014	994	1170	72	211	188	107	63
C(rat)	1.00	0.65	0.55	0.04	0.03	0.03	0.03	0.01
C(at%)	42.84	27.90	23.49	1.82	1.10	1.14	1.38	0.33

Yi Pan
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< Continued >

B 20								
I	1199	1196	1398	72	239	192	104	83
C(rat)	1.00	0.66	0.55	0.04	0.02	0.02	0.03	0.01
C(at%)	42.82	28.38	23.73	1.54	1.06	0.98	1.13	0.36
B 30								
I	1330	1487	1674	88	273	244	142	75
C(rat)	1.00	0.74	0.60	0.04	0.03	0.03	0.03	0.01
C(at%)	40.46	30.06	24.20	1.61	1.03	1.06	1.31	0.28
B 40								
I	1699	1843	2035	126	356	297	152	94
C(rat)	1.00	0.72	0.57	0.04	0.03	0.03	0.03	0.01
C(at%)	41.33	29.79	23.53	1.84	1.07	1.03	1.12	0.28
B 45								
I	1795	1890	2046	128	383	284	145	104
C(rat)	1.00	0.70	0.54	0.04	0.03	0.02	0.02	0.01
C(at%)	42.29	29.59	22.91	1.81	1.12	0.96	1.04	0.30
B 50								
I	1680	1778	1935	103	331	286	135	90
C(rat)	1.00	0.70	0.55	0.04	0.02	0.02	0.02	0.01
C(at%)	42.24	29.70	23.12	1.55	1.03	1.03	1.03	0.28
B 70								
I	1876	1973	2123	120	359	289	153	107
C(rat)	1.00	0.70	0.54	0.04	0.02	0.02	0.02	0.01
C(at%)	42.51	29.71	22.86	1.63	1.01	0.94	1.05	0.30
B 100								
I	1961	1973	2222	124	364	318	146	106
C(rat)	1.00	0.67	0.54	0.04	0.02	0.02	0.02	0.01
C(at%)	43.09	28.81	23.20	1.63	0.99	1.00	0.98	0.29
B 150								
I	1872	1921	2087	114	356	292	143	100
C(rat)	1.00	0.68	0.53	0.04	0.02	0.02	0.02	0.01
C(at%)	43.03	29.34	22.80	1.57	1.01	0.96	1.00	0.28

Yiqing Pan
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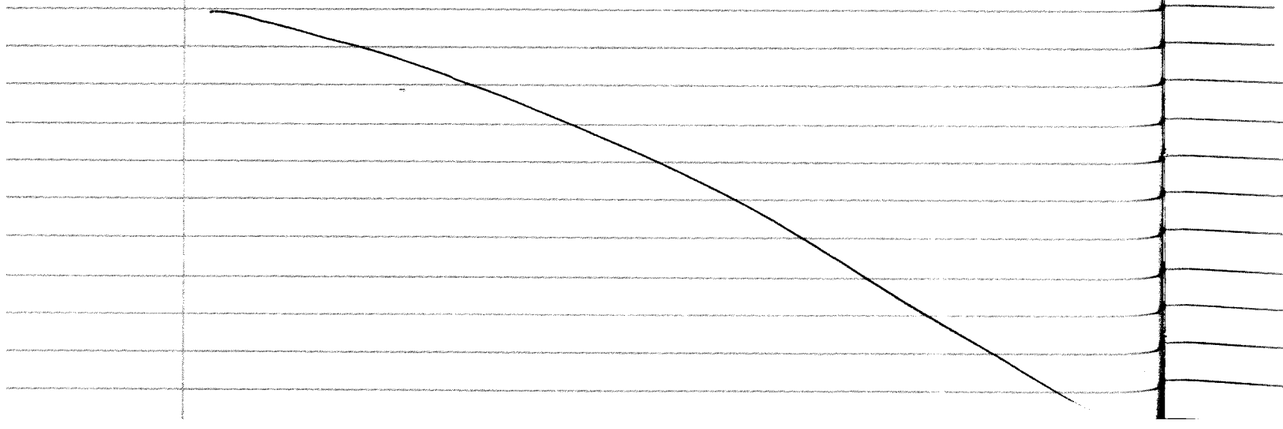
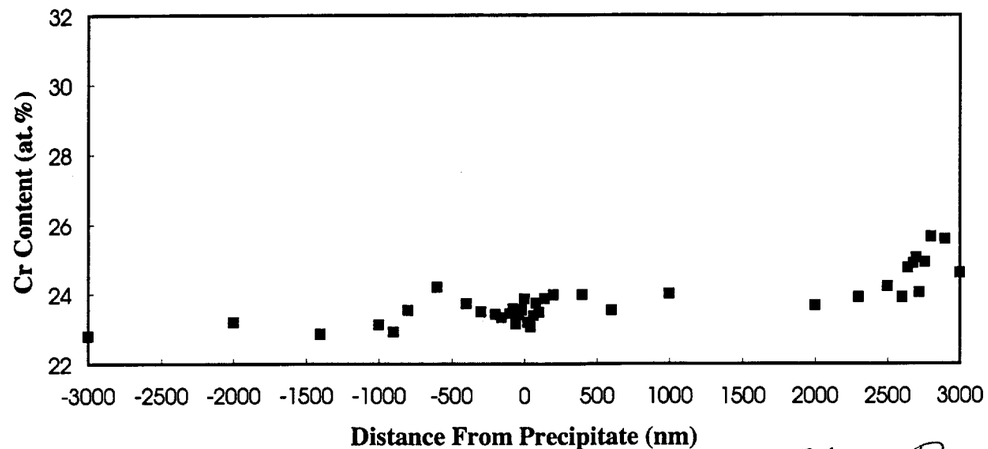
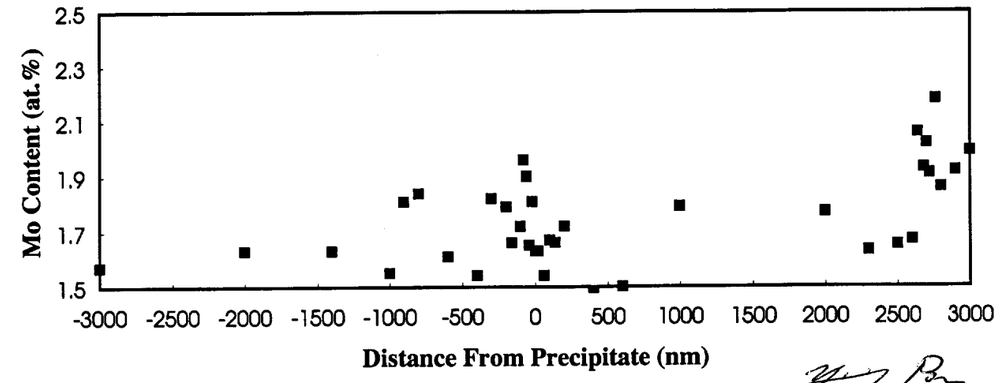


Cr Profile across ppt A & B



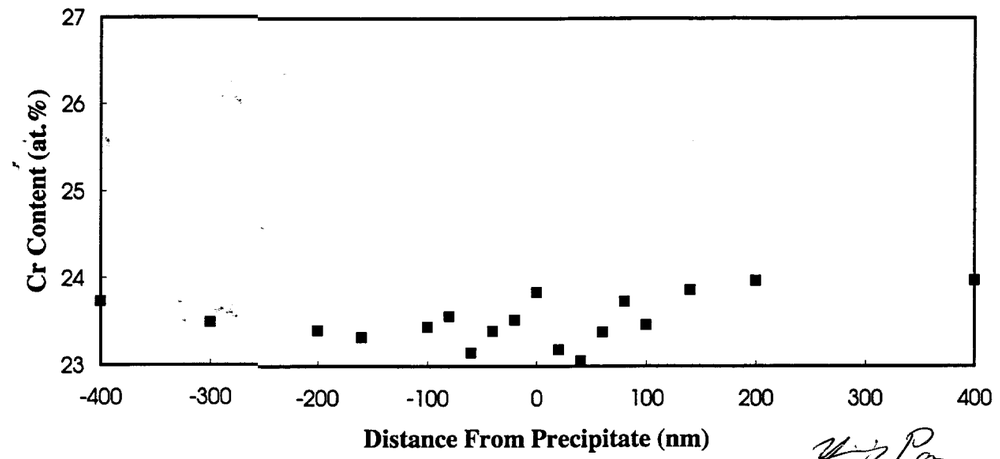
Yiqing Pan
9/26/94

Mo profile across ppt A & B



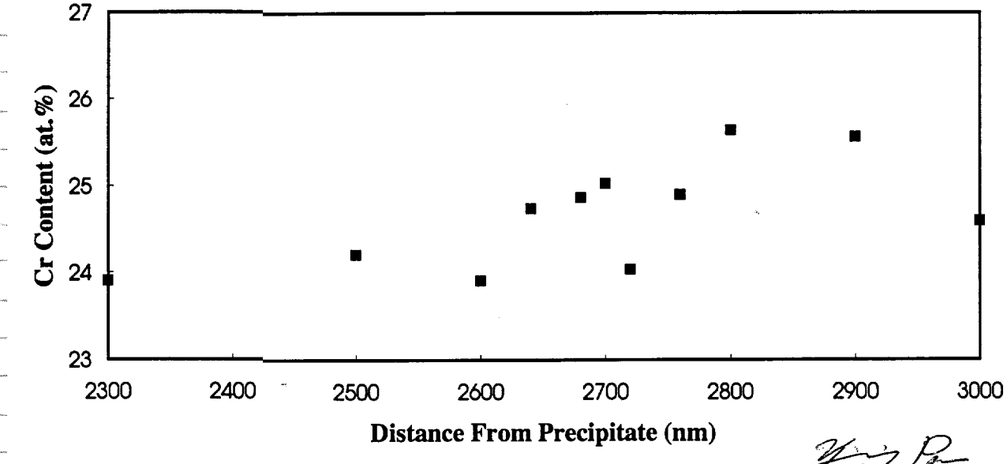
Yiqing Pan
9/26/94

Cr profile across ppt A



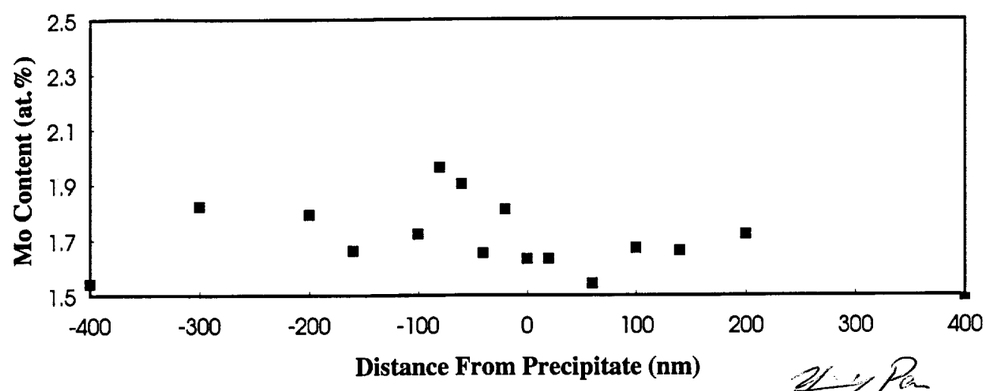
Yi Pan
9/26/94

Cr profile across ppt B



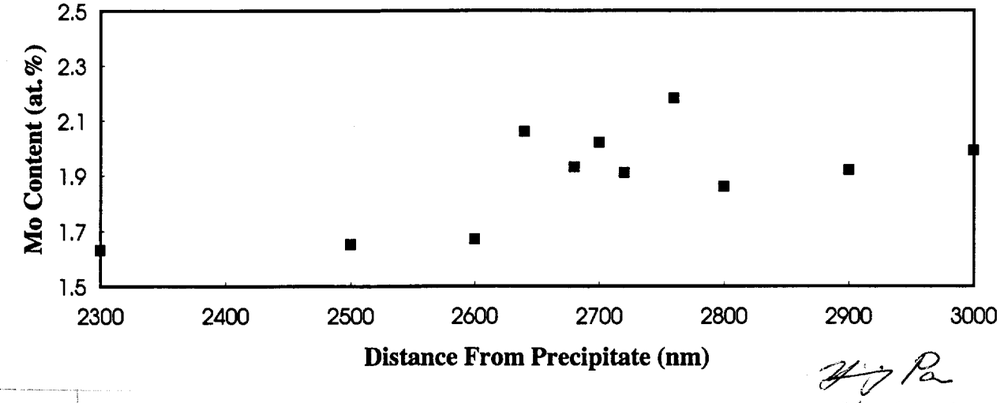
Yi Pan
9/26/94

Mo profile across ppt A



Yi Pan
9/26/94

Mo profile across ppt B



Yi Pan
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Crystal structure Information in Alloy 825

The major phases that may be present in nickel-base alloys are:

- Gamma matrix (γ)[1]
  This is an fcc nickel-base phase that usually contains a high percentage of solid-solution elements such as iron, chromium, molybdenum, cobalt, and tungsten.
  $a = 3.524$ Å

- $M_{23}C_6$ carbide[2]
  The chromium rich $M_{23}C_6$ carbide has an fcc structure and $a = 10.6$ Å.

- σ/ Sigma phase[3]
  This phase has a tetragonal structure.
  $a = b = 9.08$ Å and $c = 4.74$ Å.

References:

1.

2. M. Raghavan, et al., Metall. Trans., 13A, p 979-984 (1982).

3. M. J. Cieslak, et al., Metall. Trans., 17A, p 2035-2047 (1986).

Yiping Pan
9/27/94

Diffraction Pattern Analysis of Sample R4

1. Diffraction analysis was performed on Sample R4, both the matrix and the grain boundary precipitate. The diffraction patterns were documented as follows:

Negative No.	Remark
8449	ⓐ matrix around No. ~~8438~~ 8430 yp 9/27/94 50 sec exposure Diffraction Pattern (DP) / Camera Length (CL) 660mm.
8450	DP / 350 mm, 10sec
8451	DP / 350 mm, 20sec
8452	Image at 8200X yp
8453	ⓑ G.B. precipitate in No. ~~8440~~ 8430 - DP/350mm, 20sec
8454	DP/350 mm, 50 sec
8455	DP/350 mm, 90 sec
8456	DP/350 mm, 50 sec
8457	DP/660 mm, 50 sec
8458	DP/660 mm, 20sec
8459	DP/660mm, 100 sec
8460	DP/660mm, 50 sec
8461	Image at 23,000X
8462	ⓒ Matrix in No. 8435 - DP/350mm, 20sec
8463	DP/660mm, 20 sec.

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2. Selected diffraction patterns recorded in page 55 were printed and are presented below.

A. Matrix

Negative No. 8450

Negative No. 8462

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B. G.B. Precipitate

Negative No. 8453

Negative No. 8458

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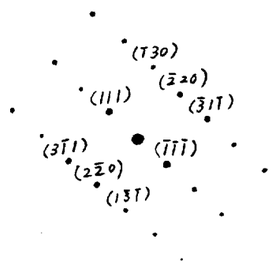
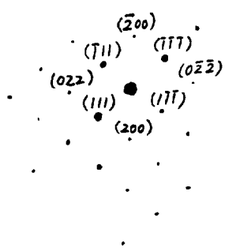
3. Determination of diffraction patterns.

The diffraction patterns for each of the major phases that may be present in alloy 82t were calculated using the crystal structure information listed in page 54. The experimentally recorded diffraction patterns were then identified.

A. Photo No. 8450 – γ matrix, zone axis $[11\bar{2}]$



B. Photo No. 8462 – γ matrix, zone axis $[01\bar{1}]$



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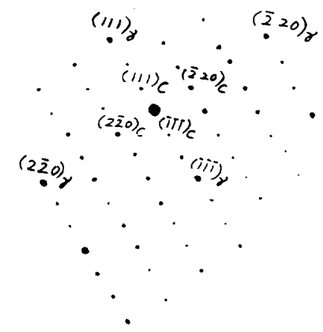
C. Photo No. 8458 – $M_{23}C_6$ carbide, zone axis $[11\bar{2}]$ and γ matrix, zone axis $[11\bar{2}]$



Yi Pan
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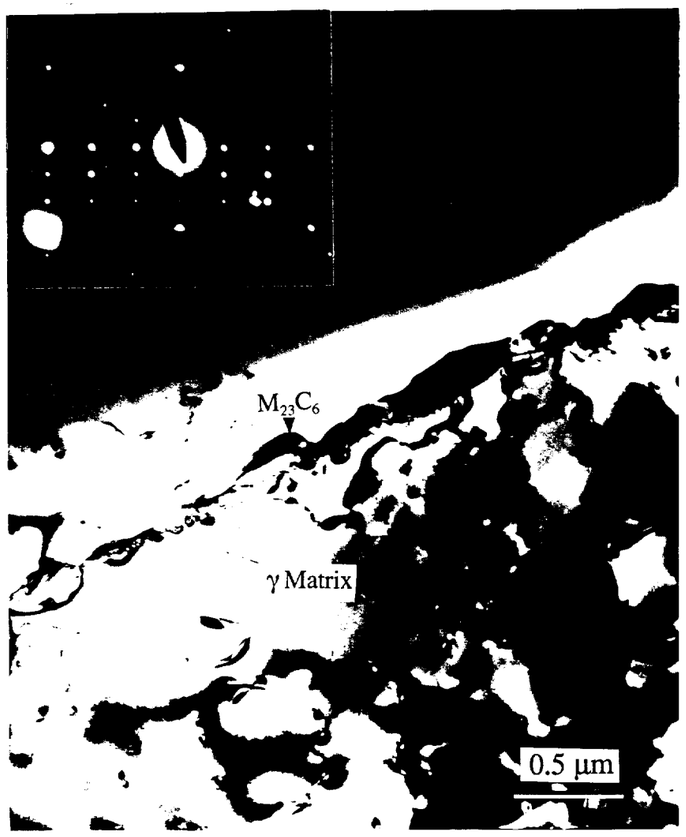
Representative TEM Micrograph from the Long-Aged Specimen

TEM bright-field image of γ matrix and $M_{23}C_6$ carbide taken from a specimen aged at 700°C for 101 h and diffraction pattern (inset) for austenite and $M_{23}C_6$ oriented in the zone axes: $[11\bar{2}]_\gamma$ and $[11\bar{2}]$ $M_{23}C_6$.

DP: No. 8458 Image: No. 8430



Yiyi Pan
11/6/94

Diffraction Pattern Analysis of Sample 36

1. Diffraction analysis was also conducted on Sample 36 (Heat No. HH4371 FG, aged at 750°C (15hr). The diffraction patterns for both the grain boundary precipitate and the matrix were recorded.

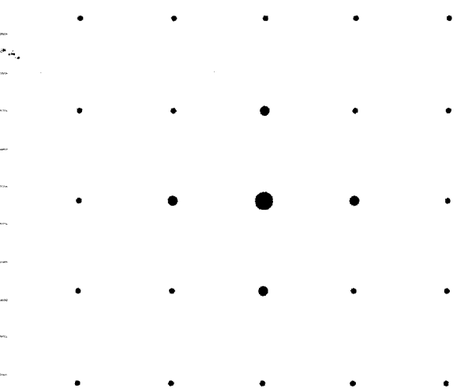
Negative No.	Remark
8472	on G.B. precipitate in No. 8421 (P38) Diffraction pattern / Camera length = 660mm / 20sec
8473	DP / 660mm / 10sec
8474	DP / 660mm / 20sec
8475	on matrix in No. 8421 DP / 660mm / 20sec.

Yiyi Pan
11/7/94

2. Determination of diffraction patterns

a. Diffraction pattern from photo No. 8475 was identified to be γ matrix oriented in the zone axis [001].

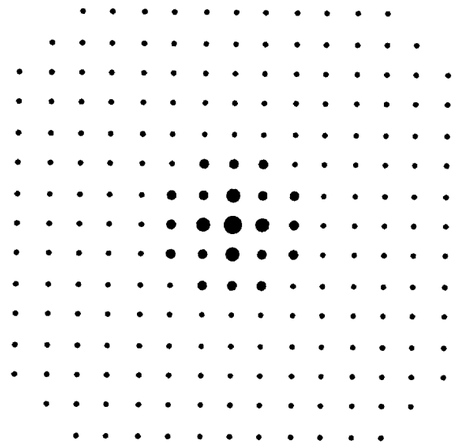
γ matrix / zone axis [001] / CL = 660mm



Hy Pa
10/13/94

b. Diffraction pattern from photos No. 8472-8474 was also identified to be $Cr_{23}C_6$ carbide oriented in the zone axes [001], which overlaps with the zone axis $[001]_\gamma$ of the austenite matrix

Zone axes $[001]_\gamma$ and $[001]_{Cr_{23}C_6}$ / CL = 660mm



Hy Pa
10/13/94

TEM Analysis of AISI 304L Thin Foil 4

a. TEM examination of AISI 304L stainless steel was performed on thin foil 4 to reveal its general microstructure and grain boundary precipitates. TEM photomicrographs were taken from different locations.

Negative NO.	Magnification	Remark
		Location 1
8476	23,000	
8477	60,000	
8478	8,200	Location 2
8479	23,000	
8480	60,000	
8481	8,200	Location 3
8482	23,000	Location 4
8483	60,000	
8484	3,300	Location 5
8485	82,000	
8486	23,000	
8487	60,000	
8488	135,000	
8489	60,000	

Yi-ji Pan
10/14/94

b. Preliminary chemical analysis was also conducted in an attempt to identify the possible grain boundary phases. Grain boundary precipitate and the near region in photo No. 8489 was selected. The scaling factor, k, was evaluated using the bulk composition from Metals Handbook, Desk Edition, Edited by H.E. Boyer and T.L. Gall, ASM, 1985, p 15.2. Chemical composition near the grain boundary region was analyzed and is presented below.

AISI 304L	Fe	Cr	Ni	Si	Mn
Bulk(wt%)	66.88	18.90	10.20	0.64	1.70
Matrix					
I	112	52	14	7	
C(rat)	1.00	0.28	0.15	0.01	
C(wt%)	69.22	19.71	10.64	0.67	
k(304)	1.00	0.61	1.22	0.15	
PPT 1					
I	237	288	27	20	
C(rat)	1.00	0.74	0.14	0.01	
C(wt%)	52.87	39.56	7.44	0.69	
PPT 2					
I	254	261	29	15	
C(rat)	1.00	0.63	0.14	0.01	
C(wt%)	56.38	35.64	7.94	0.52	
Near ppt-1					
I	296	115	36	24	
C(rat)	1.00	0.24	0.15	0.01	
C(wt%)	71.57	17.05	10.70	0.89	
Near ppt-r					
I	238	84	31	14	
C(rat)	1.00	0.21	0.16	0.01	
C(wt%)	72.32	15.64	11.57	0.66	

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Note: The 304L stainless steel specimen is an internal standard (Heat No. T0954). Chemical composition of this material has been analyzed by two independent companies. The results have been recorded in CNWRA Scientific Notebook 009, pp 7 & 56.

Yi-ji Pan 12/13/94

Diffraction Analysis of 304L

1. Diffraction analysis was conducted on thin foil 4 from the 304L stainless steel specimen (HTT0954). Diffraction patterns, along with the images, were recorded in the following.

Negative No	Remark
8490	on G.B. precipitates in No. 8489 (P 64)
8491	Diffraction pattern, camera length = 660 mm / 120sec.
8492	DP/660/120sec
8493	Image of 8490 (60,000X)
8494	DP/660/120sec
8495	DP/660/120sec
8496	Image of 8493 (60,000X)
8497	Image of 8490 (135,000X)
8498	Image of 8493 (135,000X)
8499	DP/660/30sec
8500	36,000X
8501	135,000X
	60,000X

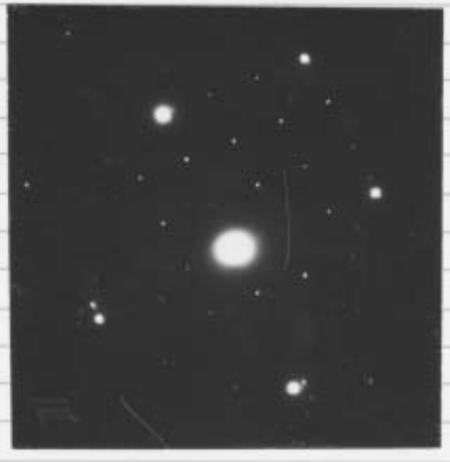
10/17/94

2. Determination of diffraction patterns

Diffraction patterns from photo No. 8493 and 8494 were identified to be $M_{23}C_6$ carbide oriented in the [251] axis.

No. 8493

10/17/94



No. 8494

10/19/94

Chemical Profile Measurements for 304L specimen

1. Chemical concentration profiles were measured for a grain boundary region in thin foil 4 of the 304L stainless steel specimen using microprobe techniques with a focus probe of 20 nm diameter. The chemical contents for each spot of analysis were calculated and listed in the table below.

AISI 304L	Fe	Cr	Ni	Si	Mn
Bulk(wt%)	66.88	18.90	10.20	0.64	1.70
Matrix					
I	352	142	41	35	43
C(rat)	1.00	0.28	0.15	0.01	0.03
C(wt%)	68.02	19.22	10.37	0.65	1.73
k(304)	1.00	0.70	1.31	0.10	0.21
GB					
I	490	123	59	72	50
C(rat)	1.00	0.18	0.16	0.01	0.02
C(wt%)	73.05	12.85	11.52	1.03	1.55
R1					
I	510	166	79	36	55
C(rat)	1.00	0.23	0.20	0.01	0.02
C(wt%)	68.49	15.62	13.89	0.47	1.54
R2					
I	439	150	61	35	48
C(rat)	1.00	0.24	0.18	0.01	0.02
C(wt%)	68.88	16.49	12.53	0.53	1.57
R3					
I	418	155	51	35	43
C(rat)	1.00	0.26	0.16	0.01	0.02
C(wt%)	69.01	17.93	11.02	0.56	1.48
R4					
I	387	152	44	34	34
C(rat)	1.00	0.28	0.15	0.01	0.02
C(wt%)	68.93	18.97	10.26	0.58	1.26
R5					
I	288	112	36	41	36
C(rat)	1.00	0.27	0.16	0.01	0.03
C(wt%)	67.76	18.46	11.21	0.94	1.78
R6					
I	264	96	36	38	28
C(rat)	1.00	0.25	0.18	0.01	0.02
C(wt%)	68.06	17.34	12.15	0.94	1.50

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R7					
I	248	93	30	28	24
C(rat)	1.00	0.26	0.16	0.01	0.02
C(wt%)	68.87	18.09	10.91	0.75	1.39
R8					
I	235	88	31	34	25
C(rat)	1.00	0.26	0.17	0.01	0.02
C(wt%)	67.98	17.83	11.74	0.95	1.50
R9					
I	254	94	38	33	31
C(rat)	1.00	0.26	0.20	0.01	0.03
C(wt%)	66.98	17.36	13.12	0.84	1.70
R10					
I	325	128	45	46	35
C(rat)	1.00	0.28	0.18	0.01	0.02
C(wt%)	66.97	18.48	12.14	0.91	1.50
R11					
I	403	155	50	61	48
C(rat)	1.00	0.27	0.16	0.01	0.02
C(wt%)	67.97	18.31	11.04	0.99	1.68
R13					
I	480	170	59	66	48
C(rat)	1.00	0.25	0.16	0.01	0.02
C(wt%)	69.30	17.19	11.15	0.92	1.44
R14					
I	521	202	63	69	57
C(rat)	1.00	0.27	0.16	0.01	0.02
C(wt%)	68.24	18.53	10.80	0.87	1.55
R15					
I	440	182	63	60	54
C(rat)	1.00	0.29	0.19	0.01	0.03
C(wt%)	65.97	19.12	12.37	0.87	1.68
R20					
I	494	186	59	74	52
C(rat)	1.00	0.26	0.16	0.01	0.02
C(wt%)	68.66	18.11	10.74	0.99	1.50
R30					
I	440	172	58	76	49
C(rat)	1.00	0.27	0.17	0.02	0.02
C(wt%)	67.28	18.42	11.61	1.12	1.56
R50					
I	352	142	41	35	43
C(rat)	1.00	0.28	0.15	0.01	0.03
C(wt%)	68.02	19.22	10.37	0.65	1.73

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L5					
I	379	139	50	67	40
C(rat)	1.00	0.26	0.17	0.02	0.02
C(wt%)	68.09	17.49	11.76	1.16	1.50
L6					
I	354	136	44	56	36
C(rat)	1.00	0.27	0.16	0.02	0.02
C(wt%)	68.11	18.33	11.08	1.04	1.44
L7					
I	356	140	48	57	43
C(rat)	1.00	0.28	0.18	0.02	0.03
C(wt%)	67.00	18.46	11.83	1.03	1.68
L8					
I	393	144	49	75	43
C(rat)	1.00	0.26	0.16	0.02	0.02
C(wt%)	68.44	17.57	11.17	1.26	1.56
L9					
I	401	171	61	70	44
C(rat)	1.00	0.30	0.20	0.02	0.02
C(wt%)	65.04	19.43	12.95	1.09	1.48
L10					
I	400	157	44	78	51
C(rat)	1.00	0.27	0.14	0.02	0.03
C(wt%)	68.29	18.78	9.84	1.28	1.81
L15					
I	441	159	65	82	48
C(rat)	1.00	0.25	0.19	0.02	0.02
C(wt%)	67.29	17.00	12.99	1.20	1.52
L1					
I	492	137	73	77	50
C(rat)	1.00	0.20	0.19	0.02	0.02
C(wt%)	70.15	13.68	13.63	1.06	1.48
L2					
I	477	153	59	80	40
C(rat)	1.00	0.22	0.16	0.02	0.02
C(wt%)	70.41	15.82	11.40	1.14	1.23
L3					
I	432	144	51	69	52
C(rat)	1.00	0.23	0.15	0.02	0.03
C(wt%)	70.00	16.35	10.82	1.08	1.75
L4					
I	404	140	46	74	41
C(rat)	1.00	0.24	0.15	0.02	0.02
C(wt%)	69.90	16.97	10.42	1.23	1.48

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L20					
I	468	162	48	85	45
C(rat)	1.00	0.24	0.13	0.02	0.02
C(wt%)	70.71	17.15	9.50	1.24	1.41
L25					
I	407	159	56	85	47
C(rat)	1.00	0.27	0.18	0.02	0.02
C(wt%)	66.76	18.27	12.03	1.34	1.60
L30					
I	399	148	48	74	49
C(rat)	1.00	0.26	0.16	0.02	0.03
C(wt%)	68.46	17.79	10.78	1.22	1.75
L50					
I	402	162	61	71	43
C(rat)	1.00	0.28	0.20	0.02	0.02
C(wt%)	65.78	18.57	13.07	1.12	1.46
PPT 2-1					
I	225	375	27	78	68
C(rat)	1.00	1.17	0.16	0.03	0.06
C(wt%)	41.31	48.23	6.49	1.38	2.60
PPT 2-2					
I	176	274	20	65	55
C(rat)	1.00	1.09	0.15	0.04	0.07
C(wt%)	42.74	46.61	6.36	1.52	2.78
PPT 3-1					
I	361	202	45	75	46
C(rat)	1.00	0.39	0.16	0.02	0.03
C(wt%)	62.43	24.47	10.19	1.25	1.66
PPT 3-2					
I	347	212	38	78	52
C(rat)	1.00	0.43	0.14	0.02	0.03
C(wt%)	61.57	26.35	8.83	1.33	1.92

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Note: The chromium contents of the ppts indicated that there are two different types of carbide precipitates.

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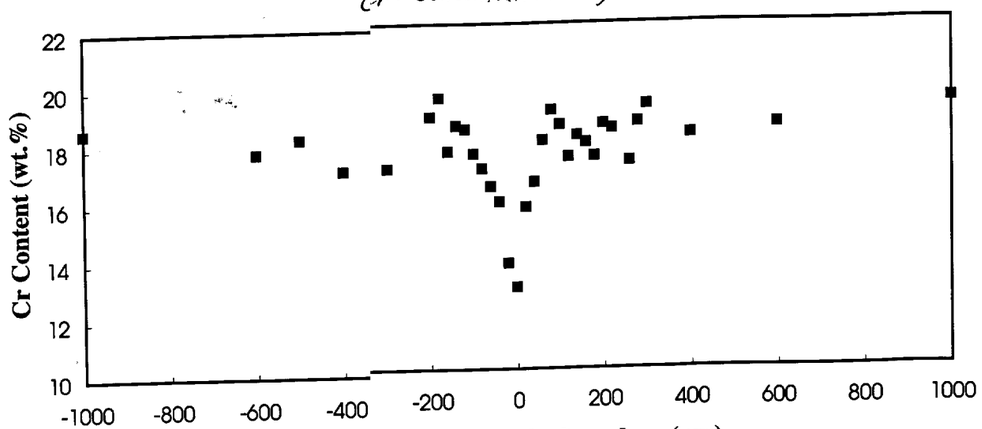
2. The chemical profiles for both Cr and Ni are plotted in the figures of chemical content vs. distance from grain boundary. Obviously, the 304L specimen, a standard reference material, does exhibit a well-defined Cr-depletion region across grain boundary. The width is about 200 nm.

Cr - Concentration Profile



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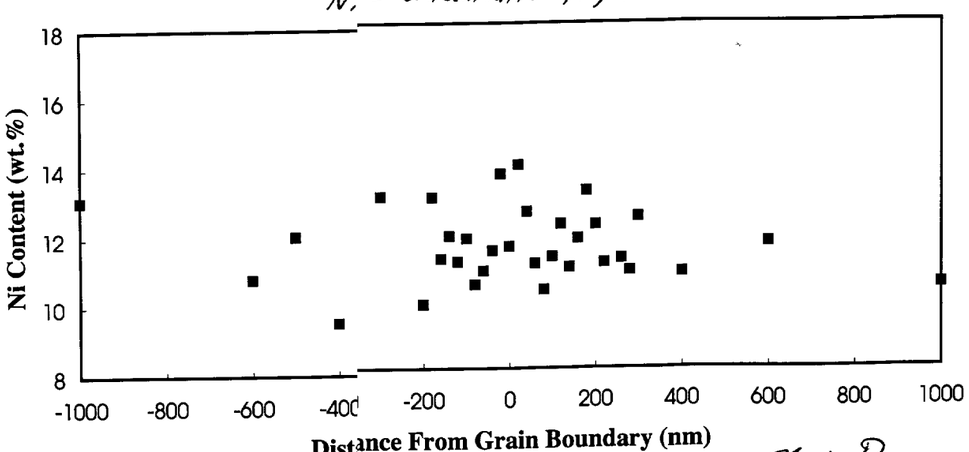
Ni - Concentration Profile



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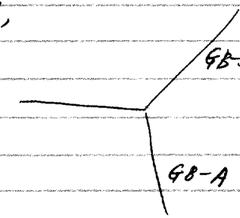
TEM Examination of the Solution-Annealed Specimen (F-4)

The solution-annealed alloy 825 specimen (Heat No. 4444511F), thin foil 4, was examined and recorded in the following.

Negative No.	Remark
8502	8,200X triple grain boundary area
8503	23,000X "
8504	60,000X grain boundary A.
8505	60,000X " (tilted 20°)
8506	60,000X "
8507	60,000X grain boundary B
8508	23,000X triple grain boundary area

Schematic drawing of the grain boundary area.

At 60,000X,



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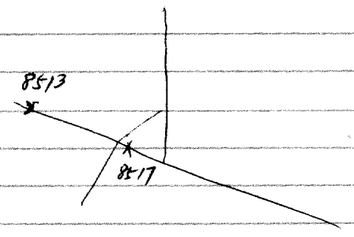
TEM Examination of the 700°C/15hr Aged specimen (FG-4)

The alloy 825 specimen aged treated at 700°C for 15 hours (Heat No. HH4371FG), thin foil 4, was examined to reveal the grain boundary area morphology.

Negative No.	Remark
8509	3,300X Region 1
8510	4,900X
8511	Diffraction pattern, cL=660mm, tilted ~9°
8512	DP " "
8513	60,000X, image of 8511
8514	23,000X
8515	4,900X Region 2
8516	60,000X, triple G.B. area
8517	60,000X
8518	135,000X
8519	60,000X, image of 8511
8520	135,000X "
8521	4,900X Region 3
8522	60,000X
8523	60,000X, dark field of 8522
8524	60,000X
8525	60,000X, dark field of 8524

Sketmatic drawing of the grain boundary region: (Negative No. 8515)

At 4,900X



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Chemical Analysis of Specimen F-4

Preliminary chemical analysis was performed of the solution-annealed alloy 825 specimen, thin foil 4, using microprobe technique with a probe size of about 20 nm diameter. The chemical concentration results were calculated and listed below.

Sample F4	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
R4(T75)								
I	935	1037	1226	94	260	180	79	59
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T75)	1.00	0.65	0.46	0.46	0.12	0.14	0.32	0.15
R4(T85)								
I	898	980	1152	69	246	168	79	69
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T85)	1.00	0.66	0.48	0.60	0.12	0.14	0.30	0.12
GB4R10[k(T85)]								
I	649	730	809	37	335	175	89	56
C(rat)	1.00	0.75	0.59	0.03	0.06	0.04	0.04	0.01
C(at%)	39.54	29.55	23.42	1.35	2.53	1.53	1.65	0.42
k(F4)	1.00	0.64	0.49	0.81	0.07	0.10	0.20	0.11
GB4R10[k(F4)]								
I	649	730	809	37	335	175	89	56
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
GB A1-1								
I	1444	1515	1760	101	647	113	99	47
C(rat)	1.00	0.68	0.60	0.06	0.03	0.01	0.01	0.00
C(at%)	41.96	28.38	25.01	2.37	1.24	0.33	0.56	0.15
GB A1-2								
I	1108	1169	1415	64	545	182	81	53
C(rat)	1.00	0.68	0.62	0.05	0.03	0.02	0.01	0.01
C(at%)	41.33	28.11	25.81	1.93	1.34	0.67	0.59	0.22
GB A2								
I	991	1098	1271	77	518	195	75	58
C(rat)	1.00	0.71	0.63	0.06	0.03	0.02	0.01	0.01
C(at%)	40.33	28.81	25.30	2.53	1.39	0.79	0.60	0.26
GB A3								
I	896	997	1150	57	477	209	80	53
C(rat)	1.00	0.72	0.63	0.05	0.04	0.02	0.02	0.01
C(at%)	40.35	28.95	25.33	2.08	1.41	0.93	0.70	0.26
GB A3R1								
I	802	916	1005	67	406	195	85	61
C(rat)	1.00	0.74	0.61	0.07	0.03	0.02	0.02	0.01
C(at%)	39.95	29.42	24.48	2.70	1.33	0.96	0.83	0.33

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GB A3R5								
I	702	796	920	54	363	181	76	53
C(rat)	1.00	0.73	0.64	0.06	0.03	0.03	0.02	0.01
C(at%)	39.63	28.97	25.40	2.46	1.35	1.01	0.84	0.33
GB A4-1								
I	899	969	1107	46	439	205	100	62
C(rat)	1.00	0.69	0.60	0.04	0.03	0.02	0.02	0.01
C(at%)	41.28	28.69	24.86	1.71	1.33	0.93	0.90	0.31
GB A4-2								
I	786	903	995	47	380	202	128	83
C(rat)	1.00	0.74	0.62	0.05	0.03	0.03	0.03	0.01
C(at%)	39.86	29.52	24.68	1.93	1.27	1.02	1.27	0.46
GB A4R1								
I	744	899	962	48	405	192	95	51
C(rat)	1.00	0.78	0.63	0.05	0.04	0.03	0.02	0.01
C(at%)	39.10	30.46	24.73	2.04	1.40	1.00	0.97	0.29
GB A4R5								
I	696	758	899	41	350	184	99	58
C(rat)	1.00	0.70	0.63	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	28.34	25.50	1.92	1.34	1.06	1.12	0.37
GB A4R10								
I	649	730	809	37	335	175	89	56
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
GB A4L1								
I	791	890	1053	47	386	182	110	63
C(rat)	1.00	0.73	0.65	0.05	0.03	0.02	0.03	0.01
C(at%)	39.76	28.84	25.89	1.91	1.28	0.91	1.08	0.35
GB A4L5								
I	754	849	939	58	364	175	109	68
C(rat)	1.00	0.73	0.61	0.06	0.03	0.02	0.03	0.01
C(at%)	40.16	29.15	24.46	2.50	1.28	0.93	1.13	0.40
GB A4L10								
I	775	827	980	52	388	184	116	76
C(rat)	1.00	0.69	0.62	0.05	0.03	0.02	0.03	0.01
C(at%)	40.70	28.00	25.17	2.21	1.34	0.96	1.19	0.44
GB B1-1								
I	951	1083	1295	58	481	176	90	47
C(rat)	1.00	0.73	0.67	0.05	0.03	0.02	0.02	0.01
C(at%)	39.60	29.07	26.37	1.95	1.32	0.73	0.73	0.21
GB B1-2								
I	890	1025	1144	53	477	182	79	60
C(rat)	1.00	0.74	0.63	0.05	0.04	0.02	0.02	0.01
C(at%)	40.01	29.71	25.15	1.93	1.41	0.81	0.69	0.29

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GB B1R1								
I	970	1077	1156	56	472	200	80	51
C(rat)	1.00	0.72	0.58	0.05	0.03	0.02	0.02	0.01
C(at%)	41.33	29.58	24.09	1.93	1.32	0.85	0.67	0.24
GB B1L1								
I	922	1036	1172	55	462	176	83	56
C(rat)	1.00	0.72	0.62	0.05	0.03	0.02	0.02	0.01
C(at%)	40.48	29.32	25.17	1.95	1.33	0.77	0.71	0.27

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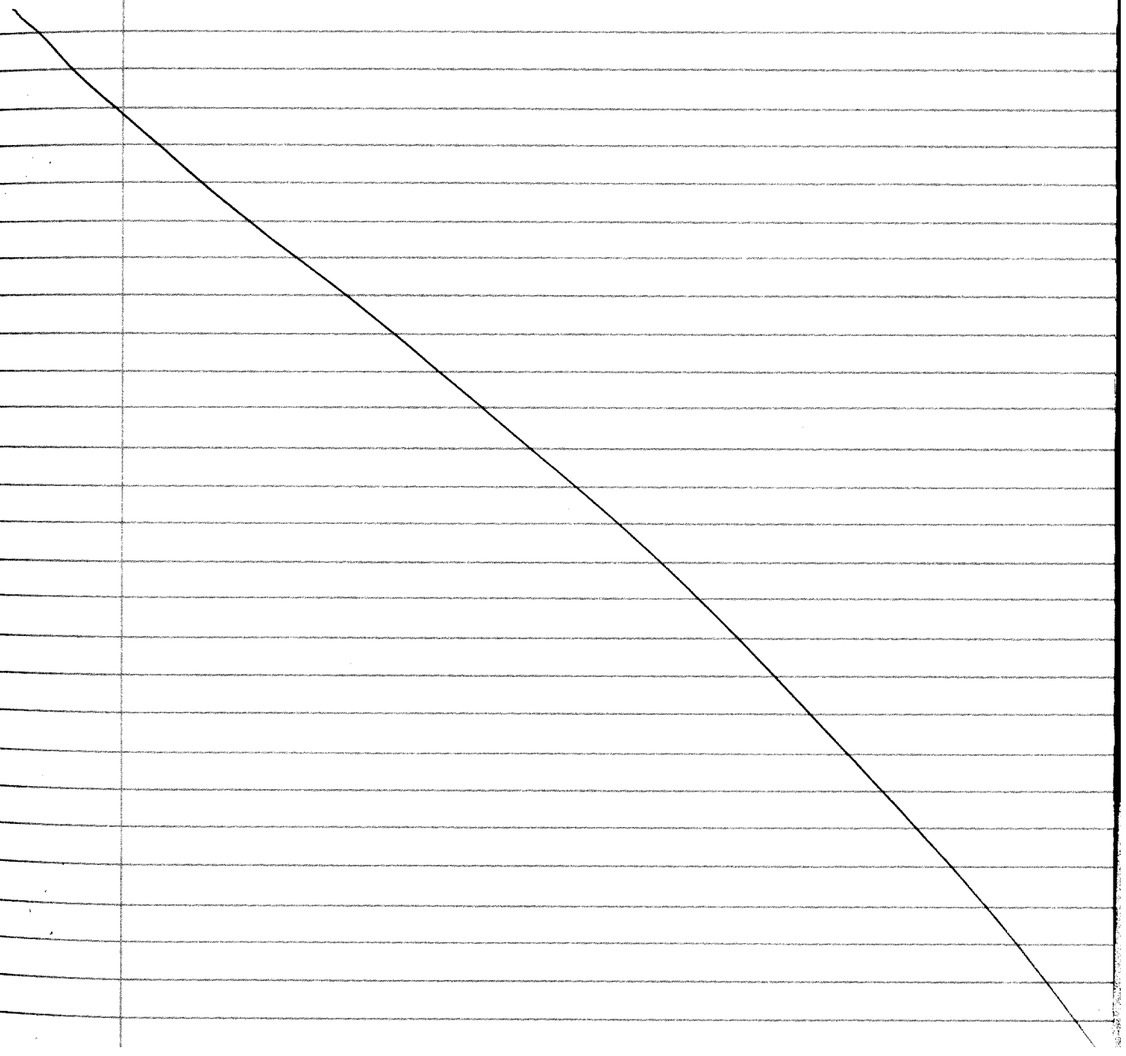

Chemical Analysis of Specimen FG-4

Preliminary chemical analysis was performed on the 700°C/15hr aged treated alloy 825 specimen, thin foil 4, using microprobe analysis techniques with a probe size of about 20 nm. The chemical concentration results were calculated and listed in the following.

Sample FG4	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
R4(T75)								
I	935	1037	1226	94	260	180	79	59
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T75)	1.00	0.65	0.46	0.46	0.12	0.14	0.32	0.15
R4(T85)								
I	898	980	1152	69	246	168	79	69
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(T85)	1.00	0.66	0.48	0.60	0.12	0.14	0.30	0.12
PPT2T10[k(T85)]								
I	704	809	926	49	379	179	65	43
C(rat)	1.00	0.76	0.63	0.04	0.07	0.04	0.03	0.01
C(at%)	38.92	29.72	24.33	1.63	2.60	1.42	1.09	0.29
k(FG4)	1.00	0.63	0.46	0.66	0.06	0.11	0.29	0.15
PPT2T10[k(FG4)]								
I	704	809	926	49	379	179	65	43
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
PPT1-1								
I	991	1208	1885	104	624	115	113	38
C(rat)	1.00	0.77	0.88	0.07	0.04	0.01	0.03	0.01
C(at%)	35.57	27.36	31.36	2.47	1.41	0.43	1.18	0.21
PPT1-2								
I	973	1159	1827	79	575	134	90	47
C(rat)	1.00	0.75	0.87	0.05	0.04	0.01	0.03	0.01
C(at%)	36.21	27.22	31.51	1.95	1.35	0.52	0.97	0.27
PPT2								
I	1015	1192	1773	92	649	221	83	59
C(rat)	1.00	0.74	0.81	0.06	0.04	0.02	0.02	0.01
C(at%)	36.95	27.38	29.92	2.22	1.49	0.85	0.88	0.33
PPT2T1								
I	862	968	1039	53	462	182	83	46
C(rat)	1.00	0.71	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	41.66	29.52	23.27	1.70	1.41	0.93	1.16	0.34

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PPT2T2								
I	838	920	1080	66	448	191	75	63
C(rat)	1.00	0.69	0.60	0.05	0.03	0.02	0.03	0.01
C(at%)	41.02	28.42	24.50	2.14	1.38	0.98	1.06	0.48
PPT2T5								
I	757	804	948	61	417	176	72	45
C(rat)	1.00	0.67	0.58	0.05	0.03	0.02	0.03	0.01
C(at%)	41.67	27.93	24.19	2.22	1.45	1.02	1.15	0.38
PPT2T10								
I	704	809	926	49	379	179	65	43
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
PPT3								
I	654	726	977	56	414	169	79	55
C(rat)	1.00	0.70	0.69	0.06	0.04	0.03	0.04	0.01
C(at%)	38.99	27.31	27.00	2.21	1.56	1.06	1.37	0.51
GB1								
I	820	879	986	53	432	195	78	57
C(rat)	1.00	0.68	0.56	0.04	0.03	0.03	0.03	0.01
C(at%)	42.14	28.51	23.49	1.80	1.40	1.05	1.16	0.45
GB2								
I	846	893	1088	58	492	215	85	58
C(rat)	1.00	0.67	0.60	0.05	0.04	0.03	0.03	0.01
C(at%)	41.48	27.63	24.73	1.88	1.52	1.11	1.21	0.44

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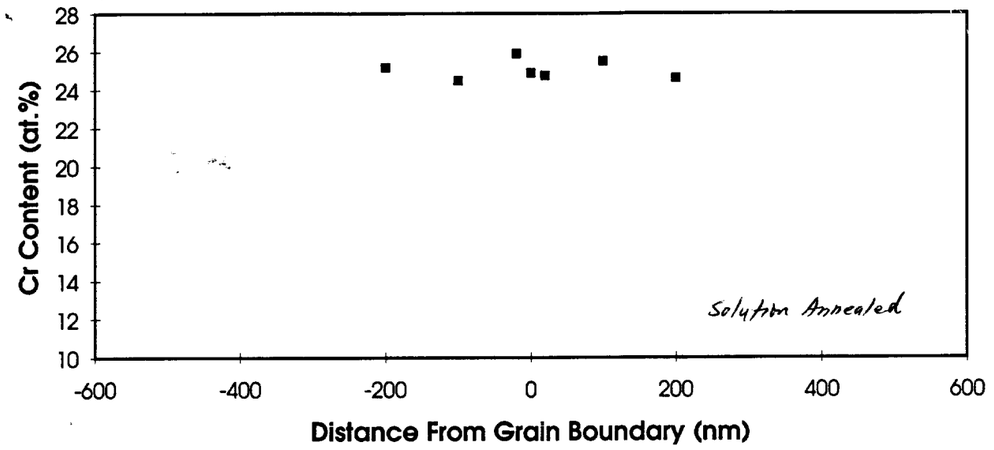
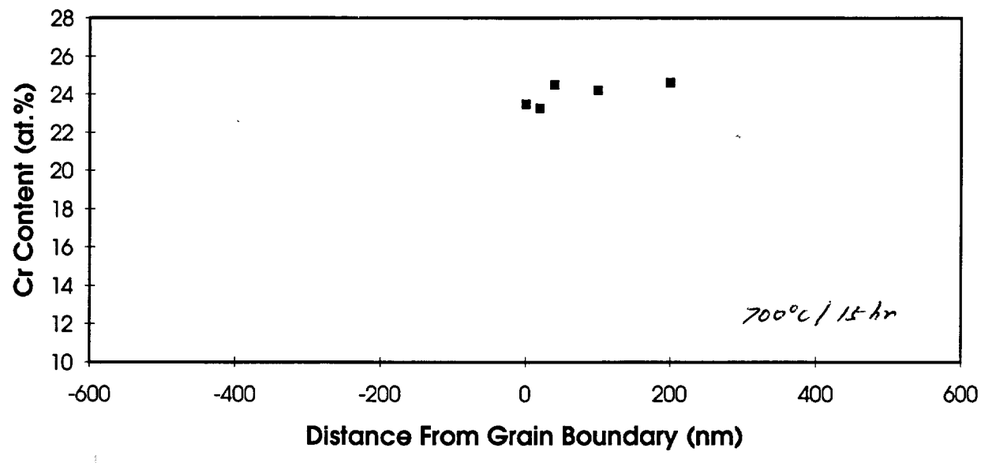
Chromium-Depletion Profiles Comparison

Chromium concentration profiles for specimens F-4 (Solution annealed) and FG-4 (700°C/15hr aged) were plotted and compared with the results from other specimens using the same scale. It is evident that both the 304L stainless steel and the 750°C/15 hr aged alloy 825 show deeper chromium-depletion zone.





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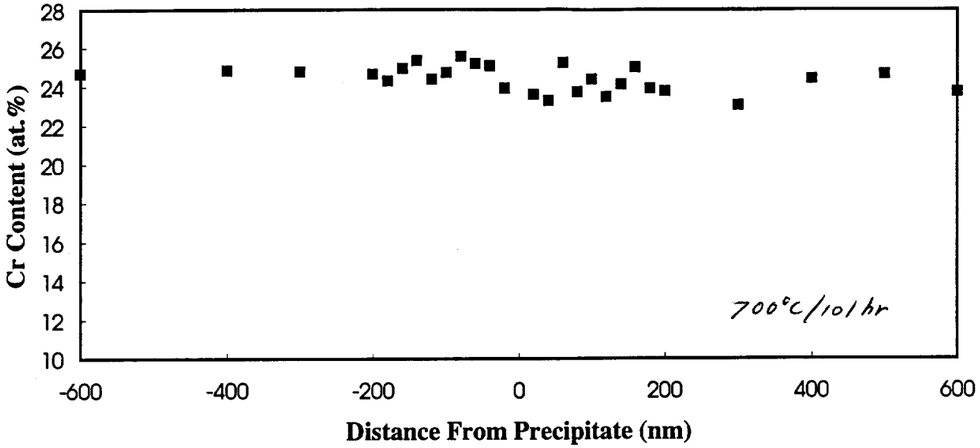
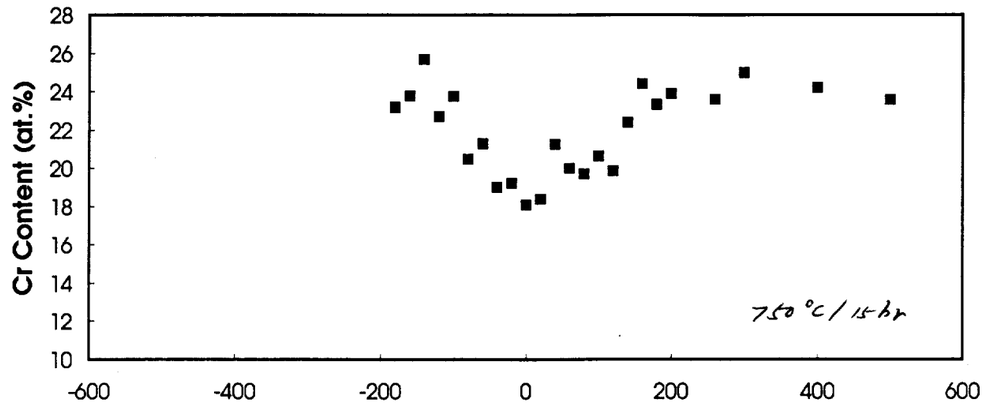
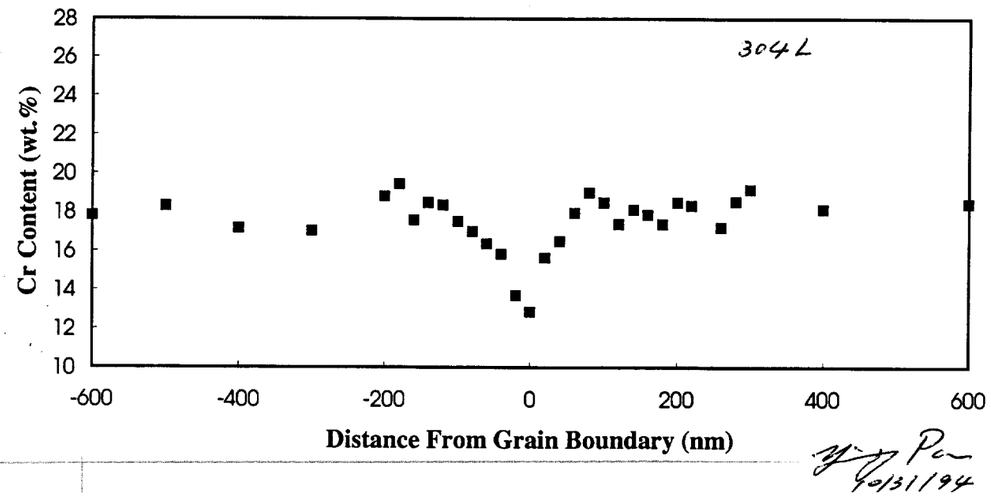
10/31/94







Yi-Ping Pan
10/31/1994

Pages 1 through 81 of this Scientific Notebook were reviewed for compliance with QAP-001 in response to Corrective Action Request 94-02. Corrections and clarifications were made as appropriate. In some cases, the date of a change will reflect the date of this review rather than the date of the original Scientific Notebook entry.

Randy Tolck
SwRI - QA
12/12/94

Chemical Profile Measurements for the 700°C/15-hr Aged Specimen (FG-4)

Chemical concentration profile was measured across a grain boundary region in the 700°C/15 hr aging treated alloy 825 specimen, thin foil 4, using microprobe technique with a probe size of 20 nm. The chemical content results were calculated and listed below. A plot of Cr content vs distance from grain boundary is also presented to reveal the Cr-depleted zone which is very shallow.

Sample FG4	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
PPT2 T10								
I	704	809	926	49	379	179	65	43
k(FG4)	1.00	0.63	0.46	0.66	0.06	0.11	0.29	0.15
GB5 T25(FG42)								
I	447	518	607	41	263	119	79	43
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(FG42)	1.00	0.63	0.45	0.50	0.06	0.10	0.15	0.10
GB5 T25(FG4)								
I	447	518	607	41	263	119	79	43
C(rat)	1.00	0.73	0.63	0.06	0.04	0.03	0.05	0.01
C(at%)	39.18	28.65	24.66	2.38	1.45	1.10	2.01	0.58
GB5-1								
I	817	906	999	58	470	171	72	52
C(rat)	1.00	0.69	0.55	0.04	0.03	0.02	0.01	0.01
C(at%)	42.51	29.50	23.34	1.52	1.41	0.89	0.57	0.26
GB5-2								
I	795	904	998	60	438	138	70	33
C(rat)	1.00	0.71	0.56	0.04	0.03	0.02	0.01	0.00
C(at%)	42.02	29.90	23.68	1.59	1.34	0.73	0.56	0.17
GB5 T1								
I	609	706	740	43	354	152	105	59
C(rat)	1.00	0.73	0.55	0.04	0.03	0.03	0.03	0.01
C(at%)	41.65	30.21	22.72	1.48	1.40	1.05	1.09	0.40
GB5 T2								
I	642	670	796	50	352	155	106	65
C(rat)	1.00	0.65	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	42.74	27.91	23.79	1.67	1.35	1.04	1.07	0.42
GB5 T3								
I	613	692	767	44	340	143	96	47
C(rat)	1.00	0.71	0.56	0.04	0.03	0.02	0.02	0.01
C(at%)	41.82	29.54	23.49	1.51	1.34	0.98	0.99	0.31
GB5 T4								
I	567	667	745	54	338	136	93	65
C(rat)	1.00	0.74	0.59	0.05	0.03	0.02	0.02	0.01
C(at%)	40.51	29.82	23.00	1.87	1.34	0.94	0.97	0.44

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GB5 T5								
I	531	582	672	45	313	126	74	49
C(rat)	1.00	0.69	0.57	0.04	0.03	0.02	0.02	0.01
C(at%)	41.93	28.76	23.82	1.79	1.43	1.00	0.88	0.38
GB5 T10								
I	490	521	613	38	285	120	68	47
C(rat)	1.00	0.67	0.56	0.04	0.03	0.02	0.02	0.01
C(at%)	42.47	28.26	23.85	1.66	1.43	1.05	0.89	0.40
GB5 T15								
I	478	553	630	43	277	114	82	48
C(rat)	1.00	0.72	0.59	0.05	0.03	0.02	0.03	0.01
C(at%)	40.75	29.50	23.88	1.82	1.35	0.97	1.05	0.40
GB5 T20								
I	472	538	604	39	285	116	81	46
C(rat)	1.00	0.71	0.57	0.04	0.03	0.02	0.03	0.01
C(at%)	41.25	29.42	23.70	1.71	1.44	1.02	1.07	0.39
GB5 T25								
I	447	518	607	41	263	119	79	43
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
GB5 T30								
I	429	472	548	34	261	109	75	42
C(rat)	1.00	0.69	0.57	0.04	0.04	0.03	0.03	0.01
C(at%)	41.69	28.70	23.91	1.66	1.46	1.06	1.10	0.40
GB5 B1								
I	736	852	982	56	447	156	74	45
C(rat)	1.00	0.72	0.60	0.04	0.04	0.02	0.02	0.01
C(at%)	41.00	29.70	24.56	1.57	1.44	0.87	0.62	0.25
GB5 B2								
I	762	822	942	55	423	172	78	43
C(rat)	1.00	0.68	0.56	0.04	0.03	0.02	0.02	0.01
C(at%)	42.70	28.82	23.70	1.55	1.37	0.97	0.66	0.24
GB5 B3								
I	702	860	959	58	447	161	77	49
C(rat)	1.00	0.77	0.61	0.04	0.04	0.02	0.02	0.01
C(at%)	39.92	30.60	24.48	1.66	1.47	0.92	0.66	0.27
GB5 B4								
I	713	847	926	58	434	177	73	58
C(rat)	1.00	0.74	0.58	0.04	0.04	0.02	0.02	0.01
C(at%)	40.80	30.33	23.79	1.67	1.43	1.02	0.63	0.32
GB5 B5								
I	724	847	970	53	458	164	69	53
C(rat)	1.00	0.73	0.60	0.04	0.04	0.02	0.01	0.01
C(at%)	40.80	29.87	24.54	1.50	1.49	0.93	0.59	0.29
GB5 B10								
I	678	773	922	55	410	168	79	50
C(rat)	1.00	0.71	0.61	0.04	0.03	0.02	0.02	0.01
C(at%)	40.83	29.13	24.93	1.66	1.42	1.02	0.72	0.29
GB5 B15								
I	636	764	835	50	400	167	74	44
C(rat)	1.00	0.75	0.59	0.04	0.04	0.03	0.02	0.01
C(at%)	40.52	30.46	23.88	1.60	1.47	1.07	0.71	0.27

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GB5 B20								
I	638	704	845	52	362	163	72	47
C(rat)	1.00	0.69	0.59	0.04	0.03	0.03	0.02	0.01
C(at%)	41.51	28.66	24.68	1.70	1.36	1.07	0.71	0.30
GB5 B25								
I	590	709	822	50	343	159	73	48
C(rat)	1.00	0.75	0.63	0.04	0.03	0.03	0.02	0.01
C(at%)	39.88	29.99	24.95	1.70	1.34	1.08	0.75	0.32
GB5 B30								
I	584	692	806	48	340	149	85	48
C(rat)	1.00	0.74	0.62	0.04	0.03	0.03	0.02	0.01
C(at%)	40.13	29.76	24.87	1.66	1.35	1.03	0.88	0.32
GB3								
I	1243	1311	1450	76	587	145	77	42
C(rat)	1.00	0.66	0.52	0.03	0.03	0.01	0.01	0.00
C(at%)	44.13	29.13	23.11	1.36	1.20	0.52	0.41	0.15
GB3 T1								
I	795	904	998	60	438	138	70	33
C(rat)	1.00	0.71	0.56	0.04	0.03	0.02	0.01	0.00
C(at%)	42.02	29.90	23.68	1.59	1.34	0.73	0.56	0.17
GB3 T2								
I	735	836	986	55	400	158	60	40
C(rat)	1.00	0.71	0.60	0.04	0.03	0.02	0.01	0.01
C(at%)	41.28	29.38	24.86	1.55	1.30	0.89	0.51	0.22
GB3 T3								
I	703	757	858	50	366	158	55	47
C(rat)	1.00	0.67	0.55	0.04	0.03	0.02	0.01	0.01
C(at%)	42.95	28.94	23.53	1.54	1.29	0.97	0.51	0.28
GB3 T4								
I	386	439	523	25	245	106	51	34
C(rat)	1.00	0.71	0.61	0.03	0.04	0.03	0.02	0.01
C(at%)	40.89	29.10	24.87	1.33	1.50	1.13	0.82	0.35
GB3 T5								
I	298	352	391	24	181	91	32	21
C(rat)	1.00	0.74	0.59	0.04	0.04	0.03	0.02	0.01
C(at%)	40.69	30.08	23.97	1.65	1.43	1.25	0.66	0.28
GB3 T10								
I	256	267	335	19	170	76	41	21
C(rat)	1.00	0.65	0.59	0.04	0.04	0.03	0.02	0.01
C(at%)	42.05	27.44	24.70	1.57	1.61	1.26	1.02	0.34
GB3 T20								
I	204	230	258	15	122	77	31	22
C(rat)	1.00	0.71	0.57	0.04	0.03	0.04	0.02	0.01
C(at%)	41.39	29.20	23.50	1.53	1.43	1.57	0.95	0.44
GB3 T30								
I	161	194	245	17	121	62	36	18
C(rat)	1.00	0.75	0.68	0.05	0.04	0.04	0.03	0.01
C(at%)	38.21	28.81	26.11	2.03	1.66	1.48	1.29	0.42
PPT4								
I	570	662	860	45	365	161	101	62
C(rat)	1.00	0.73	0.68	0.04	0.04	0.03	0.03	0.01
C(at%)	39.27	28.54	26.60	1.56	1.45	1.12	1.05	0.42

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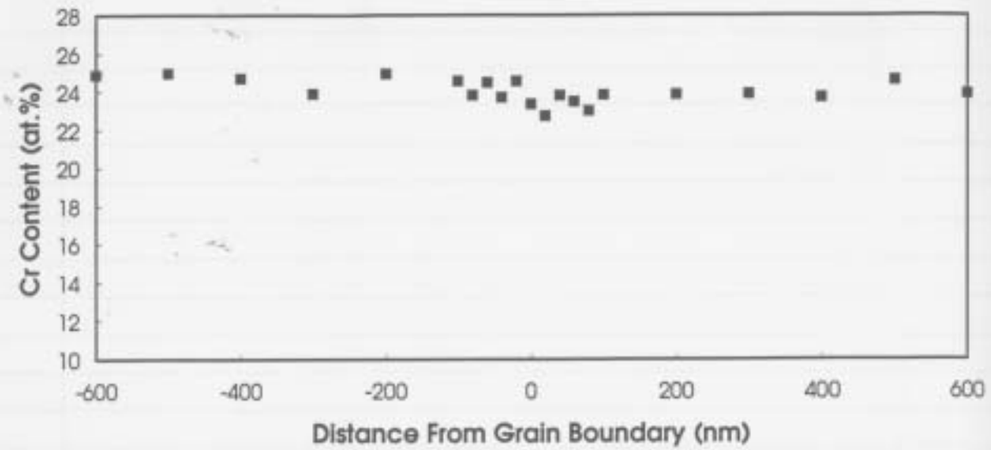
Cr - Concentration Profile



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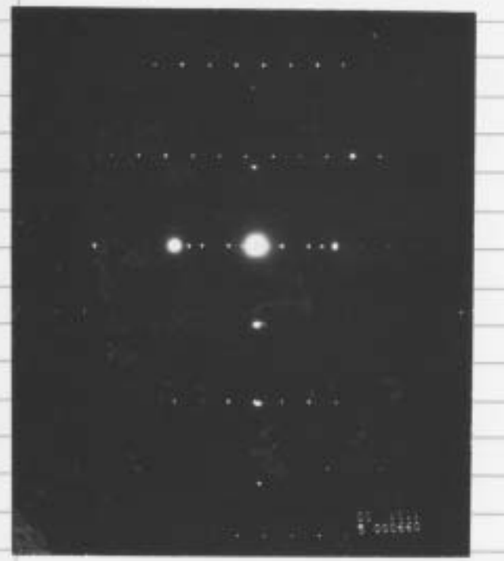
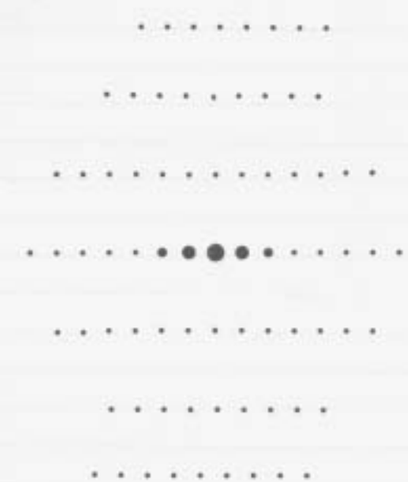
Diffraction Pattern Analysis for the 700°C/15 hr Aged Specimen (FG-4)

Diffraction pattern from photo no. 8511 (page 74) was determined to be $M_{23}C_6$ carbide precipitate oriented in the [72$\bar{5}$] axis. Both the diffraction patterns taken from TEM analysis and from simulation analysis are presented below.





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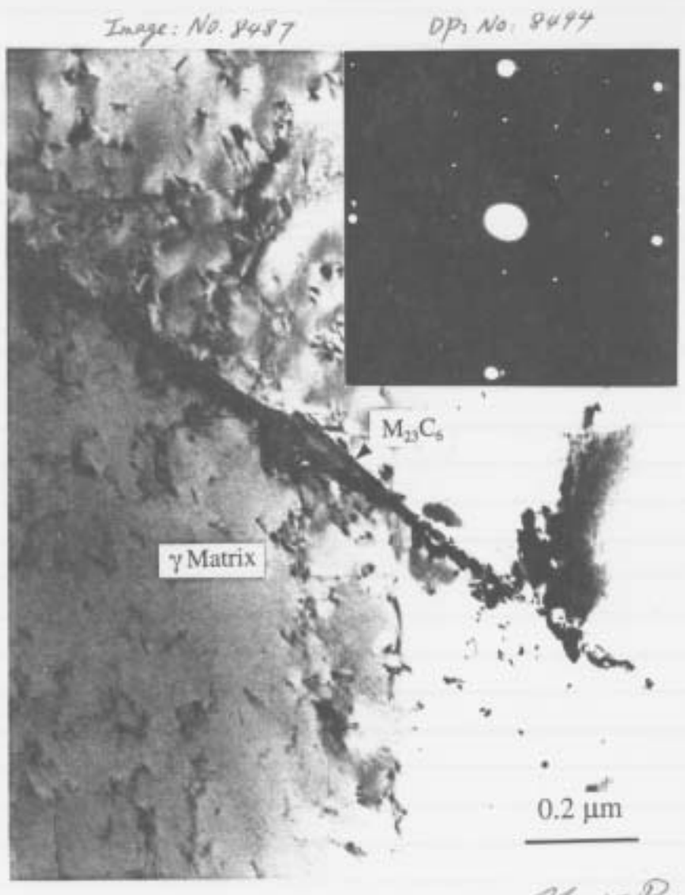
Representative TEM Micrographs from the 304L Steel Specimen

TEM bright-field image of γ matrix and $M_{23}C_6$ carbide taken from an AISI 304L stainless steel specimen aged at 621°C for 24 h and diffraction pattern (inset) for $M_{23}C_6$ oriented in the zone axis of $[\bar{2}51]$.



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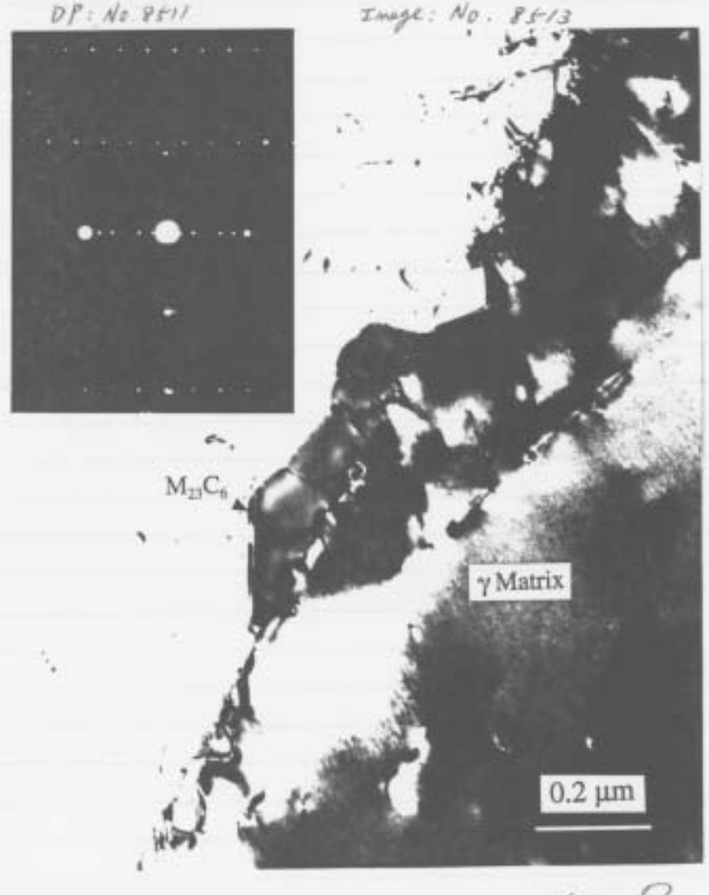
Representative TEM micrographs from the 700°C/15h Aged specimen

TEM bright-field image of γ matrix and $M_{23}C_6$ carbide taken from a specimen aged at 700°C for 15 h and diffraction pattern (inset) for $M_{23}C_6$ oriented in the zone axis of $[72\bar{5}]$.



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Reanalysis of the Chemical Profile for the 750°C/15hr Aged Specimen

1. To justify the Cr-depleted zone in the alloy 825 specimen after 750°C/15hr aging treatment, TEM examination was performed on other thin foils. Thin foil no. 5 was identified to be a good sample for chemical profile re-analysis. The general microstructure morphology was observed and photographed.

Negative No.	Remark
8595	GB Area I, 23,000X
8596	36,000X
8597	60,000X
8598	23,000X
8599	36,000X
8600	GB Area II, 8,200X
8601	23,000X
8602	60,000X
8603	60,000X
8604	60,000X

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2. Chemical concentration profile was measured across a grain boundary region in Area I of the 750°C/15hr aged specimen. The results are reported in the following.

Sample51	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
B 25	757	856	950	57	153	152	78	65
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.64	0.49	0.61	0.17	0.13	0.26	0.11
GB1								
I	1306	1293	1401	104	233	246	123	93
C(rat)	1.00	0.63	0.52	0.05	0.03	0.03	0.02	0.01
C(at%)	43.63	27.70	22.74	2.13	1.31	1.10	1.07	0.34
GB2								
I	1252	1285	1413	81	212	181	105	73
C(rat)	1.00	0.66	0.55	0.04	0.03	0.02	0.02	0.01
C(at%)	43.07	28.35	23.61	1.71	1.23	0.83	0.94	0.28
PPT								
I	1092	1319	2260	139	249	166	115	64
C(rat)	1.00	0.77	1.01	0.08	0.04	0.02	0.03	0.01
C(at%)	33.89	26.25	34.07	2.64	1.30	0.69	0.93	0.22
T 1								
I	1134	1277	1311	78	218	191	98	63
C(rat)	1.00	0.72	0.56	0.04	0.03	0.02	0.02	0.01
C(at%)	41.51	29.98	23.31	1.75	1.34	0.93	0.93	0.25
T 2								
I	900	980	1073	69	187	190	89	58
C(rat)	1.00	0.70	0.58	0.05	0.03	0.03	0.03	0.01
C(at%)	41.32	28.85	23.93	1.94	1.44	1.16	1.06	0.29
T 3								
I	857	933	1011	59	162	164	86	51
C(rat)	1.00	0.70	0.57	0.04	0.03	0.03	0.03	0.01
C(at%)	41.61	29.05	23.85	1.75	1.32	1.06	1.08	0.27
T 4								
I	824	858	987	53	137	158	78	55
C(rat)	1.00	0.67	0.58	0.04	0.03	0.03	0.02	0.01
C(at%)	42.12	28.13	24.51	1.66	1.18	1.08	1.04	0.31
T 5								
I	800	832	906	56	133	149	77	50
C(rat)	1.00	0.67	0.55	0.04	0.03	0.02	0.03	0.01
C(at%)	42.65	28.44	23.47	1.83	1.19	1.06	1.07	0.29
T 6								
I	809	957	977	62	144	154	88	55
C(rat)	1.00	0.76	0.59	0.05	0.03	0.03	0.03	0.01
C(at%)	40.27	30.55	23.63	1.89	1.20	1.02	1.14	0.30

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T 10								
I	805	863	913	61	140	156	77	53
C(rat)	1.00	0.69	0.55	0.05	0.03	0.03	0.02	0.01
C(at%)	42.16	28.98	23.23	1.96	1.23	1.09	1.05	0.30
T 11								
I	813	829	962	63	134	165	83	56
C(rat)	1.00	0.65	0.57	0.05	0.03	0.03	0.03	0.01
C(at%)	42.28	27.65	24.30	2.01	1.17	1.14	1.12	0.32
T 15								
I	812	851	934	59	137	156	80	53
C(rat)	1.00	0.67	0.56	0.04	0.03	0.03	0.03	0.01
C(at%)	42.34	28.46	23.66	1.88	1.20	1.08	1.08	0.30
T 16								
I	794	856	934	58	131	138	75	52
C(rat)	1.00	0.69	0.57	0.04	0.03	0.02	0.02	0.01
C(at%)	41.84	28.93	23.91	1.87	1.16	0.97	1.03	0.30
T 20								
I	742	779	922	55	138	141	73	49
C(rat)	1.00	0.67	0.60	0.05	0.03	0.03	0.03	0.01
C(at%)	41.46	27.91	25.03	1.88	1.30	1.05	1.06	0.30
T 25								
I	792	835	956	57	139	144	73	57
C(rat)	1.00	0.68	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	41.80	28.26	24.51	1.84	1.23	1.01	1.00	0.33
T 29								
I	862	806	940	54	124	154	78	59
C(rat)	1.00	0.60	0.53	0.04	0.02	0.02	0.02	0.01
C(at%)	44.51	26.69	23.58	1.71	1.08	1.06	1.05	0.33
T 30								
I	817	860	904	60	150	164	78	52
C(rat)	1.00	0.68	0.54	0.04	0.03	0.03	0.02	0.01
C(at%)	42.61	28.76	22.90	1.92	1.31	1.14	1.06	0.30
T 31								
I	776	819	903	59	132	132	74	49
C(rat)	1.00	0.68	0.57	0.05	0.03	0.02	0.02	0.01
C(at%)	42.17	28.54	23.84	1.96	1.21	0.96	1.04	0.29
T 40								
I	903	946	1012	63	145	161	91	59
C(rat)	1.00	0.67	0.54	0.04	0.03	0.02	0.03	0.01
C(at%)	42.68	28.67	23.75	1.86	1.18	1.04	1.14	0.31
T 50								
I	902	914	1017	65	143	175	82	54
C(rat)	1.00	0.65	0.55	0.04	0.03	0.03	0.02	0.01
C(at%)	43.02	27.96	23.56	1.90	1.15	1.11	1.02	0.28
B 1								
I	1152	1182	1300	81	212	181	97	67
C(rat)	1.00	0.66	0.55	0.04	0.03	0.02	0.02	0.01
C(at%)	42.93	28.25	23.54	1.85	1.33	0.90	0.94	0.27
B 2								
I	943	1045	1119	95	214	212	140	66
C(rat)	1.00	0.71	0.58	0.06	0.04	0.03	0.04	0.01
C(at%)	40.60	28.85	23.40	2.50	1.55	1.22	1.57	0.31

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B 3								
I	967	969	1191	74	191	220	103	72
C(rat)	1.00	0.64	0.60	0.05	0.03	0.03	0.03	0.01
C(at%)	41.89	26.92	25.06	1.96	1.39	1.27	1.16	0.34
B 4								
I	959	1015	1153	68	188	198	106	71
C(rat)	1.00	0.68	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	41.61	28.24	24.30	1.81	1.37	1.15	1.19	0.34
B 5								
I	899	1008	1196	72	192	196	92	57
C(rat)	1.00	0.72	0.65	0.05	0.04	0.03	0.03	0.01
C(at%)	39.80	28.62	25.72	1.95	1.43	1.16	1.06	0.28
B 6								
I	901	1001	1134	67	175	173	101	58
C(rat)	1.00	0.71	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.59	28.92	24.82	1.85	1.32	1.04	1.18	0.29
B 7								
I	912	987	1120	65	172	183	92	66
C(rat)	1.00	0.69	0.60	0.04	0.03	0.03	0.03	0.01
C(at%)	41.21	28.60	24.59	1.80	1.31	1.10	1.08	0.33
B 10								
I	872	951	1037	66	147	160	98	47
C(rat)	1.00	0.70	0.58	0.05	0.03	0.02	0.03	0.01
C(at%)	41.47	29.00	23.96	1.92	1.17	1.01	1.21	0.25
B 11								
I	861	904	1020	61	158	170	89	58
C(rat)	1.00	0.67	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	41.95	28.25	24.14	1.82	1.29	1.10	1.13	0.31
B 15								
I	861	917	1061	71	160	168	87	60
C(rat)	1.00	0.68	0.60	0.05	0.03	0.03	0.03	0.01
C(at%)	41.27	28.19	24.71	2.08	1.29	1.07	1.08	0.32
B 17								
I	913	927	1067	66	164	184	87	57
C(rat)	1.00	0.65	0.57	0.04	0.03	0.03	0.02	0.01
C(at%)	42.52	27.69	24.14	1.88	1.28	1.14	1.05	0.29
B 20								
I	805	899	1079	63	159	149	92	46
C(rat)	1.00	0.72	0.65	0.05	0.03	0.02	0.03	0.01
C(at%)	39.86	28.55	25.96	1.91	1.32	0.98	1.18	0.25
B 21								
I	757	853	954	56	155	160	80	60
C(rat)	1.00	0.72	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.34	29.15	24.70	1.83	1.39	1.14	1.11	0.35
B 25								
I	757	856	950	57	153	152	78	65
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
B 30								
I	663	737	838	54	132	145	66	49
C(rat)	1.00	0.71	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.43	28.82	24.83	2.02	1.35	1.18	1.05	0.33

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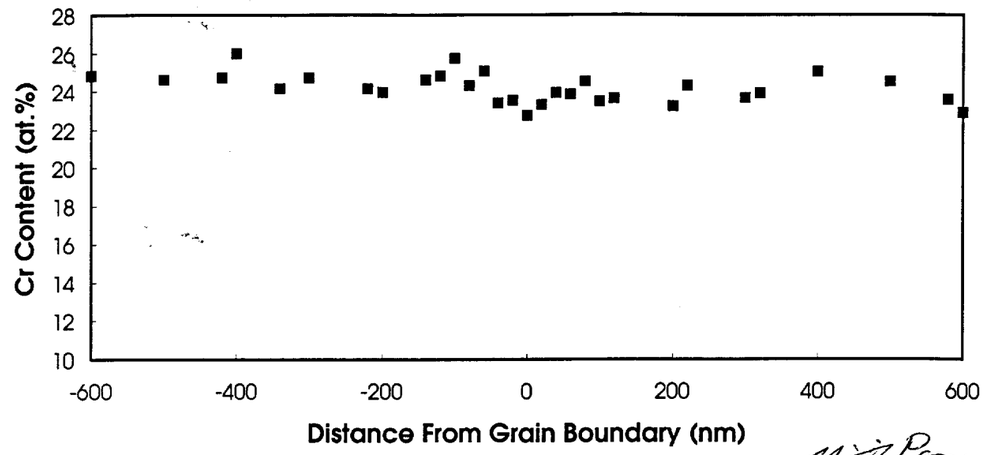
Cr - concentration profiles with different y-axis scale to reveal the Cr-depleted zone which is not well-defined due to data scattering.



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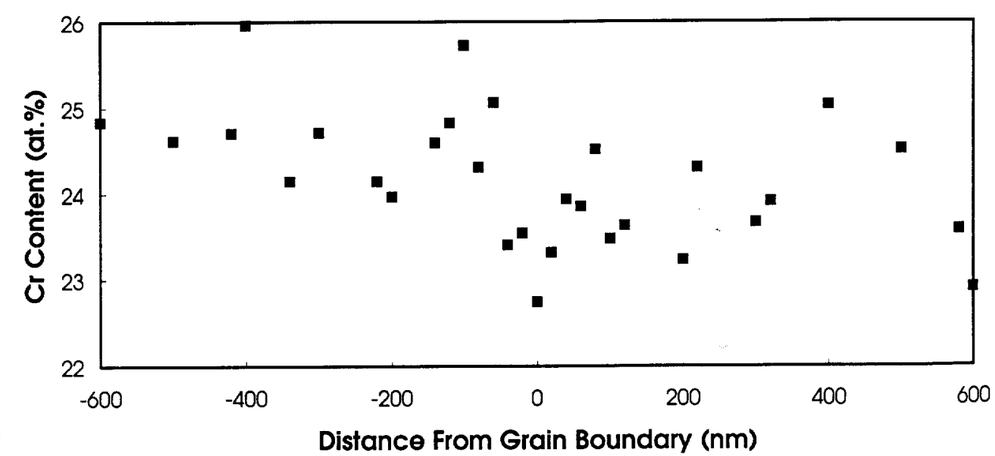

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Further Chemical Profiles Determination for the 750°C/15hr Aged Specimen

To better define the Cr-depleted zone in the alloy 625 specimen aging treated at 750°C for 15 hours, two additional grain boundary regions were identified in thin foil no. 5 for chemical concentration profiles analysis. The results are presented below.

Sample52	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
B 20	446	488	562	45	107	127	77	48
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.66	0.48	0.46	0.14	0.09	0.16	0.09
GB3								
I	505	537	589	51	129	133	54	41
C(rat)	1.00	0.70	0.56	0.05	0.04	0.02	0.02	0.01
C(at%)	41.67	29.37	23.51	1.92	1.51	1.03	0.69	0.30
GB4								
I	484	502	562	48	118	128	53	36
C(rat)	1.00	0.69	0.56	0.05	0.03	0.02	0.02	0.01
C(at%)	42.06	28.91	23.63	1.91	1.45	1.05	0.71	0.27
GB5								
I	543	587	627	47	135	107	64	29
C(rat)	1.00	0.72	0.56	0.04	0.04	0.02	0.02	0.00
C(at%)	41.82	29.96	23.36	1.65	1.47	0.77	0.76	0.20
PPT2								
I	328	383	592	37	96	35	43	16
C(rat)	1.00	0.77	0.87	0.05	0.04	0.01	0.02	0.00
C(at%)	36.04	27.89	31.47	1.86	1.49	0.36	0.73	0.15
T 1								
I	424	481	501	40	106	109	68	38
C(rat)	1.00	0.75	0.57	0.04	0.04	0.02	0.02	0.01
C(at%)	40.67	30.58	23.25	1.75	1.44	0.98	1.01	0.32
T 2								
I	449	487	529	44	102	125	51	39
C(rat)	1.00	0.72	0.57	0.04	0.03	0.03	0.02	0.01
C(at%)	41.37	29.74	23.58	1.85	1.33	1.08	0.73	0.31
T 3								
I	410	469	488	37	106	95	53	39
C(rat)	1.00	0.76	0.58	0.04	0.04	0.02	0.02	0.01
C(at%)	40.62	30.79	23.39	1.67	1.49	0.88	0.81	0.34
T 4								
I	459	532	580	42	124	110	52	43
C(rat)	1.00	0.77	0.61	0.04	0.04	0.02	0.02	0.01
C(at%)	39.87	30.63	24.38	1.67	1.52	0.90	0.70	0.33
T 5								
I	407	451	517	34	94	101	62	36
C(rat)	1.00	0.73	0.61	0.04	0.03	0.02	0.02	0.01
C(at%)	40.41	29.68	24.84	1.54	1.32	0.94	0.95	0.31

T 10								
I	433	480	541	37	99	104	65	35
C(rat)	1.00	0.73	0.60	0.04	0.03	0.02	0.02	0.01
C(at%)	40.59	29.82	24.54	1.58	1.31	0.92	0.94	0.29
T 15								
I	463	492	562	36	113	105	71	47
C(rat)	1.00	0.70	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	41.40	29.16	24.31	1.47	1.43	0.88	0.98	0.37
T 20								
I	479	515	606	48	111	115	70	45
C(rat)	1.00	0.71	0.61	0.05	0.03	0.02	0.02	0.01
C(at%)	40.71	29.01	24.92	1.86	1.34	0.92	0.92	0.33
T 25								
I	490	555	594	52	121	113	76	55
C(rat)	1.00	0.75	0.59	0.05	0.03	0.02	0.02	0.01
C(at%)	40.39	30.32	23.69	1.96	1.41	0.88	0.97	0.40
T 29								
I	457	500	567	37	101	121	82	43
C(rat)	1.00	0.73	0.60	0.04	0.03	0.02	0.03	0.01
C(at%)	40.74	29.54	24.46	1.51	1.27	1.01	1.13	0.34
T 30								
I	500	541	578	43	124	119	71	43
C(rat)	1.00	0.72	0.56	0.04	0.04	0.02	0.02	0.01
C(at%)	41.62	29.85	23.28	1.64	1.46	0.93	0.92	0.31
B 1								
I	413	460	503	27	109	82	43	35
C(rat)	1.00	0.74	0.59	0.03	0.04	0.02	0.02	0.01
C(at%)	41.04	30.29	24.18	1.23	1.53	0.77	0.66	0.30
B 2								
I	355	387	440	35	97	103	57	40
C(rat)	1.00	0.72	0.60	0.05	0.04	0.03	0.02	0.01
C(at%)	40.52	29.28	24.30	1.83	1.57	1.11	1.01	0.40
B 3								
I	332	361	410	34	84	92	60	38
C(rat)	1.00	0.72	0.60	0.05	0.04	0.03	0.03	0.01
C(at%)	40.57	29.24	24.24	1.90	1.45	1.06	1.14	0.41
B 4								
I	316	350	398	31	81	104	59	38
C(rat)	1.00	0.73	0.61	0.04	0.04	0.03	0.03	0.01
C(at%)	40.08	29.42	24.42	1.80	1.45	1.24	1.16	0.42
B 5								
I	271	308	355	25	71	67	43	28
C(rat)	1.00	0.75	0.63	0.04	0.04	0.02	0.02	0.01
C(at%)	39.63	29.85	25.12	1.67	1.47	0.92	0.97	0.36
B 6								
I	410	439	525	37	93	95	69	45
C(rat)	1.00	0.71	0.62	0.04	0.03	0.02	0.03	0.01
C(at%)	40.65	28.85	25.18	1.68	1.30	0.89	1.06	0.39
B 10								
I	403	466	524	39	101	102	77	55
C(rat)	1.00	0.77	0.63	0.04	0.04	0.02	0.03	0.01
C(at%)	39.36	30.16	24.76	1.74	1.40	0.94	1.17	0.47

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B 15								
I	460	502	592	40	122	115	92	54
C(rat)	1.00	0.72	0.62	0.04	0.04	0.02	0.03	0.01
C(at%)	40.19	29.07	25.02	1.60	1.51	0.94	1.25	0.41
B 20								
I	446	488	562	45	107	127	77	48
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
B 25								
I	432	469	548	37	106	101	76	49
C(rat)	1.00	0.72	0.61	0.04	0.03	0.02	0.03	0.01
C(at%)	40.55	29.18	24.89	1.59	1.41	0.89	1.11	0.40
B 30								
I	317	354	400	28	80	80	51	37
C(rat)	1.00	0.74	0.61	0.04	0.04	0.02	0.02	0.01
C(at%)	40.23	29.77	24.56	1.62	1.44	0.95	1.00	0.41

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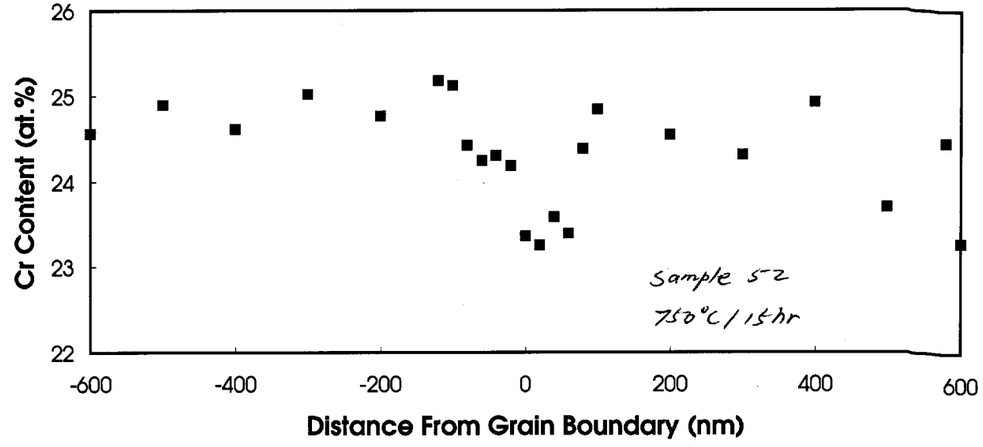

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Sample53

GB 6								
I	425	440	487	40	112	98	75	54
C(rat)	1.00	0.69	0.55	0.04	0.04	0.02	0.03	0.01
C(at%)	42.00	28.82	23.29	1.81	1.57	0.91	1.15	0.47
T 1								
I	378	397	439	33	96	87	59	42
C(rat)	1.00	0.70	0.56	0.04	0.04	0.02	0.02	0.01
C(at%)	41.85	29.13	23.52	1.67	1.50	0.91	1.01	0.41
T 2								
I	367	396	449	39	104	84	76	42
C(rat)	1.00	0.72	0.59	0.05	0.04	0.02	0.03	0.01
C(at%)	40.66	29.08	24.07	1.97	1.63	0.87	1.31	0.41
T 3								
I	361	382	450	33	97	85	70	41
C(rat)	1.00	0.70	0.60	0.04	0.04	0.02	0.03	0.01
C(at%)	40.88	28.67	24.66	1.71	1.55	0.90	1.23	0.41
T 4								
I	414	436	495	40	96	101	74	50
C(rat)	1.00	0.70	0.58	0.04	0.03	0.02	0.03	0.01
C(at%)	41.41	28.90	23.96	1.83	1.36	0.95	1.15	0.44
T 5								
I	436	465	527	36	114	91	83	51
C(rat)	1.00	0.71	0.58	0.04	0.04	0.02	0.03	0.01
C(at%)	41.22	29.14	24.11	1.55	1.53	0.81	1.22	0.42
T 10								
I	486	526	586	51	114	114	82	55
C(rat)	1.00	0.72	0.58	0.05	0.03	0.02	0.03	0.01
C(at%)	40.98	29.39	23.91	1.96	1.36	0.90	1.07	0.41
T 15								
I	508	553	618	43	117	111	93	53
C(rat)	1.00	0.72	0.59	0.04	0.03	0.02	0.03	0.01
C(at%)	40.99	29.57	24.13	1.59	1.34	0.84	1.16	0.37
T 20								
I	481	507	597	34	108	92	82	46
C(rat)	1.00	0.70	0.60	0.03	0.03	0.02	0.03	0.01
C(at%)	41.39	28.91	24.86	1.34	1.32	0.74	1.09	0.35
T 25								
I	519	560	623	37	100	100	78	48
C(rat)	1.00	0.72	0.58	0.03	0.03	0.02	0.02	0.01
C(at%)	41.58	29.73	24.15	1.35	1.13	0.75	0.97	0.34
T 30								
I	502	535	608	40	98	105	69	49
C(rat)	1.00	0.71	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	41.57	29.36	24.36	1.51	1.15	0.82	0.89	0.36
B 1								
I	462	492	534	44	110	114	81	50
C(rat)	1.00	0.71	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	41.63	29.38	23.28	1.81	1.40	0.97	1.13	0.39
B 2								
I	494	509	581	42	110	119	80	55
C(rat)	1.00	0.68	0.57	0.04	0.03	0.02	0.03	0.01
C(at%)	42.02	28.69	23.91	1.63	1.32	0.95	1.05	0.41

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B 3								
I	489	543	591	42	130	117	93	49
C(rat)	1.00	0.74	0.58	0.04	0.04	0.02	0.03	0.01
C(at%)	40.68	29.94	23.79	1.60	1.53	0.91	1.20	0.36
B 4								
I	464	543	590	42	117	108	83	58
C(rat)	1.00	0.78	0.62	0.04	0.04	0.02	0.03	0.01
C(at%)	39.55	30.67	24.33	1.64	1.41	0.87	1.10	0.43
B 5								
I	485	572	620	36	136	124	82	60
C(rat)	1.00	0.78	0.62	0.03	0.04	0.02	0.03	0.01
C(at%)	39.45	30.84	24.40	1.34	1.57	0.95	1.03	0.43
B 10								
I	530	589	683	42	122	132	86	65
C(rat)	1.00	0.74	0.62	0.04	0.03	0.02	0.03	0.01
C(at%)	40.19	29.60	25.06	1.46	1.31	0.94	1.01	0.43
B 15								
I	521	564	657	43	101	112	79	58
C(rat)	1.00	0.72	0.61	0.04	0.03	0.02	0.02	0.01
C(at%)	40.88	29.33	24.94	1.54	1.12	0.83	0.96	0.40
B 20								
I	505	552	641	39	106	108	76	56
C(rat)	1.00	0.72	0.61	0.04	0.03	0.02	0.02	0.01
C(at%)	40.71	29.49	25.00	1.44	1.21	0.82	0.95	0.40
B 25								
I	513	588	662	46	125	119	84	57
C(rat)	1.00	0.76	0.62	0.04	0.03	0.02	0.03	0.01
C(at%)	39.74	30.19	24.81	1.63	1.37	0.87	1.01	0.39
B 30								
I	496	551	625	44	124	114	79	58
C(rat)	1.00	0.74	0.61	0.04	0.04	0.02	0.02	0.01
C(at%)	40.35	29.71	24.60	1.64	1.43	0.87	1.00	0.41

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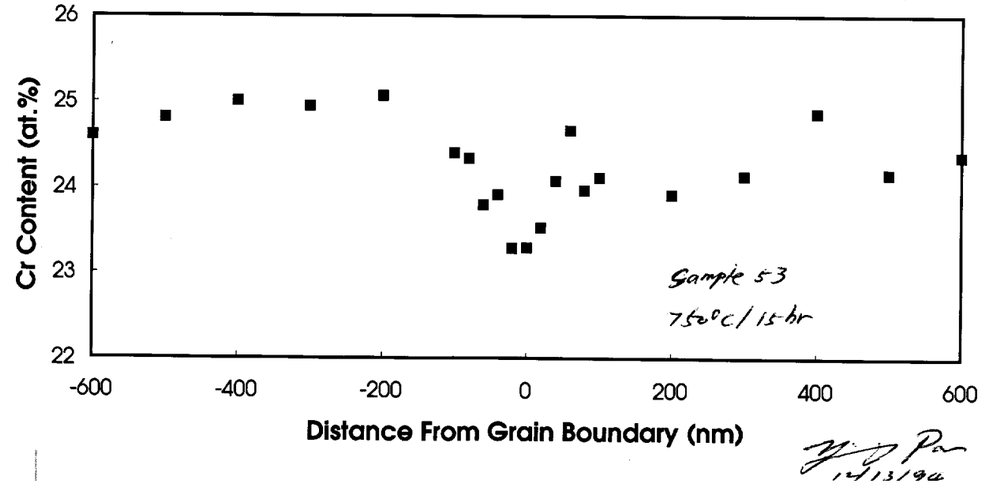

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Further Chemical Profiles Analysis for the 700°C/101hr Aged Specimens

1. Two additional grain boundary regions have been identified in the alloy 825 specimens after aging treatment at 700°C for 101 hours. One location in sample R4 and the location in sample R3. The images of the locations for analysis were photographed below.

Negative No.	Remarks
	sample R4 / Location 2
8605	60,000X
8606	23,000X
8607	60,000X
8608	23,000X
	sample R3
8609	23,000X
8610	60,000X
8611	8,200X

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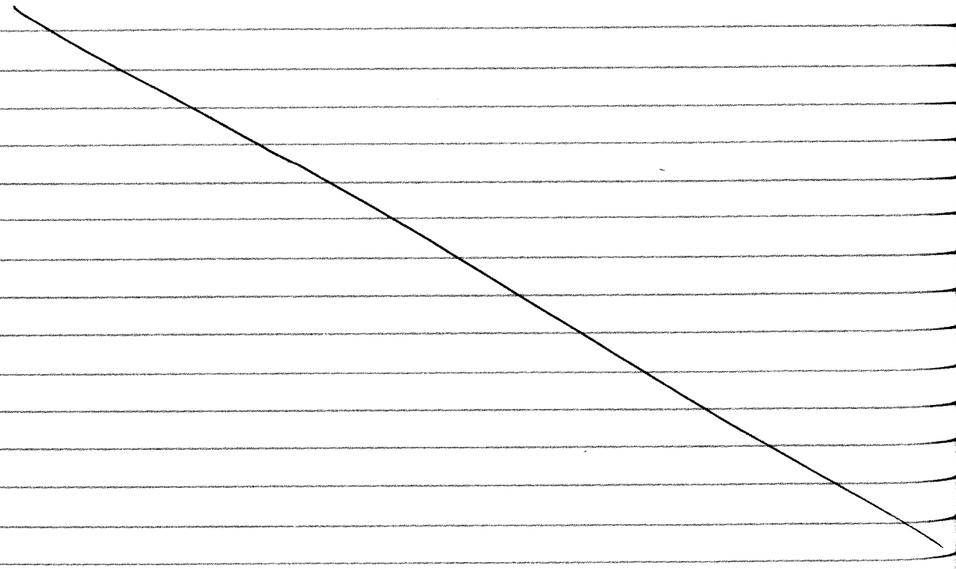

2. Chemical concentration profiles for the two selected grain boundary regions were measured using microprobe technique with a probe size of about 20nm. The results are presented below.

Samp R42	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
L 15	766	855	951	63	176	141	93	55
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.65	0.49	0.56	0.15	0.15	0.22	0.13
GB1-1								
I	925	809	943	62	173	233	87	65
C(rat)	1.00	0.57	0.50	0.04	0.03	0.04	0.02	0.01
C(at%)	45.44	25.82	22.75	1.71	1.26	1.66	0.94	0.42
GB1-2								
I	508	495	526	29	101	117	62	39
C(rat)	1.00	0.63	0.51	0.03	0.03	0.03	0.03	0.01
C(at%)	43.99	27.85	22.37	1.41	1.29	1.47	1.18	0.44
R 1								
I	901	939	1036	67	177	170	91	59
C(rat)	1.00	0.68	0.56	0.04	0.03	0.03	0.02	0.01
C(at%)	42.18	28.56	23.82	1.76	1.22	1.16	0.94	0.36
R 2								
I	1073	1171	1291	66	217	131	119	53
C(rat)	1.00	0.71	0.59	0.03	0.03	0.02	0.02	0.01
C(at%)	41.44	29.38	24.48	1.43	1.24	0.74	1.01	0.27
R 3								
I	944	1072	1154	66	204	127	113	51
C(rat)	1.00	0.74	0.60	0.04	0.03	0.02	0.03	0.01
C(at%)	40.61	29.96	24.38	1.59	1.30	0.79	1.07	0.29
R 4								
I	943	1017	1209	61	199	151	115	53
C(rat)	1.00	0.70	0.63	0.04	0.03	0.02	0.03	0.01
C(at%)	40.73	28.54	25.64	1.48	1.27	0.95	1.10	0.30
R 5								
I	862	941	1061	63	176	138	100	51
C(rat)	1.00	0.71	0.60	0.04	0.03	0.02	0.03	0.01
C(at%)	40.96	29.05	24.76	1.68	1.24	0.95	1.05	0.32
R 10								
I	501	547	642	33	110	102	65	34
C(rat)	1.00	0.71	0.63	0.04	0.03	0.03	0.03	0.01
C(at%)	40.40	28.66	25.42	1.49	1.31	1.20	1.16	0.36
R 15								
I	369	412	447	30	84	74	44	24
C(rat)	1.00	0.73	0.59	0.05	0.03	0.03	0.03	0.01
C(at%)	40.59	29.44	24.15	1.85	1.37	1.18	1.07	0.35
R 20								
I	427	483	590	30	93	108	61	45
C(rat)	1.00	0.73	0.68	0.04	0.03	0.04	0.03	0.01
C(at%)	38.96	28.63	26.44	1.53	1.25	1.43	1.23	0.54

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R 25								
I	413	477	517	35	86	82	54	35
C(rat)	1.00	0.75	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	39.81	29.87	24.47	1.89	1.22	1.15	1.15	0.44
R 30								
I	434	465	497	31	98	88	51	38
C(rat)	1.00	0.70	0.56	0.04	0.03	0.03	0.03	0.01
C(at%)	41.69	29.02	23.44	1.67	1.39	1.23	1.08	0.48
L 1								
I	880	882	1008	68	179	197	93	50
C(rat)	1.00	0.65	0.56	0.04	0.03	0.03	0.02	0.01
C(at%)	42.55	27.71	23.93	1.84	1.28	1.39	0.99	0.32
L 2								
I	889	943	1041	59	178	174	116	57
C(rat)	1.00	0.69	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	41.73	28.76	24.00	1.55	1.23	1.19	1.20	0.35
L 3								
I	745	841	902	58	162	146	79	63
C(rat)	1.00	0.73	0.59	0.04	0.03	0.03	0.02	0.01
C(at%)	40.54	29.73	24.10	1.77	1.30	1.16	0.95	0.45
L 4								
I	731	801	877	50	138	140	92	48
C(rat)	1.00	0.71	0.59	0.04	0.03	0.03	0.03	0.01
C(at%)	41.13	29.28	24.23	1.58	1.15	1.15	1.14	0.35
L 5								
I	690	740	846	57	146	139	78	42
C(rat)	1.00	0.70	0.60	0.05	0.03	0.03	0.02	0.01
C(at%)	41.01	28.57	24.69	1.90	1.28	1.20	1.02	0.33
L 10								
I	681	754	844	53	148	127	79	45
C(rat)	1.00	0.72	0.61	0.04	0.03	0.03	0.03	0.01
C(at%)	40.57	29.18	24.69	1.77	1.30	1.10	1.04	0.35
L 15								
I	766	855	951	63	176	141	93	55
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
L 20								
I	885	940	1055	61	159	149	96	59
C(rat)	1.00	0.69	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	41.71	28.78	24.42	1.61	1.11	1.02	1.00	0.36
L 25								
I	889	917	1064	67	168	158	101	63
C(rat)	1.00	0.67	0.59	0.04	0.03	0.03	0.03	0.01
C(at%)	41.87	28.06	24.61	1.77	1.17	1.08	1.05	0.39
L 30								
I	862	923	1054	63	172	155	95	62
C(rat)	1.00	0.70	0.60	0.04	0.03	0.03	0.02	0.01
C(at%)	41.21	28.67	24.74	1.69	1.22	1.08	1.00	0.39

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Samp R3

PPT 2								
I	2967	3333	5159	267	608	287	294	115
C(rat)	1.00	0.73	0.85	0.05	0.03	0.01	0.02	0.01
C(at%)	36.96	26.97	31.56	1.86	1.12	0.52	0.81	0.19
PPT 3-1								
I	2991	3333	4688	263	622	397	267	130
C(rat)	1.00	0.72	0.77	0.05	0.03	0.02	0.02	0.01
C(at%)	38.19	27.65	29.39	1.88	1.17	0.74	0.75	0.22
PPT 3-2								
I	2834	3213	4264	234	585	427	253	141
C(rat)	1.00	0.74	0.74	0.05	0.03	0.02	0.02	0.01
C(at%)	38.46	28.33	28.42	1.78	1.17	0.84	0.76	0.25
GB 23								
I	2537	2617	2920	168	479	451	199	133
C(rat)	1.00	0.67	0.57	0.04	0.03	0.03	0.02	0.01
C(at%)	42.55	28.52	24.05	1.58	1.19	1.10	0.74	0.29
R 1								
I	2056	2204	2375	154	397	378	174	110
C(rat)	1.00	0.70	0.57	0.04	0.03	0.03	0.02	0.01
C(at%)	41.90	29.18	23.77	1.76	1.20	1.12	0.78	0.29
R 2								
I	1951	2061	2302	146	374	390	149	111
C(rat)	1.00	0.69	0.58	0.04	0.03	0.03	0.02	0.01
C(at%)	41.85	28.72	24.25	1.76	1.19	1.22	0.70	0.31
R 3								
I	1906	2063	2272	131	368	340	144	95
C(rat)	1.00	0.70	0.59	0.04	0.03	0.03	0.02	0.01
C(at%)	41.58	29.24	24.34	1.60	1.19	1.08	0.69	0.27
R 4								
I	1664	1846	2096	131	330	297	121	82
C(rat)	1.00	0.72	0.62	0.04	0.03	0.03	0.02	0.01
C(at%)	40.63	29.28	25.13	1.79	1.19	1.05	0.65	0.26
R 5								
I	1710	1854	2125	139	344	311	150	92
C(rat)	1.00	0.70	0.61	0.05	0.03	0.03	0.02	0.01
C(at%)	40.94	28.84	24.98	1.87	1.22	1.08	0.79	0.29
R 10								
I	1916	2076	2321	136	357	338	145	100
C(rat)	1.00	0.70	0.59	0.04	0.03	0.03	0.02	0.01
C(at%)	41.40	29.14	24.63	1.65	1.14	1.06	0.69	0.28
R 15								
I	2431	2612	3008	158	427	439	178	143
C(rat)	1.00	0.70	0.61	0.04	0.03	0.03	0.02	0.01
C(at%)	41.35	28.86	25.13	1.51	1.07	1.09	0.67	0.32
R 20								
I	2380	2501	2936	164	434	413	191	116
C(rat)	1.00	0.68	0.61	0.04	0.03	0.03	0.02	0.01
C(at%)	41.61	28.41	25.21	1.61	1.12	1.05	0.74	0.27
R 25								
I	2556	2665	3084	170	466	424	226	131
C(rat)	1.00	0.68	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	41.94	28.41	24.85	1.56	1.13	1.01	0.82	0.28

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R 30								
I	2610	2776	3125	187	467	441	178	150
C(rat)	1.00	0.69	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	41.79	28.88	24.57	1.68	1.10	1.03	0.63	0.32
D 1								
I	2415	2594	2838	171	442	429	183	152
C(rat)	1.00	0.70	0.58	0.04	0.03	0.03	0.02	0.01
C(at%)	41.80	29.17	24.12	1.66	1.13	1.08	0.70	0.35
L 2								
I	2511	2724	2950	185	438	439	171	132
C(rat)	1.00	0.70	0.58	0.04	0.03	0.03	0.02	0.01
C(at%)	41.73	29.41	24.07	1.72	1.08	1.06	0.63	0.29
L 3								
I	2484	2655	2986	169	445	437	180	144
C(rat)	1.00	0.69	0.59	0.04	0.03	0.03	0.02	0.01
C(at%)	41.69	28.95	24.61	1.59	1.10	1.07	0.67	0.32
L 4								
I	2526	2705	2991	163	467	441	195	137
C(rat)	1.00	0.70	0.58	0.04	0.03	0.03	0.02	0.01
C(at%)	41.84	29.11	24.33	1.51	1.14	1.06	0.71	0.30
L 5								
I	2502	2814	3063	192	502	455	195	137
C(rat)	1.00	0.73	0.60	0.04	0.03	0.03	0.02	0.01
C(at%)	40.73	29.76	24.49	1.75	1.21	1.08	0.70	0.29
L 10								
I	2621	2730	3269	194	467	454	181	150
C(rat)	1.00	0.68	0.61	0.04	0.03	0.03	0.02	0.01
C(at%)	41.58	28.14	25.47	1.72	1.09	1.05	0.63	0.31
L 15								
I	2497	2587	2966	174	474	411	190	137
C(rat)	1.00	0.67	0.58	0.04	0.03	0.02	0.02	0.01
C(at%)	42.17	28.38	24.60	1.65	1.18	1.01	0.71	0.30
L 20								
I	2270	2515	2768	152	437	402	177	131
C(rat)	1.00	0.72	0.60	0.04	0.03	0.03	0.02	0.01
C(at%)	41.07	29.56	24.59	1.54	1.17	1.06	0.71	0.31
L 25								
I	2144	2253	2645	148	391	372	172	105
C(rat)	1.00	0.68	0.61	0.04	0.03	0.03	0.02	0.01
C(at%)	41.61	28.41	25.21	1.61	1.12	1.05	0.74	0.27
L 30								
I	1753	1852	2214	136	328	320	132	89
C(rat)	1.00	0.69	0.62	0.04	0.03	0.03	0.02	0.01
C(at%)	41.19	28.27	25.55	1.79	1.14	1.09	0.68	0.27

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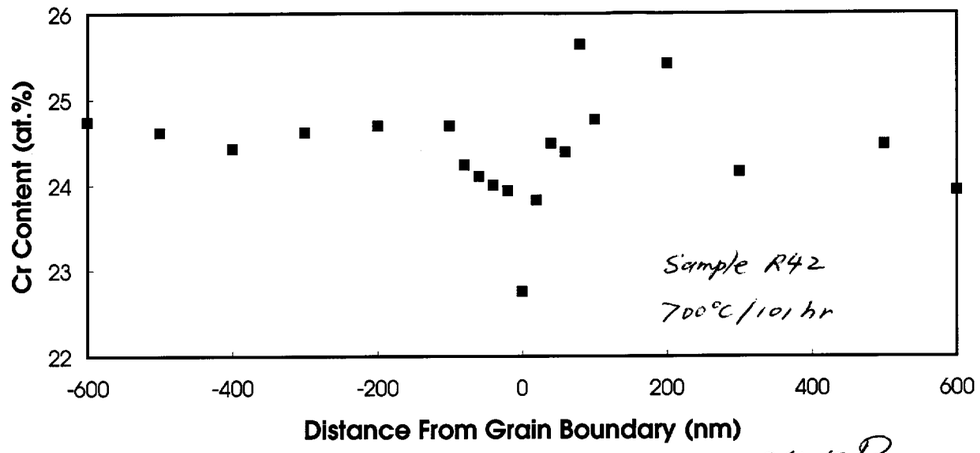

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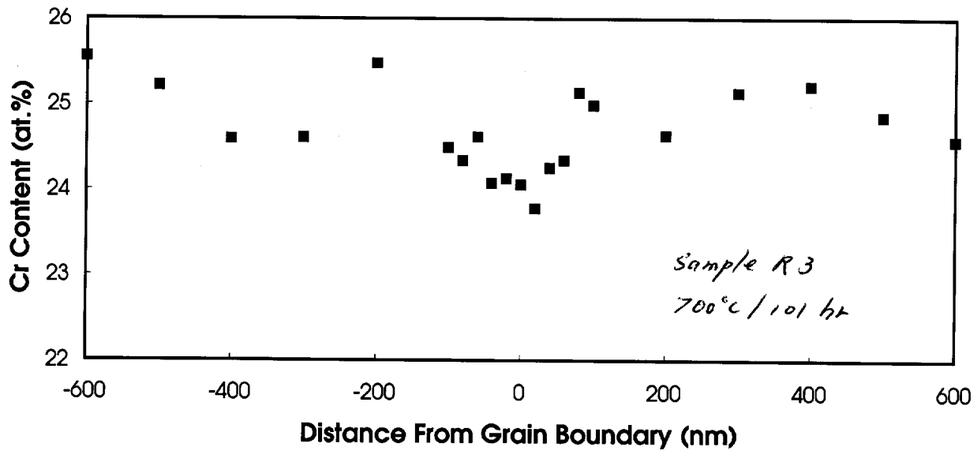

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Representative TEM Micrograph from the 750°C/15hr Aged Specimen

TEM bright-field image of γ matrix and $M_{23}C_6$ carbide taken from a specimen aged at 750°C for 15 h and diffraction pattern (inset) for austenite and $M_{23}C_6$ oriented in the zone axes: $[001]_\gamma$ and $[001]$ $M_{23}C_6$.

DP: No. 8474

Image : No. 8421

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Nanoprobe chemical Analysis of the 304 L Specimen

Because the Cr-depleted zone determined in the 825 alloy appeared to be narrow, nanoprobe chemical analysis was assessed, which allows a probe size down to 1 nm. The analysis was first performed on the 304L stainless steel specimen, an internal reference material. Both the microprobe and nanoprobe analyses were conducted. While the microprobe analysis used a probe size of 20 nm, the nanoprobe analysis was about 2nm. The selection of the 2nm probe size is a trade off, instead of a 1nm minimum probe size, which allows a reasonable intensity for sample inspection. The results are reported for both the chemical contents and the chromium profiles, which are consistent each other.

Microprobe Analysis:

304L-42	Fe	Cr	Ni	Si	Mn
Bulk(wt%)	66.88	18.90	10.20	0.64	1.70
Micro-sp6					
Matrix					
I	352	142	41	35	43
C(rat)	1.00	0.28	0.15	0.01	0.03
C(wt%)	68.02	19.22	10.37	0.65	1.73
k(304)	1.00	0.70	1.31	0.10	0.21
PPT 3					
I	470	794	41	35	57
C(rat)	1.00	1.18	0.11	0.01	0.03
C(wt%)	42.92	50.79	4.90	0.31	1.08
PPT 4					
I	437	606	53	32	52
C(rat)	1.00	0.97	0.16	0.01	0.02
C(wt%)	46.25	44.93	7.34	0.33	1.15
GB					
I	814	224	101	40	89
C(rat)	1.00	0.19	0.16	0.00	0.02
C(wt%)	72.32	13.94	11.75	0.34	1.65
R1					
I	688	209	87	42	78
C(rat)	1.00	0.21	0.17	0.01	0.02
C(wt%)	71.03	15.12	11.76	0.42	1.68
R2					
I	636	219	79	42	72
C(rat)	1.00	0.24	0.16	0.01	0.02
C(wt%)	69.75	16.82	11.34	0.44	1.64

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R3					
I	605	226	77	46	69
C(rat)	1.00	0.26	0.17	0.01	0.02
C(wt%)	68.52	17.93	11.42	0.50	1.63
R4					
I	605	224	73	51	71
C(rat)	1.00	0.26	0.16	0.01	0.02
C(wt%)	68.97	17.89	10.90	0.56	1.68
R5					
I	587	204	79	54	68
C(rat)	1.00	0.24	0.18	0.01	0.02
C(wt%)	68.84	16.76	12.13	0.61	1.66
R6					
I	554	214	74	57	64
C(rat)	1.00	0.27	0.17	0.01	0.02
C(wt%)	67.59	18.29	11.82	0.67	1.62
R7					
I	573	230	63	59	63
C(rat)	1.00	0.28	0.14	0.01	0.02
C(wt%)	68.59	19.29	9.87	0.68	1.57
R8					
I	559	216	64	57	64
C(rat)	1.00	0.27	0.15	0.01	0.02
C(wt%)	68.76	18.61	10.31	0.67	1.64
R9					
I	581	237	66	68	62
C(rat)	1.00	0.29	0.15	0.01	0.02
C(wt%)	68.12	19.47	10.13	0.77	1.51
R10					
I	580	187	57	50	66
C(rat)	1.00	0.23	0.13	0.01	0.02
C(wt%)	72.12	16.29	9.28	0.60	1.71
R15					
I	260	115	37	12	29
C(rat)	1.00	0.31	0.19	0.00	0.02
C(wt%)	65.62	20.33	12.23	0.29	1.52
R20					
I	164	61	21	9	24
C(rat)	1.00	0.26	0.17	0.01	0.03
C(wt%)	68.31	17.80	11.45	0.36	2.08
R30					
I	124	45	16	9	14
C(rat)	1.00	0.25	0.17	0.01	0.02
C(wt%)	68.79	17.49	11.62	0.48	1.62

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L1					
I	345	101	41	31	37
C(rat)	1.00	0.21	0.16	0.01	0.02
C(wt%)	71.86	14.74	11.18	0.62	1.60
L2					
I	357	120	46	32	36
C(rat)	1.00	0.24	0.17	0.01	0.02
C(wt%)	69.75	16.42	11.77	0.60	1.46
L3					
I	387	137	45	36	36
C(rat)	1.00	0.25	0.15	0.01	0.02
C(wt%)	70.00	17.36	10.66	0.63	1.35
L4					
I	376	139	48	37	38
C(rat)	1.00	0.26	0.17	0.01	0.02
C(wt%)	68.65	17.78	11.48	0.65	1.44
L5					
I	395	150	54	43	50
C(rat)	1.00	0.27	0.18	0.01	0.03
C(wt%)	67.48	17.95	12.08	0.71	1.78
L6					
I	410	146	51	49	44
C(rat)	1.00	0.25	0.16	0.01	0.02
C(wt%)	69.15	17.25	11.26	0.80	1.54
L7					
I	451	156	50	36	48
C(rat)	1.00	0.24	0.15	0.01	0.02
C(wt%)	70.56	17.10	10.24	0.54	1.56
L8					
I	439	171	52	35	49
C(rat)	1.00	0.27	0.16	0.01	0.02
C(wt%)	68.55	18.71	10.63	0.53	1.59
L9					
I	458	161	51	37	44
C(rat)	1.00	0.25	0.15	0.01	0.02
C(wt%)	70.43	17.34	10.27	0.55	1.41
L10					
I	473	164	53	38	52
C(rat)	1.00	0.24	0.15	0.01	0.02
C(wt%)	70.41	17.10	10.33	0.54	1.61
L15					
I	631	237	68	53	78
C(rat)	1.00	0.26	0.14	0.01	0.03
C(wt%)	69.54	18.30	9.81	0.56	1.79

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L20					
I	754	258	82	69	87
C(rat)	1.00	0.24	0.14	0.01	0.02
C(wt%)	70.68	16.94	10.06	0.62	1.70
L30					
I	707	302	90	61	83
C(rat)	1.00	0.30	0.17	0.01	0.02
C(wt%)	66.73	19.97	11.12	0.55	1.63

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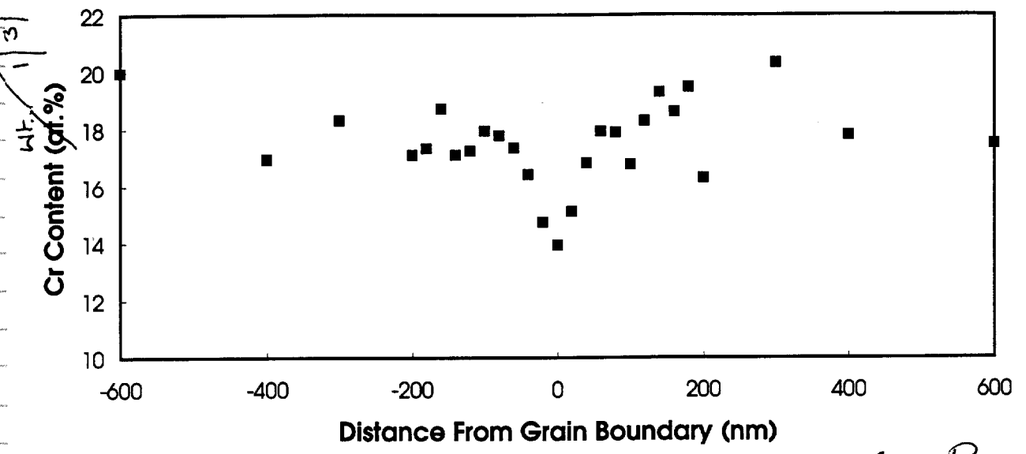

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Nanoprobe Analysis:

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PPT 3					
I	92	107	10	10	30
C(rat)	1.00	0.81	0.14	0.01	0.07
C(wt%)	49.13	40.03	6.99	0.51	3.33
PPT 4					
I	94	122	13	10	19
C(rat)	1.00	0.91	0.18	0.01	0.04
C(wt%)	46.67	42.43	8.45	0.48	1.96
GB					
I	175	52	23	9	18
C(rat)	1.00	0.21	0.17	0.00	0.02
C(wt%)	71.09	14.80	12.23	0.35	1.52
R1					
I	155	47	20	8	16
C(rat)	1.00	0.21	0.17	0.00	0.02
C(wt%)	71.03	15.09	12.00	0.35	1.53
R2					
I	146	53	22	11	16
C(rat)	1.00	0.25	0.20	0.01	0.02
C(wt%)	67.49	17.16	13.32	0.49	1.54
R3					
I	135	52	19	10	16
C(rat)	1.00	0.27	0.18	0.01	0.02
C(wt%)	67.30	18.16	12.40	0.48	1.66
R4					
I	117	45	18	9	16
C(rat)	1.00	0.27	0.20	0.01	0.03
C(wt%)	66.37	17.88	13.37	0.49	1.89
R5					
I	124	44	16	10	11
C(rat)	1.00	0.25	0.17	0.01	0.02
C(wt%)	69.26	17.22	11.70	0.54	1.28
R6					
I	119	45	17	11	14
C(rat)	1.00	0.26	0.19	0.01	0.02
C(wt%)	67.33	17.84	12.59	0.60	1.65
R8					
I	122	45	16	12	17
C(rat)	1.00	0.26	0.17	0.01	0.03
C(wt%)	68.09	17.59	11.69	0.64	1.97
R9					
I	131	47	18	11	13
C(rat)	1.00	0.25	0.18	0.01	0.02
C(wt%)	68.49	17.21	12.32	0.55	1.41

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R10					
I	134	47	17	12	17
C(rat)	1.00	0.25	0.17	0.01	0.03
C(wt%)	69.12	16.98	11.48	0.60	1.82
R12					
I	116	47	15	13	18
C(rat)	1.00	0.28	0.17	0.01	0.03
C(wt%)	66.84	18.97	11.32	0.72	2.16
L1					
I	176	49	20	8	15
C(rat)	1.00	0.20	0.15	0.00	0.02
C(wt%)	73.21	14.28	10.89	0.32	1.30
L2					
I	153	52	19	9	15
C(rat)	1.00	0.24	0.16	0.01	0.02
C(wt%)	70.09	16.69	11.40	0.40	1.43
L3					
I	173	58	23	7	16
C(rat)	1.00	0.23	0.17	0.00	0.02
C(wt%)	69.83	16.40	12.16	0.27	1.34
L4					
I	147	49	18	10	13
C(rat)	1.00	0.23	0.16	0.01	0.02
C(wt%)	70.48	16.63	11.42	0.47	1.31
L5					
I	148	53	21	7	18
C(rat)	1.00	0.25	0.19	0.00	0.03
C(wt%)	68.19	16.78	12.43	0.30	1.69
L6					
I	161	56	20	9	15
C(rat)	1.00	0.24	0.16	0.01	0.02
C(wt%)	69.88	17.34	11.58	0.38	1.38
L8					
I	143	51	18	9	16
C(rat)	1.00	0.25	0.16	0.01	0.02
C(wt%)	69.25	17.30	11.41	0.42	1.61
L10					
I	156	52	18	6	15
C(rat)	1.00	0.23	0.15	0.00	0.02
C(wt%)	71.01	16.58	10.73	0.26	1.42
L12					
I	130	42	15	8	16
C(rat)	1.00	0.23	0.15	0.01	0.03
C(wt%)	70.98	16.06	10.72	0.42	1.82
L14					
I	143	55	20	7	18
C(rat)	1.00	0.27	0.18	0.00	0.03
C(wt%)	67.41	18.16	12.34	0.32	1.77

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L16					
I	140	59	21	7	14
C(rat)	1.00	0.30	0.20	0.00	0.02
C(wt%)	65.91	19.46	12.95	0.32	1.37
L18					
I	153	56	20	10	17
C(rat)	1.00	0.26	0.17	0.01	0.02
C(wt%)	68.64	17.60	11.75	0.43	1.59
L20					
I	155	48	16	8	15
C(rat)	1.00	0.22	0.14	0.00	0.02
C(wt%)	72.61	15.75	9.81	0.36	1.46
L22					
I	138	52	19	10	21
C(rat)	1.00	0.26	0.18	0.01	0.03
C(wt%)	67.44	17.80	12.16	0.47	2.14
L24					
I	154	57	17	12	18
C(rat)	1.00	0.26	0.14	0.01	0.02
C(wt%)	69.66	18.06	10.07	0.52	1.69
L26					
I	138	58	18	13	15
C(rat)	1.00	0.29	0.17	0.01	0.02
C(wt%)	66.81	19.67	11.41	0.61	1.51
L28					
I	173	60	19	16	18
C(rat)	1.00	0.24	0.14	0.01	0.02
C(wt%)	70.56	17.14	10.15	0.63	1.53
L30					
I	150	63	19	10	21
C(rat)	1.00	0.29	0.17	0.01	0.03
C(wt%)	66.86	19.67	11.09	0.43	1.95
L40					
I	188	74	25	15	19
C(rat)	1.00	0.28	0.17	0.01	0.02
C(wt%)	67.63	18.65	11.78	0.52	1.42
L50					
I	197	75	26	28	23
C(rat)	1.00	0.27	0.17	0.01	0.02
C(wt%)	67.68	18.05	11.70	0.93	1.64

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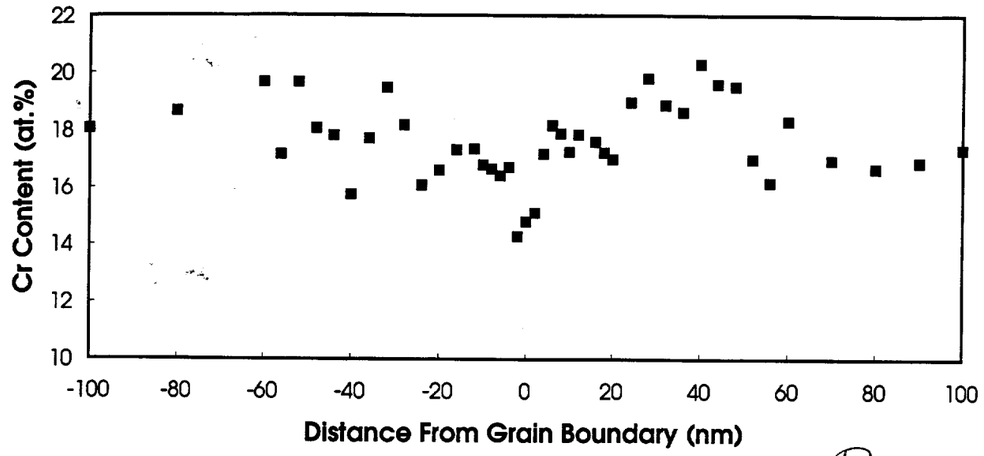

12/14/94

Nanoprobe chemical analysis was performed on sample R4, aging treated at 700°C for 101 hours, using a probe size of 2 nm. The chemical composition results of one grain boundary region are measured and listed below.

Samp R42N	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
L15(R42)	766	855	951	63	176	141	93	55
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(R42)	1.00	0.65	0.49	0.56	0.15	0.15	0.22	0.13
Nano-spot5								
Obj-out	1. Locate beam spot using a 50 μm objective aperture } beam spot shift							
GB	2. Take EDS reading without objective aperture							
I	52	43	51	2	22	12	7	8
C(rat)	1.00	0.54	0.48	0.02	0.06	0.03	0.03	0.02
C(at%)	45.74	24.57	22.03	0.99	2.86	1.53	1.36	0.92
R1								
I	34	35	45	2	15	8	6	6
C(rat)	1.00	0.67	0.65	0.03	0.07	0.03	0.04	0.02
C(at%)	39.79	26.61	25.86	1.31	2.59	1.36	1.55	0.92
R2								
I	39	32	43	2	16	7	5	9
C(rat)	1.00	0.53	0.54	0.03	0.06	0.03	0.03	0.03
C(at%)	44.47	23.71	24.08	1.28	2.70	1.16	1.26	1.35
R3								
I	35	35	47	3	14	6	8	6
C(rat)	1.00	0.65	0.66	0.05	0.06	0.02	0.05	0.02
C(at%)	39.78	25.84	26.23	1.91	2.35	0.99	2.00	0.89
R5								
I	37	31	43	2	13	9	4	6
C(rat)	1.00	0.54	0.57	0.03	0.05	0.04	0.02	0.02
C(at%)	43.90	23.90	25.05	1.33	2.28	1.55	1.05	0.93
R7								
I	43	36	42	2	13	11	11	7
C(rat)	1.00	0.54	0.48	0.03	0.04	0.04	0.06	0.02
C(at%)	45.26	24.62	21.71	1.18	2.02	1.68	2.55	0.97
R10								
I	49	32	34	3	14	8	4	4
C(rat)	1.00	0.42	0.34	0.03	0.04	0.02	0.02	0.01
C(at%)	52.80	22.40	17.99	1.81	2.23	1.25	0.95	0.57
R12								
I	39	35	43	4	14	4	9	5
C(rat)	1.00	0.58	0.54	0.06	0.05	0.01	0.05	0.02
C(at%)	43.15	25.16	23.36	2.48	2.29	0.64	2.20	0.73
R15								
I	43	34	38	2	13	6	6	4
C(rat)	1.00	0.51	0.43	0.03	0.04	0.02	0.03	0.01
C(at%)	48.04	24.68	20.85	1.25	2.15	0.97	1.48	0.59
R17								
I	39	30	30	2	12	7	6	7
C(rat)	1.00	0.50	0.38	0.03	0.05	0.03	0.03	0.02
C(at%)	49.13	24.55	18.56	1.41	2.23	1.28	1.67	1.16

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R20								
I	42	31	33	2	12	7	5	5
C(rat)	1.00	0.48	0.39	0.03	0.04	0.02	0.03	0.02
C(at%)	49.99	23.97	19.29	1.33	2.11	1.21	1.31	0.78
R22								
I	40	34	34	2	12	9	5	6
C(rat)	1.00	0.55	0.42	0.03	0.04	0.03	0.03	0.02
C(at%)	47.13	26.03	19.67	1.32	2.09	1.54	1.30	0.93
R22-60s								
I	111	90	95	6	39	20	18	18
C(rat)	1.00	0.53	0.42	0.03	0.05	0.03	0.04	0.02
C(at%)	47.34	24.94	19.90	1.43	2.46	1.24	1.69	1.01
R25								
I	32	33	34	2	13	7	6	5
C(rat)	1.00	0.67	0.52	0.04	0.06	0.03	0.04	0.02
C(at%)	42.01	28.15	21.92	1.47	2.52	1.34	1.74	0.86
R30								
I	35	31	28	5	10	9	6	4
C(rat)	1.00	0.58	0.39	0.08	0.04	0.04	0.04	0.01
C(at%)	45.86	26.39	18.02	3.67	1.94	1.71	1.73	0.69

Obj-out2 (Locate beam spot without objective aperture) / No beam shift problem!

PPT-2								
I	47	34	54	3	16	8	6	5
C(rat)	1.00	0.47	0.56	0.04	0.05	0.02	0.03	0.01
C(at%)	45.72	21.49	25.80	1.64	2.30	1.13	1.29	0.64
GB-2								
I	64	59	62	5	17	8	8	5
C(rat)	1.00	0.60	0.48	0.04	0.04	0.02	0.03	0.01
C(at%)	45.17	27.05	21.49	1.98	1.77	0.82	1.24	0.46
GB-22								
I	49	53	52	4	19	12	7	4
C(rat)	1.00	0.70	0.52	0.05	0.06	0.04	0.03	0.01
C(at%)	41.59	29.23	21.67	1.90	2.38	1.48	1.31	0.45
R1-2								
I	49	43	49	2	15	10	7	4
C(rat)	1.00	0.57	0.49	0.02	0.05	0.03	0.03	0.01
C(at%)	45.43	25.90	22.31	1.04	2.06	1.35	1.43	0.49
R2-2								
I	30	29	32	2	11	4	5	3
C(rat)	1.00	0.63	0.52	0.04	0.05	0.02	0.04	0.01
C(at%)	43.24	27.16	22.65	1.62	2.34	0.84	1.59	0.57
R5-2								
I	41	39	42	2	14	8	5	5
C(rat)	1.00	0.62	0.50	0.03	0.05	0.03	0.03	0.02
C(at%)	44.05	27.22	22.16	1.20	2.22	1.25	1.18	0.70
R10-2								
I	43	42	45	3	13	8	7	6
C(rat)	1.00	0.63	0.51	0.04	0.04	0.03	0.04	0.02
C(at%)	43.22	27.43	22.21	1.69	1.93	1.17	1.55	0.79
R15-2								
I	45	35	43	2	18	7	4	5
C(rat)	1.00	0.51	0.47	0.02	0.06	0.02	0.02	0.01
C(at%)	47.27	23.89	22.18	1.18	2.79	1.07	0.93	0.69

Y. Pa 12/19/94

Obj-50um (EDS survey with a 50 μm objective aperture)

PPT-3								
I	420	409	613	33	504	44	41	23
C(rat)	1.00	0.63	0.72	0.04	0.18	0.02	0.02	0.01
C(at%)	38.25	24.20	27.41	1.68	6.78	0.58	0.82	0.27
PPT-32								
I	389	406	598	23	442	50	31	24
C(rat)	1.00	0.68	0.75	0.03	0.17	0.02	0.02	0.01
C(at%)	37.34	25.32	28.19	1.24	6.27	0.70	0.66	0.30
PPT-33								
I	318	351	490	32	413	92	36	37
C(rat)	1.00	0.72	0.76	0.06	0.19	0.04	0.02	0.02
C(at%)	35.66	25.57	26.98	2.01	6.84	1.50	0.89	0.54
PPT-34								
I	338	367	524	24	396	67	31	23
C(rat)	1.00	0.71	0.76	0.04	0.17	0.03	0.02	0.01
C(at%)	36.53	25.77	27.81	1.45	6.32	1.05	0.74	0.33
GB-3								
I	350	381	499	26	385	77	35	24
C(rat)	1.00	0.71	0.70	0.04	0.16	0.03	0.02	0.01
C(at%)	37.39	26.44	26.18	1.56	6.08	1.20	0.82	0.34
R5-3								
I	321	364	520	33	405	77	34	28
C(rat)	1.00	0.74	0.80	0.06	0.19	0.03	0.02	0.01
C(at%)	35.14	25.89	27.95	2.02	6.55	1.23	0.82	0.40
R10-3								
I	307	352	499	29	391	81	39	24
C(rat)	1.00	0.74	0.80	0.05	0.19	0.04	0.03	0.01
C(at%)	34.95	26.03	27.90	1.85	6.58	1.34	0.98	0.36
R15-3								
I	343	373	494	31	392	68	34	20
C(rat)	1.00	0.71	0.71	0.05	0.17	0.03	0.02	0.01
C(at%)	37.15	26.25	26.27	1.88	6.27	1.07	0.81	0.28

Several measurement techniques have been tested to resolve the problem of beam shift during focusing. Chemical composition variation results. Further refinement of the nanoprobe analysis techniques is needed for chemical profile determination.

Y. Pa
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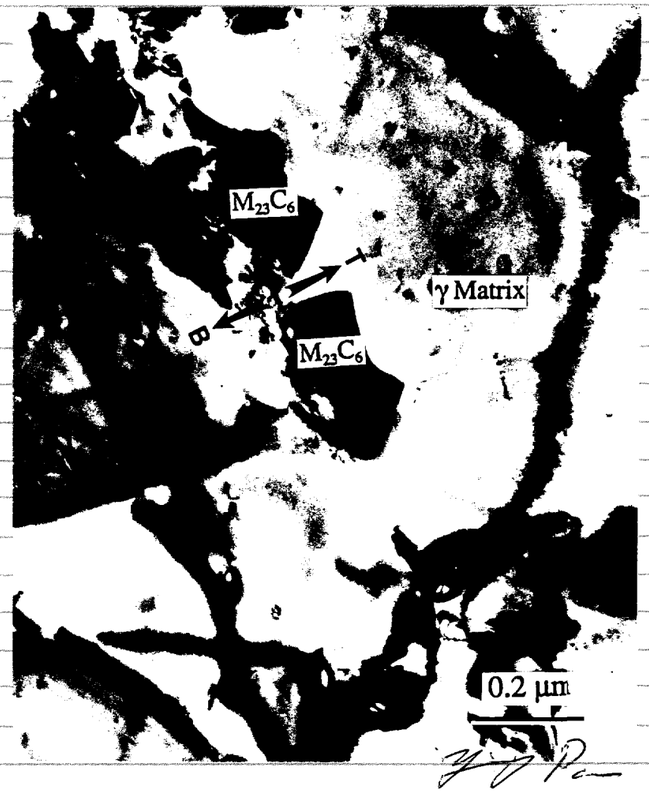
TEM Micrograph of the Grain Boundary Region in Sample 52

TEM bright-field image was taken from thin foil no. 5 of the alloy 825 specimen after 750°C/15-hr aging treatment, which represents the grain boundary region of sample 52. γ matrix and $M_{23}C_6$ carbide were also identified in the micrograph.

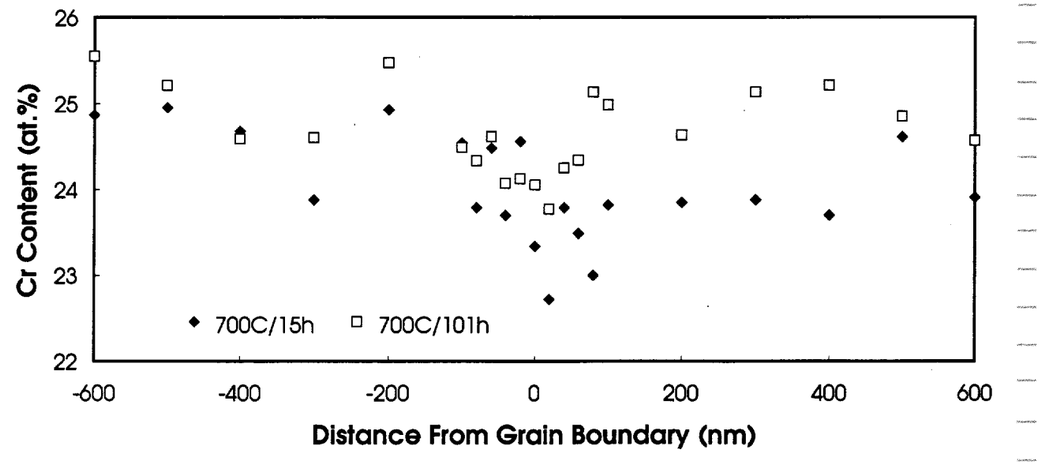


12/21/94

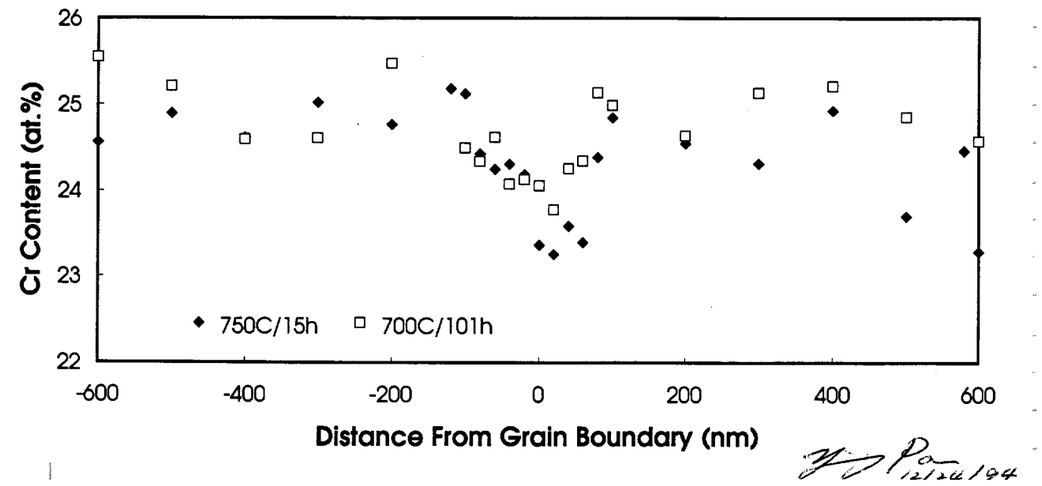
Comparison of Cr-depletion Region in Alloy 825

A comparison of Cr-depletion zone in alloy 825 after different aging treatments was made. All the TEM foils were prepared using an electrolyte of a nitric acid solution. Nevertheless, the Cr-depletion zone is not well-defined in the alloy 825 with different aging treatment conditions.

(A) Profile FG42 (700°C/15hr) vs. R3 (700°C/101 hr)



(B). Profile sample 52 (750°C/15hr) vs. R3 (700°C/101 hr)



12/24/94

Chemical Analysis of the 750°C/15hr Aged Alloy 825 Specimen Electropolished with Perchloric Acid (Sample 2)

Ref. to p. 4 for perchloride acid electropolishing. 1/10/97

A review of the chemical composition of the grain boundary carbide precipitates indicates a low Cr-content in the carbides of the alloy 825 specimens electropolished with a nitric acid solution. It is speculated that preferential etching between carbide precipitate and other grain boundary area may be occurred during electropolish within the nitric acid solution.

Another batch of TEM foils was prepared using a perchloric acid electrolyte. Chemical analysis was performed on foil sample 2 aging treated at 750°C for 15 hours. The chemical composition of the carbide precipitates clearly shows a much higher Cr-content in the foil electropolished with a perchloric acid solution compared to that with a nitric acid electrolyte. This high Cr-content is consistant with those reported in the literature.

Sample 22	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix A1								
I	80	69	59	3	9	18	11	14
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(A1)	1.00	0.84	0.83	1.23	0.30	0.12	0.19	0.05
Matrix B3								
I	84	72	69	3	11	18	18	14
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k(B3)	1.00	0.85	0.74	1.29	0.26	0.12	0.12	0.06
PPT FC1(kB3)								
I	16	19	190	8	4	10	12	6
C(rat)	1.00	1.00	8.81	0.65	0.06	0.08	0.09	0.02
C(at%)	8.53	8.57	75.18	5.50	0.55	0.67	0.80	0.18
PPT FC2								
I	13	18	145	6	5	10	13	8
C(rat)	1.00	1.17	8.28	0.60	0.10	0.10	0.12	0.03
C(at%)	8.77	10.27	72.60	5.22	0.87	0.84	1.10	0.30
PPT FC3								
I	11	14	152	6	5	16	7	8
C(rat)	1.00	1.08	10.26	0.70	0.12	0.18	0.08	0.04
C(at%)	7.43	8.00	76.20	5.23	0.88	1.35	0.59	0.31
PPT FE1								
I	26	30	137	5	8	15	13	11
C(rat)	1.00	0.98	3.91	0.25	0.08	0.07	0.06	0.02
C(at%)	15.69	15.32	61.36	3.89	1.25	1.13	0.98	0.38

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PPT FE2								
I	23	25	134	7	5	15	17	14
C(rat)	1.00	0.92	4.32	0.39	0.06	0.08	0.09	0.03
C(at%)	14.49	13.32	62.66	5.69	0.82	1.18	1.34	0.50
PPT FE3								
I	17	15	146	7	3	13	14	11
C(rat)	1.00	0.75	6.37	0.53	0.05	0.10	0.10	0.04
C(at%)	11.19	8.35	71.33	5.95	0.51	1.07	1.15	0.41
PPT H1								
I	89	90	140	6	10	30	27	21
C(rat)	1.00	0.86	1.17	0.09	0.03	0.04	0.04	0.01
C(at%)	30.94	26.47	36.12	2.69	0.90	1.30	1.17	0.41
PPT H2								
I	86	71	132	6	11	26	21	16
C(rat)	1.00	0.70	1.14	0.09	0.03	0.04	0.03	0.01
C(at%)	32.90	22.98	37.48	2.96	1.09	1.24	1.00	0.35
PPT H3								
I	76	59	132	5	10	25	21	18
C(rat)	1.00	0.66	1.29	0.08	0.03	0.04	0.03	0.01
C(at%)	31.71	20.83	40.88	2.69	1.08	1.30	1.09	0.42
PPT 31								
I	18	22	198	6	6	13	22	10
C(rat)	1.00	1.03	8.16	0.43	0.09	0.09	0.15	0.03
C(at%)	9.10	9.41	74.29	3.92	0.79	0.82	1.39	0.29
PPT 32								
I	16	27	215	9	3	14	21	17
C(rat)	1.00	1.43	9.97	0.73	0.05	0.11	0.16	0.06
C(at%)	7.40	10.56	73.80	5.37	0.36	0.81	1.21	0.44
GB G1								
I	77	83	49	2	9	15	11	13
C(rat)	1.00	0.91	0.47	0.03	0.03	0.02	0.02	0.01
C(at%)	40.00	36.48	18.89	1.34	1.21	0.97	0.71	0.38
GB G2								
I	97	63	51	3	14	16	13	8
C(rat)	1.00	0.55	0.39	0.04	0.04	0.02	0.02	0.00
C(at%)	48.57	26.69	18.95	1.94	1.82	1.00	0.81	0.23
Matrix A1								
I	80	69	59	3	9	18	11	14
C(rat)	1.00	0.73	0.55	0.05	0.03	0.03	0.02	0.01
C(at%)	41.50	30.28	22.72	2.01	1.21	1.17	0.71	0.41
Matrix A2								
I	81	65	63	3	7	19	10	14
C(rat)	1.00	0.68	0.58	0.05	0.02	0.03	0.02	0.01
C(at%)	42.00	28.51	24.25	2.01	0.94	1.23	0.65	0.41
Matrix B1								
I	85	79	70	5	8	16	16	15
C(rat)	1.00	0.79	0.61	0.08	0.02	0.02	0.02	0.01
C(at%)	39.14	30.78	23.92	2.97	0.96	0.92	0.92	0.39
Matrix B2								
I	78	80	64	3	12	20	14	16
C(rat)	1.00	0.87	0.61	0.05	0.04	0.03	0.02	0.01
C(at%)	37.99	32.96	23.14	1.89	1.52	1.22	0.85	0.44
Matrix B3								
I	84	72	69	3	11	18	18	14
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

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Chemical Profile Analysis of Sample 2 Aged at 750°C/15hr

Chemical concentration profile was measured across a grain boundary region in the alloy 80A sample 2, aging treated at 750°C for 15 hours and electropolished with a perchloric acid solution. The chemical composition results and the Cr content profile are presented below.

Sample23	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
B 30								
I	426	377	324	12	69	53	78	49
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.82	0.80	1.64	0.21	0.22	0.15	0.08
GB1								
I	362	312	209	8	57	51	28	23
C(rat)	1.00	0.71	0.46	0.04	0.03	0.03	0.01	0.01
C(at%)	43.76	30.90	20.25	1.58	1.44	1.33	0.49	0.23
GB12								
I	254	207	141	7	36	44	44	31
C(rat)	1.00	0.67	0.44	0.05	0.03	0.04	0.03	0.01
C(at%)	44.24	29.54	19.69	2.00	1.31	1.65	1.12	0.44
PPTL								
I	53	65	564	19	14	33	65	49
C(rat)	1.00	1.00	8.53	0.59	0.06	0.13	0.18	0.08
C(at%)	8.65	8.69	73.79	5.07	0.48	1.16	1.55	0.65
PPTR								
I	51	76	500	12	10	39	66	52
C(rat)	1.00	1.22	7.86	0.39	0.04	0.16	0.19	0.08
C(at%)	9.14	11.16	71.83	3.52	0.38	1.50	1.73	0.76
T 1								
I	304	242	174	7	51	48	35	29
C(rat)	1.00	0.65	0.46	0.04	0.04	0.03	0.02	0.01
C(at%)	44.59	29.09	20.46	1.68	1.57	1.51	0.75	0.35
T 2								
I	280	238	168	5	46	43	31	29
C(rat)	1.00	0.70	0.48	0.03	0.03	0.03	0.02	0.01
C(at%)	43.50	30.30	20.92	1.27	1.50	1.44	0.70	0.37
T 3								
I	294	210	166	7	39	47	34	26
C(rat)	1.00	0.59	0.45	0.04	0.03	0.03	0.02	0.01
C(at%)	46.23	27.06	20.92	1.80	1.29	1.59	0.78	0.33
T 4								
I	295	234	171	7	48	44	31	29
C(rat)	1.00	0.65	0.46	0.04	0.03	0.03	0.02	0.01
C(at%)	44.58	28.98	20.71	1.73	1.52	1.43	0.68	0.36
T 5								
I	292	236	175	7	45	48	29	31
C(rat)	1.00	0.66	0.48	0.04	0.03	0.04	0.01	0.01
C(at%)	44.00	29.14	21.14	1.73	1.42	1.56	0.64	0.38
T 6								
I	329	266	195	9	55	48	31	26
C(rat)	1.00	0.66	0.48	0.04	0.04	0.03	0.01	0.01
C(at%)	44.07	29.20	20.94	1.97	1.54	1.38	0.61	0.29

Y.D. Pan 11/7/95

T 8								
I	313	230	183	12	43	39	31	31
C(rat)	1.00	0.60	0.47	0.06	0.03	0.03	0.01	0.01
C(at%)	45.21	27.22	21.19	2.84	1.30	1.21	0.65	0.37
T 10								
I	319	257	206	12	44	45	49	30
C(rat)	1.00	0.66	0.52	0.06	0.03	0.03	0.02	0.01
C(at%)	42.94	28.35	22.23	2.64	1.24	1.30	0.96	0.33
T 12								
I	332	282	210	9	45	42	46	32
C(rat)	1.00	0.70	0.51	0.04	0.03	0.03	0.02	0.01
C(at%)	42.90	29.86	21.75	1.90	1.22	1.17	0.87	0.34
T 14								
I	314	252	207	13	54	46	52	36
C(rat)	1.00	0.66	0.53	0.07	0.04	0.03	0.02	0.01
C(at%)	42.46	27.92	22.44	2.88	1.53	1.34	1.03	0.40
T 16								
I	303	290	223	10	53	50	40	42
C(rat)	1.00	0.78	0.59	0.05	0.04	0.04	0.02	0.01
C(at%)	39.51	30.99	23.31	2.13	1.45	1.40	0.76	0.45
T 18								
I	305	275	219	10	47	51	51	38
C(rat)	1.00	0.74	0.58	0.05	0.03	0.04	0.02	0.01
C(at%)	40.47	29.90	23.29	2.17	1.31	1.46	0.99	0.41
T 20								
I	308	284	255	10	47	57	47	39
C(rat)	1.00	0.76	0.66	0.05	0.03	0.04	0.02	0.01
C(at%)	38.81	29.32	25.76	2.06	1.24	1.55	0.87	0.40
T 25								
I	320	279	262	10	51	57	48	43
C(rat)	1.00	0.71	0.66	0.05	0.03	0.04	0.02	0.01
C(at%)	39.58	28.28	25.98	2.02	1.32	1.52	0.87	0.44
T 30								
I	313	280	254	12	52	51	47	44
C(rat)	1.00	0.73	0.65	0.06	0.03	0.04	0.02	0.01
C(at%)	39.22	28.75	25.51	2.46	1.37	1.37	0.86	0.45
B 1								
I	365	315	201	8	55	50	65	44
C(rat)	1.00	0.71	0.44	0.04	0.03	0.03	0.03	0.01
C(at%)	43.83	30.99	19.35	1.57	1.38	1.29	1.14	0.43
B 2								
I	264	195	156	9	43	36	52	32
C(rat)	1.00	0.61	0.47	0.06	0.03	0.03	0.03	0.01
C(at%)	44.70	27.05	21.17	2.49	1.53	1.31	1.29	0.44
B 3								
I	284	235	168	8	40	34	54	38
C(rat)	1.00	0.68	0.47	0.05	0.03	0.03	0.03	0.01
C(at%)	43.62	29.58	20.68	2.01	1.29	1.12	1.21	0.48
B 4								
I	277	251	172	9	41	43	55	35
C(rat)	1.00	0.74	0.50	0.05	0.03	0.03	0.03	0.01
C(at%)	41.72	30.98	20.77	2.22	1.29	1.39	1.21	0.43
B 5								
I	311	217	178	8	44	40	53	48
C(rat)	1.00	0.57	0.46	0.04	0.03	0.03	0.02	0.01
C(at%)	46.14	26.38	21.17	1.94	1.37	1.28	1.15	0.58

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B 6								
I	256	214	157	8	41	49	43	35
C(rat)	1.00	0.68	0.49	0.05	0.03	0.04	0.02	0.01
C(at%)	42.77	29.30	21.03	2.19	1.44	1.76	1.05	0.48
B 8								
I	382	310	242	8	55	53	70	45
C(rat)	1.00	0.66	0.51	0.03	0.03	0.03	0.03	0.01
C(at%)	43.41	28.87	22.04	1.49	1.31	1.30	1.16	0.42
B 10								
I	340	308	245	9	55	44	78	50
C(rat)	1.00	0.74	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	40.48	30.05	23.38	1.75	1.37	1.13	1.36	0.49
B 12								
I	356	332	255	9	55	49	60	56
C(rat)	1.00	0.76	0.57	0.04	0.03	0.03	0.02	0.01
C(at%)	40.34	30.83	23.16	1.67	1.31	1.19	0.99	0.52
B 14								
I	352	324	271	9	62	45	60	51
C(rat)	1.00	0.75	0.62	0.04	0.04	0.03	0.02	0.01
C(at%)	39.77	30.00	24.54	1.66	1.47	1.09	0.99	0.47
B 16								
I	385	334	263	11	62	44	65	54
C(rat)	1.00	0.71	0.55	0.05	0.03	0.02	0.02	0.01
C(at%)	41.67	29.62	22.82	1.95	1.41	1.02	1.03	0.48
B 18								
I	355	302	267	13	56	50	69	49
C(rat)	1.00	0.70	0.60	0.06	0.03	0.03	0.03	0.01
C(at%)	40.60	28.30	24.48	2.43	1.34	1.23	1.15	0.46
B 20								
I	393	326	272	10	64	48	73	47
C(rat)	1.00	0.68	0.55	0.04	0.03	0.03	0.03	0.01
C(at%)	42.13	28.64	23.37	1.75	1.44	1.11	1.14	0.41
B 25								
I	391	350	301	9	68	46	71	56
C(rat)	1.00	0.73	0.62	0.04	0.04	0.03	0.03	0.01
C(at%)	40.19	29.48	24.80	1.51	1.47	1.02	1.07	0.47
B 30								
I	426	377	324	12	69	53	78	49
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

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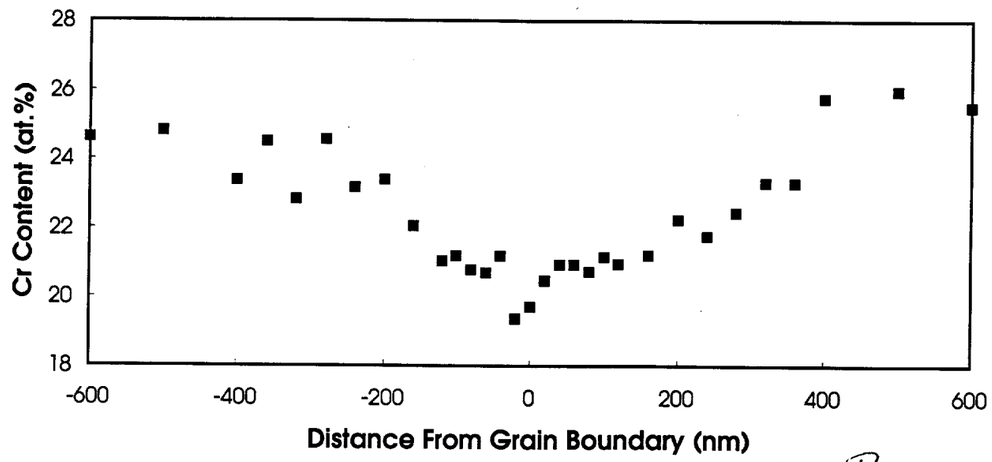

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Chemical Analysis of the 800°C/15hr Aged Alloy 825 Specimen

(Sample No. 1)

Preliminary chemical analysis was conducted on the alloy 825 sample no. 1, aging treated at 800°C/15hr and electropolished with a perchloric acid solution.

A81	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
E 15								
I	227	216	181	7	19	38	36	21
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.76	0.76	1.49	0.41	0.16	0.17	0.10
PPT1								
I	315	325	1233	24	31	31	35	33
C(rat)	1.00	0.79	2.99	0.11	0.04	0.02	0.02	0.01
C(at%)	20.09	15.80	60.13	2.29	0.80	0.32	0.38	0.21
PPT1-2								
I	299	314	1277	26	30	53	44	21
C(rat)	1.00	0.80	3.27	0.13	0.04	0.03	0.02	0.01
C(at%)	18.88	15.11	61.65	2.45	0.77	0.54	0.47	0.13
PPT2								
I	353	299	470	34	29	77	34	21
C(rat)	1.00	0.65	1.02	0.14	0.03	0.03	0.02	0.01
C(at%)	34.51	22.28	35.13	4.97	1.15	1.20	0.56	0.21
PPT3								
I	324	325	891	31	36	58	41	25
C(rat)	1.00	0.76	2.10	0.14	0.05	0.03	0.02	0.01
C(at%)	24.31	18.58	51.12	3.48	1.10	0.70	0.52	0.19
PPT4								
I	166	152	438	32	20	43	24	21
C(rat)	1.00	0.70	2.02	0.29	0.05	0.04	0.02	0.01
C(at%)	24.21	16.89	48.84	6.98	1.18	1.00	0.59	0.31
PPT5								
I	283	270	722	25	28	67	31	18
C(rat)	1.00	0.73	1.95	0.13	0.04	0.04	0.02	0.01
C(at%)	25.56	18.58	49.86	3.38	1.03	0.97	0.47	0.17
PPT6								
I	151	222	1156	24	30	67	28	23
C(rat)	1.00	1.12	5.85	0.24	0.08	0.07	0.03	0.02
C(at%)	11.89	13.32	69.60	2.82	0.96	0.84	0.37	0.18
PPT7								
I	304	349	1505	50	29	70	57	35
C(rat)	1.00	0.87	3.79	0.25	0.04	0.04	0.03	0.01
C(at%)	16.60	14.52	62.84	4.08	0.64	0.61	0.53	0.19
PPT8								
I	189	162	358	12	22	43	20	15
C(rat)	1.00	0.65	1.45	0.09	0.05	0.04	0.02	0.01
C(at%)	30.25	19.76	43.81	2.87	1.43	1.10	0.54	0.24
E 1								
I	42	37	34	2	8	9	5	4
C(rat)	1.00	0.67	0.62	0.07	0.08	0.03	0.02	0.01
C(at%)	39.95	26.82	24.73	2.84	3.09	1.37	0.80	0.39
E 2								
I	68	71	63	3	11	16	9	10
C(rat)	1.00	0.80	0.71	0.07	0.07	0.04	0.02	0.01
C(at%)	36.89	29.35	26.13	2.43	2.42	1.39	0.82	0.55

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Chemical Analysis of the 640°C/15hr Aged Alloy 825 Specimen

(Sample No. 3)

Prilimnery chemical analysis was also conducted on the alloy 825 sample no. 3, aging treated at 640°C/15hr and electropolished with a perchloric acid solution. Even though a large thin area has been produced, very few gram boundary precipitates were observed.

A63								
PPT1								
I	14	17	100	4	3	6	5	5
C(rat)	1.00	0.93	5.46	0.43	0.09	0.07	0.06	0.04
C(at%)	12.40	11.47	67.72	5.30	1.08	0.85	0.75	0.45
PPT2								
I	58	61	86	4	7	11	8	9
C(rat)	1.00	0.80	1.13	0.10	0.05	0.03	0.02	0.02
C(at%)	31.68	25.39	35.92	3.27	1.55	0.96	0.74	0.50
PPT3								
I	542	567	651	36	118	93	48	26
C(rat)	1.00	0.80	0.92	0.10	0.09	0.03	0.01	0.00
C(at%)	33.89	27.02	31.12	3.36	2.99	0.93	0.51	0.17

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Chemical Profile Analysis of the 800°C/15hr Aged Alloy 825 Specimen (Foil No. A)

Chemical concentration profile was measured across a grain boundary region in the alloy 825 sample no. A, aging treated at 800°C/15hr and electropolished with a perchloric acid solution. The results are listed below.

A8a	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
R 25-60								
I	57	48	43	2	5	9	7	6
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.86	0.81	1.31	0.39	0.17	0.22	0.09
PPT1								
I	13	13	119	5	1	10	9	7
C(rat)	1.00	0.86	7.40	0.51	0.03	0.13	0.15	0.05
C(at%)	9.88	8.51	73.09	4.99	0.29	1.29	1.49	0.48
PPT2								
I	11	18	158	7	3	10	9	7
C(rat)	1.00	1.41	11.61	0.84	0.11	0.15	0.18	0.06
C(at%)	6.52	9.19	75.69	5.45	0.69	1.00	1.16	0.37
PPT3								
I	11	18	177	7	4	8	8	4
C(rat)	1.00	1.41	13.00	0.84	0.14	0.12	0.16	0.03
C(at%)	5.99	8.44	77.89	5.01	0.84	0.74	0.95	0.19
PPT4								
I	34	31	76	5	3	4	4	4
C(rat)	1.00	0.79	1.81	0.19	0.03	0.02	0.03	0.01
C(at%)	25.81	20.26	46.63	4.99	0.88	0.51	0.66	0.27
PPT5								
I	13	26	296	6	4	16	11	6
C(rat)	1.00	1.72	18.40	0.61	0.12	0.21	0.18	0.04
C(at%)	4.49	7.73	82.62	2.72	0.53	0.94	0.83	0.19
PPT6-C1								
I	47	49	248	4	5	17	11	7
C(rat)	1.00	0.90	4.26	0.11	0.04	0.06	0.05	0.01
C(at%)	15.53	13.94	66.23	1.74	0.64	0.95	0.79	0.21
PPT6-C2								
I	55	62	293	6	7	14	11	7
C(rat)	1.00	0.97	4.31	0.14	0.05	0.04	0.04	0.01
C(at%)	15.23	14.78	65.57	2.18	0.75	0.66	0.66	0.17
PPT6-E								
I	22	26	199	5	4	8	8	4
C(rat)	1.00	1.02	7.31	0.30	0.07	0.06	0.08	0.02
C(at%)	10.15	10.33	74.20	3.03	0.71	0.63	0.80	0.17
GB56								
I	68	56	41	4	7	4	4	4
C(rat)	1.00	0.71	0.49	0.08	0.04	0.01	0.01	0.01
C(at%)	42.71	30.29	20.81	3.30	1.70	0.43	0.55	0.22
L 1								
I	55	56	38	1	8	4	3	3
C(rat)	1.00	0.88	0.56	0.02	0.06	0.01	0.01	0.00
C(at%)	39.30	34.46	21.94	0.94	2.21	0.48	0.47	0.19
L 2								
I	54	43	38	5	6	9	6	2
C(rat)	1.00	0.69	0.57	0.12	0.04	0.03	0.02	0.00
C(at%)	40.41	27.71	22.98	4.92	1.74	1.14	0.98	0.13

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L 3								
I	57	40	34	1	8	4	5	4
C(rat)	1.00	0.60	0.48	0.02	0.05	0.01	0.02	0.01
C(at%)	45.43	27.51	21.95	1.05	2.47	0.54	0.87	0.29
L 4								
I	55	44	34	2	5	5	5	4
C(rat)	1.00	0.69	0.50	0.05	0.04	0.02	0.02	0.01
C(at%)	43.23	29.78	21.60	2.07	1.52	0.67	0.86	0.28
L 5								
I	47	43	32	5	5	2	5	3
C(rat)	1.00	0.79	0.55	0.14	0.04	0.01	0.02	0.01
C(at%)	39.14	30.84	21.54	5.47	1.61	0.28	0.91	0.22
L 6								
I	43	40	28	5	6	8	4	3
C(rat)	1.00	0.80	0.53	0.15	0.05	0.03	0.02	0.01
C(at%)	38.58	30.90	20.30	5.89	2.08	1.22	0.78	0.24
L 8								
I	37	33	28	2	4	5	7	4
C(rat)	1.00	0.77	0.61	0.07	0.04	0.02	0.04	0.01
C(at%)	38.97	29.93	23.83	2.77	1.63	0.89	1.61	0.38
L 10								
I	42	39	29	1	2	5	4	4
C(rat)	1.00	0.80	0.56	0.03	0.02	0.02	0.02	0.01
C(at%)	40.70	32.54	22.71	1.27	0.75	0.82	0.84	0.35
L 12								
I	37	31	27	3	4	5	5	3
C(rat)	1.00	0.72	0.59	0.11	0.04	0.02	0.03	0.01
C(at%)	39.70	28.64	23.41	4.23	1.66	0.91	1.17	0.29
L 14								
I	38	37	28	2	3	7	5	3
C(rat)	1.00	0.84	0.60	0.07	0.03	0.03	0.03	0.01
C(at%)	38.45	32.24	22.90	2.66	1.17	1.20	1.10	0.27
L 16								
I	35	26	23	2	5	6	4	4
C(rat)	1.00	0.64	0.53	0.08	0.06	0.03	0.02	0.01
C(at%)	42.28	27.05	22.45	3.17	2.34	1.23	1.05	0.43
L 18								
I	35	26	26	2	6	5	5	5
C(rat)	1.00	0.64	0.60	0.08	0.07	0.02	0.03	0.01
C(at%)	40.82	26.11	24.51	3.06	2.71	0.99	1.27	0.52
L 20								
I	39	28	26	1	3	6	2	2
C(rat)	1.00	0.62	0.54	0.03	0.03	0.03	0.01	0.00
C(at%)	44.20	27.33	23.81	1.49	1.32	1.15	0.49	0.20
L 25								
I	32	31	24	2	3	6	4	4
C(rat)	1.00	0.83	0.61	0.08	0.04	0.03	0.03	0.01
C(at%)	38.04	31.73	23.06	3.12	1.38	1.21	1.04	0.43
L 30								
I	30	20	22	2	3	7	6	4
C(rat)	1.00	0.57	0.59	0.09	0.04	0.04	0.04	0.01
C(at%)	41.87	24.04	24.81	3.67	1.62	1.66	1.83	0.50

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R 1								
I	50	38	29	1	5	7	5	5
C(rat)	1.00	0.65	0.47	0.03	0.04	0.02	0.02	0.01
C(at%)	44.59	29.18	20.90	1.17	1.73	1.06	0.97	0.40
R 2								
I	45	42	31	3	5	5	4	3
C(rat)	1.00	0.80	0.56	0.09	0.04	0.02	0.02	0.01
C(at%)	39.44	31.70	21.96	3.45	1.70	0.74	0.76	0.24
R 3								
I	49	33	36	1	2	9	9	7
C(rat)	1.00	0.58	0.59	0.03	0.02	0.03	0.04	0.01
C(at%)	43.47	25.21	25.81	1.17	0.69	1.35	1.74	0.56
R 4								
I	50	33	37	1	4	7	5	4
C(rat)	1.00	0.57	0.60	0.03	0.03	0.02	0.02	0.01
C(at%)	43.93	24.97	26.27	1.15	1.36	1.04	0.96	0.31
R 5								
I	58	61	40	2	7	10	5	3
C(rat)	1.00	0.91	0.56	0.05	0.05	0.03	0.02	0.00
C(at%)	38.35	34.73	21.37	1.74	1.79	1.12	0.72	0.18
R 6								
I	44	38	33	1	6	7	4	4
C(rat)	1.00	0.74	0.61	0.03	0.05	0.03	0.02	0.01
C(at%)	40.20	29.90	24.37	1.20	2.12	1.08	0.80	0.33
R 8								
I	41	40	29	1	5	9	7	5
C(rat)	1.00	0.84	0.57	0.03	0.05	0.04	0.04	0.01
C(at%)	38.82	32.61	22.19	1.24	1.83	1.44	1.44	0.42
R 10								
I	64	53	42	3	5	7	8	4
C(rat)	1.00	0.71	0.53	0.06	0.03	0.02	0.03	0.01
C(at%)	41.90	29.88	22.22	2.58	1.27	0.78	1.14	0.23
R 12								
I	51	37	35	1	5	7	8	4
C(rat)	1.00	0.62	0.55	0.03	0.04	0.02	0.03	0.01
C(at%)	43.34	27.08	24.04	1.12	1.64	1.01	1.48	0.30
R 14								
I	39	40	32	2	4	7	5	4
C(rat)	1.00	0.88	0.66	0.07	0.04	0.03	0.03	0.01
C(at%)	36.75	32.46	24.37	2.48	1.46	1.12	1.03	0.34
R 16								
I	31	33	29	2	4	8	4	2
C(rat)	1.00	0.92	0.76	0.08	0.05	0.04	0.03	0.01
C(at%)	34.66	31.77	26.20	2.94	1.73	1.52	0.97	0.20
R 18								
I	36	26	26	2	2	7	3	5
C(rat)	1.00	0.62	0.58	0.07	0.02	0.03	0.02	0.01
C(at%)	42.31	26.31	24.70	3.09	0.91	1.39	0.77	0.53
R 20								
I	41	43	37	2	5	5	8	4
C(rat)	1.00	0.90	0.73	0.06	0.05	0.02	0.04	0.01
C(at%)	35.52	32.08	25.91	2.28	1.68	0.73	1.51	0.31

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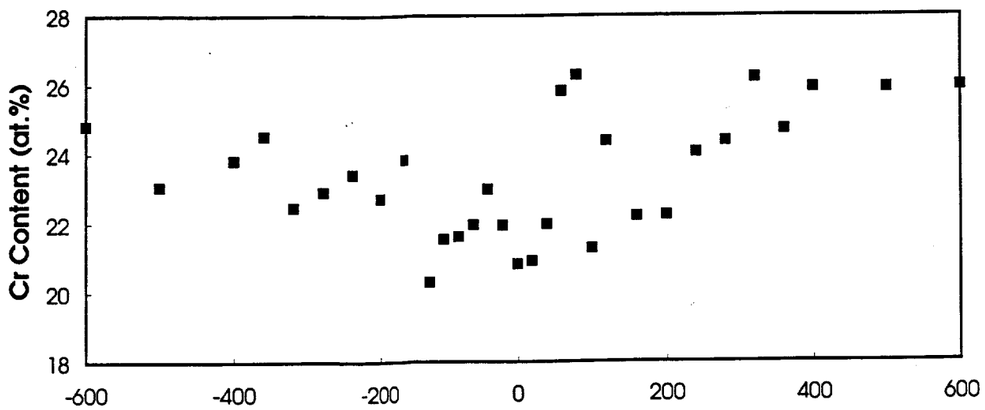
R 25								
I	51	36	39	2	6	9	6	4
C(rat)	1.00	0.61	0.62	0.05	0.05	0.03	0.03	0.01
C(at%)	41.92	25.48	25.91	2.16	1.91	1.25	1.07	0.29
R 30								
I	38	29	31	3	4	8	6	4
C(rat)	1.00	0.66	0.66	0.10	0.04	0.04	0.03	0.01
C(at%)	39.36	25.87	25.95	4.08	1.60	1.40	1.35	0.37



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2nd Chemical Profile Analysis for Specimen A8A

The second chemical concentration profile measurements were performed and the results are presented below.

A8a2	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.377	1.08	1.08	0.38
Matrix								
I	100	98	83	4	100	12	13	8
C(rat)	1.00	0.73	0.61	0.05	0.033	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.377	1.08	1.08	0.38
k	1.00	0.74	0.73	1.15	0.344	0.22	0.21	0.12
PPT1								
I	15	38	312	22	55	7	17	8
C(rat)	1.00	1.87	15.28	1.69	0.111	0.10	0.23	0.06
C(at%)	4.91	9.20	75.02	8.30	0.565	0.51	1.15	0.31
PPT2								
I	56	51	34	11	77	71	9	2
C(rat)	1.00	0.67	0.45	0.23	0.041	0.28	0.03	0.00
C(at%)	36.92	24.88	16.47	8.36	1.577	10.44	1.22	0.16
PPT3								
I	94	79	68	9	83	113	11	6
C(rat)	1.00	0.62	0.53	0.11	0.033	0.27	0.02	0.01
C(at%)	38.58	23.99	20.50	4.26	1.111	10.34	0.93	0.29
PPT4								
I	50	42	222	13	55	23	8	8
C(rat)	1.00	0.62	3.26	0.30	0.033	0.10	0.03	0.02
C(at%)	18.62	11.57	60.73	5.58	0.631	1.91	0.61	0.35
GB34								
I	109	84	63	4	91	12	10	8
C(rat)	1.00	0.57	0.42	0.04	0.033	0.02	0.02	0.01
C(at%)	47.23	26.93	20.05	2.00	1.321	1.16	0.89	0.41
GB34-2								
I	100	66	57	4	7	10	11	8
C(rat)	1.00	0.49	0.42	0.05	0.021	0.02	0.02	0.01
C(at%)	49.23	24.04	20.61	2.27	1.17	1.10	1.11	0.46
T 1								
I	88	78	56	5	10	14	11	6
C(rat)	1.00	0.66	0.47	0.07	0.04	0.04	0.03	0.01
C(at%)	43.54	28.56	20.35	2.85	1.68	1.55	1.12	0.35
T 2								
I	89	76	63	4	12	9	6	5
C(rat)	1.00	0.63	0.52	0.05	0.05	0.02	0.01	0.01
C(at%)	43.62	27.56	22.68	2.26	2.00	0.98	0.61	0.29
T 3								
I	83	76	68	3	7	10	7	7
C(rat)	1.00	0.68	0.60	0.04	0.03	0.03	0.02	0.01
C(at%)	41.60	28.19	25.03	1.73	1.19	1.12	0.72	0.41
T 4								
I	73	69	54	3	10	14	7	5
C(rat)	1.00	0.70	0.54	0.05	0.05	0.04	0.02	0.01
C(at%)	41.54	29.05	22.57	1.97	1.93	1.78	0.82	0.33

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T 5								
I	69	58	63	2	9	10	6	6
C(rat)	1.00	0.62	0.67	0.03	0.04	0.03	0.02	0.01
C(at%)	41.14	25.59	27.59	1.37	1.82	1.33	0.74	0.42
T 6								
I	70	57	45	2	9	10	9	7
C(rat)	1.00	0.60	0.47	0.03	0.04	0.03	0.03	0.01
C(at%)	45.02	27.13	21.26	1.48	1.97	1.43	1.19	0.53
T 8								
I	73	63	57	2	9	11	6	6
C(rat)	1.00	0.64	0.57	0.03	0.04	0.03	0.02	0.01
C(at%)	42.63	27.22	24.45	1.35	1.78	1.43	0.72	0.41
T 10								
I	66	56	43	2	5	10	5	7
C(rat)	1.00	0.63	0.48	0.03	0.03	0.03	0.02	0.01
C(at%)	44.86	28.16	21.47	1.57	1.15	1.52	0.70	0.56
T 12								
I	68	60	44	2	6	12	6	7
C(rat)	1.00	0.65	0.48	0.03	0.03	0.04	0.02	0.01
C(at%)	44.21	28.86	21.01	1.50	1.32	1.74	0.80	0.54
T 14								
I	61	55	47	2	5	9	9	5
C(rat)	1.00	0.67	0.57	0.04	0.03	0.03	0.03	0.01
C(at%)	42.16	28.13	23.86	1.59	1.17	1.39	1.28	0.41
T 16								
I	70	60	46	3	6	8	7	4
C(rat)	1.00	0.63	0.48	0.05	0.03	0.03	0.02	0.01
C(at%)	44.48	28.21	21.47	2.20	1.29	1.13	0.92	0.30
T 18								
I	46	45	35	3	5	9	8	6
C(rat)	1.00	0.72	0.56	0.08	0.04	0.04	0.04	0.02
C(at%)	40.17	29.08	22.45	3.02	1.48	1.75	1.44	0.62
T 20								
I	47	44	35	2	4	8	8	6
C(rat)	1.00	0.69	0.55	0.05	0.03	0.04	0.04	0.02
C(at%)	41.57	28.80	22.74	2.04	1.20	1.58	1.46	0.62
T 25								
I	40	40	33	3	5	8	10	4
C(rat)	1.00	0.74	0.61	0.09	0.04	0.04	0.05	0.01
C(at%)	38.72	28.65	23.46	3.35	1.64	1.73	1.99	0.46
T 30								
I	44	40	32	3	7	8	7	3
C(rat)	1.00	0.67	0.53	0.08	0.05	0.04	0.03	0.01
C(at%)	41.31	27.79	22.07	3.25	2.23	1.68	1.35	0.33
B 1								
I	72	64	50	4	6	12	11	7
C(rat)	1.00	0.66	0.51	0.06	0.03	0.04	0.03	0.01
C(at%)	42.73	28.11	21.80	2.74	1.21	1.59	1.34	0.49

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B 2

I	68	66	50	2	7	14	11	7
C(rat)	1.00	0.72	0.54	0.03	0.03	0.05	0.03	0.01
C(at%)	41.35	29.70	22.33	1.40	1.45	1.90	1.38	0.50

B 3

I	71	71	49	4	7	13	10	9
C(rat)	1.00	0.74	0.51	0.06	0.03	0.04	0.03	0.01
C(at%)	41.15	30.45	20.86	2.67	1.38	1.68	1.19	0.61

B 4

I	77	57	50	4	10	15	10	7
C(rat)	1.00	0.55	0.48	0.06	0.04	0.04	0.03	0.01
C(at%)	45.26	24.79	21.59	2.71	2.00	1.97	1.21	0.48

B 5

I	92	64	65	3	5	18	14	7
C(rat)	1.00	0.51	0.52	0.04	0.02	0.04	0.03	0.01
C(at%)	46.01	23.68	23.88	1.73	0.85	2.01	1.44	0.41

B 6

I	77	66	60	2	6	11	11	8
C(rat)	1.00	0.63	0.57	0.03	0.03	0.03	0.03	0.01
C(at%)	42.80	27.15	24.50	1.28	1.13	1.36	1.26	0.52

B 8

I	78	64	63	5	9	18	12	7
C(rat)	1.00	0.61	0.59	0.07	0.04	0.05	0.03	0.01
C(at%)	41.54	25.22	24.64	3.07	1.63	2.14	1.32	0.44

B 10

I	82	80	64	4	9	15	14	9
C(rat)	1.00	0.72	0.57	0.06	0.04	0.04	0.04	0.01
C(at%)	40.36	29.14	23.14	2.27	1.50	1.65	1.42	0.52

B 12

I	92	75	69	3	6	12	16	11
C(rat)	1.00	0.60	0.55	0.04	0.02	0.03	0.04	0.01
C(at%)	43.61	26.31	24.02	1.64	0.97	1.27	1.56	0.61

B 14

I	83	69	66	3	10	15	14	9
C(rat)	1.00	0.62	0.58	0.04	0.04	0.04	0.03	0.01
C(at%)	42.20	25.96	24.65	1.76	1.73	1.70	1.47	0.54

B 16

I	90	70	66	5	13	20	15	11
C(rat)	1.00	0.58	0.54	0.06	0.05	0.05	0.03	0.01
C(at%)	43.00	24.75	23.16	2.75	2.11	2.13	1.48	0.62

B 18

I	75	68	53	3	8	11	11	10
C(rat)	1.00	0.67	0.52	0.05	0.04	0.03	0.03	0.02
C(at%)	42.54	28.54	22.08	1.96	1.54	1.39	1.28	0.67

B 20

I	85	68	67	5	6	17	13	9
C(rat)	1.00	0.59	0.58	0.07	0.02	0.04	0.03	0.01
C(at%)	42.53	25.18	24.62	2.88	1.02	1.90	1.34	0.53

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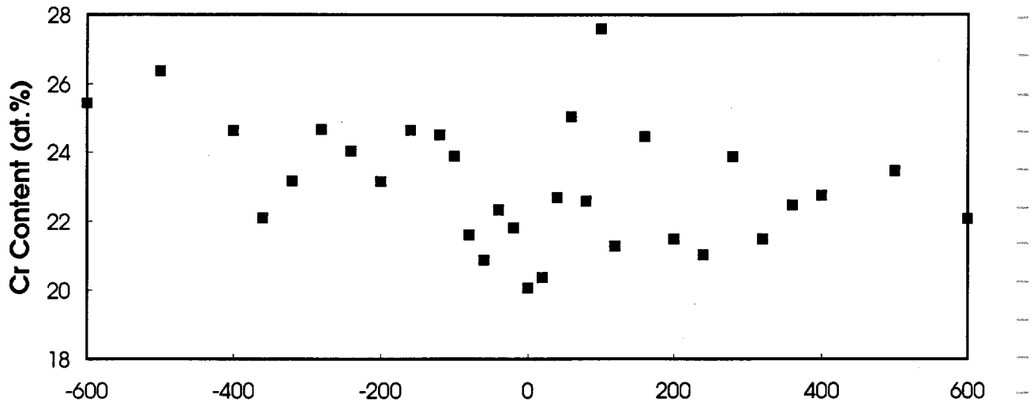
B 25

I	75	66	68	5	10	14	12	8
C(rat)	1.00	0.65	0.67	0.08	0.05	0.04	0.03	0.01
C(at%)	39.58	25.77	26.36	3.04	1.79	1.65	1.30	0.50

B 30

I	73	77	66	3	7	14	11	9
C(rat)	1.00	0.78	0.66	0.05	0.03	0.04	0.03	0.01
C(at%)	38.27	29.87	25.42	1.81	1.25	1.64	1.19	0.56



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2nd Chemical Profile Analysis for Sample 2 (750°C/15hr)

The second chemical concentration profile was measured and is presented below.

Sample24	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
B 20								
I	72	66	59	4	13	15	18	10
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.79	0.74	0.83	0.19	0.13	0.11	0.07
PPT R								
I	19	26	218	9	9	19	15	14
C(rat)	1.00	1.08	8.54	0.39	0.09	0.13	0.08	0.05
C(at%)	8.80	9.53	75.12	3.46	0.78	1.13	0.74	0.44
PPT L								
I	24	25	248	11	12	16	20	18
C(rat)	1.00	0.82	7.69	0.38	0.09	0.09	0.09	0.05
C(at%)	9.79	8.07	75.27	3.72	0.92	0.84	0.87	0.50
GB								
I	102	78	59	4	13	13	13	9
C(rat)	1.00	0.60	0.43	0.03	0.02	0.02	0.01	0.01
C(at%)	47.00	28.43	20.23	1.53	1.13	0.77	0.64	0.28
T 1								
I	76	67	50	5	11	14	24	17
C(rat)	1.00	0.70	0.49	0.05	0.03	0.02	0.03	0.02
C(at%)	42.71	29.79	20.91	2.33	1.16	1.01	1.44	0.65
T 2								
I	89	75	59	6	14	16	20	17
C(rat)	1.00	0.67	0.49	0.06	0.03	0.02	0.02	0.01
C(at%)	43.37	28.91	21.39	2.43	1.28	1.00	1.04	0.56
T 3								
I	90	72	56	2	9	16	26	19
C(rat)	1.00	0.63	0.46	0.02	0.02	0.02	0.03	0.01
C(at%)	45.43	28.75	21.03	0.84	0.85	1.04	1.41	0.65
T 4								
I	86	73	58	5	12	12	26	16
C(rat)	1.00	0.67	0.50	0.05	0.03	0.02	0.03	0.01
C(at%)	43.28	29.06	21.72	2.09	1.14	0.78	1.40	0.55
T 5								
I	79	77	56	3	15	17	23	25
C(rat)	1.00	0.77	0.53	0.03	0.04	0.03	0.03	0.02
C(at%)	40.88	31.52	21.56	1.29	1.46	1.13	1.27	0.88
T 6								
I	90	89	61	3	13	18	20	26
C(rat)	1.00	0.78	0.50	0.03	0.03	0.03	0.02	0.02
C(at%)	41.49	32.46	20.92	1.15	1.13	1.07	0.99	0.81
T 8								
I	100	101	67	3	12	17	30	23
C(rat)	1.00	0.80	0.50	0.02	0.02	0.02	0.03	0.02
C(at%)	41.42	33.09	20.65	1.03	0.93	0.90	1.33	0.65
T 10								
I	92	87	59	3	11	21	20	19
C(rat)	1.00	0.75	0.48	0.03	0.02	0.03	0.02	0.01
C(at%)	42.71	31.95	20.38	1.16	0.96	1.25	0.99	0.60

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T 12								
I	110	102	74	4	11	21	34	23
C(rat)	1.00	0.73	0.50	0.03	0.02	0.02	0.03	0.01
C(at%)	42.47	31.15	21.26	1.28	0.80	1.04	1.41	0.60
T 14								
I	126	101	85	3	13	18	37	22
C(rat)	1.00	0.63	0.50	0.02	0.02	0.02	0.03	0.01
C(at%)	44.71	28.35	22.44	0.88	0.87	0.82	1.41	0.53
T 16								
I	108	100	73	6	17	18	38	19
C(rat)	1.00	0.73	0.50	0.05	0.03	0.02	0.04	0.01
C(at%)	41.98	30.75	21.11	1.94	1.24	0.90	1.58	0.50
T 18								
I	107	108	86	4	20	20	32	31
C(rat)	1.00	0.80	0.60	0.03	0.04	0.02	0.03	0.02
C(at%)	39.40	31.46	23.56	1.22	1.38	0.95	1.26	0.77
T 20								
I	116	106	91	5	17	22	38	19
C(rat)	1.00	0.72	0.58	0.04	0.03	0.02	0.04	0.01
C(at%)	40.98	29.62	23.92	1.47	1.13	1.00	1.44	0.46
T 25								
I	121	105	97	7	21	25	37	32
C(rat)	1.00	0.69	0.60	0.05	0.03	0.03	0.03	0.02
C(at%)	40.97	28.12	24.44	1.97	1.34	1.09	1.34	0.73
T 30								
I	109	118	93	4	16	23	31	23
C(rat)	1.00	0.86	0.63	0.03	0.03	0.03	0.03	0.01
C(at%)	38.15	32.67	24.22	1.16	1.05	1.03	1.16	0.55
B 1								
I	87	73	53	5	12	16	10	10
C(rat)	1.00	0.66	0.45	0.05	0.03	0.02	0.01	0.01
C(at%)	44.76	29.71	20.29	2.13	1.16	1.06	0.55	0.35
B 2								
I	71	73	51	3	10	14	11	8
C(rat)	1.00	0.81	0.53	0.04	0.03	0.03	0.02	0.01
C(at%)	40.67	33.08	21.73	1.43	1.08	1.03	0.67	0.31
B 3								
I	72	65	54	3	11	14	17	10
C(rat)	1.00	0.71	0.56	0.03	0.03	0.02	0.03	0.01
C(at%)	41.75	29.82	23.30	1.44	1.20	1.04	1.06	0.39
B 4								
I	66	62	48	3	11	14	12	11
C(rat)	1.00	0.74	0.54	0.04	0.03	0.03	0.02	0.01
C(at%)	41.47	30.82	22.44	1.56	1.30	1.13	0.81	0.47
B 5								
I	77	64	54	4	10	12	12	8
C(rat)	1.00	0.66	0.52	0.04	0.02	0.02	0.02	0.01
C(at%)	43.66	28.71	22.78	1.88	1.07	0.87	0.73	0.31
B 6								
I	80	72	58	3	13	12	19	11
C(rat)	1.00	0.71	0.54	0.03	0.03	0.02	0.03	0.01
C(at%)	42.25	30.08	22.79	1.31	1.29	0.81	1.07	0.39

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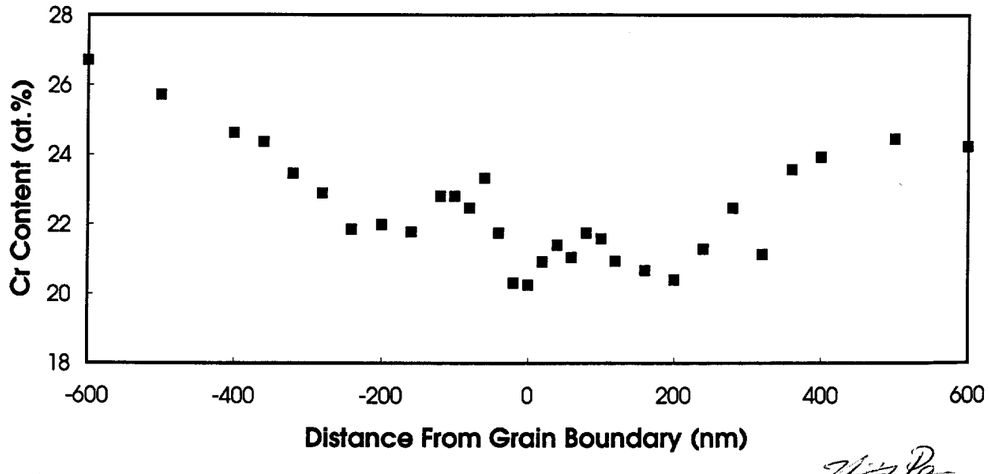
B 8								
I	74	71	52	3	14	13	12	12
C(rat)	1.00	0.76	0.52	0.03	0.04	0.02	0.02	0.01
C(at%)	41.63	31.60	21.76	1.40	1.48	0.94	0.72	0.46
B 10								
I	68	67	49	3	9	15	15	11
C(rat)	1.00	0.78	0.54	0.04	0.02	0.03	0.02	0.01
C(at%)	40.98	31.94	21.97	1.50	1.02	1.16	0.97	0.45
B 12								
I	76	73	53	2	10	11	15	13
C(rat)	1.00	0.76	0.52	0.02	0.02	0.02	0.02	0.01
C(at%)	42.08	31.97	21.83	0.92	1.04	0.78	0.89	0.49
B 14								
I	75	68	55	3	12	16	16	10
C(rat)	1.00	0.72	0.55	0.03	0.03	0.03	0.02	0.01
C(at%)	41.92	30.07	22.87	1.39	1.26	1.15	0.96	0.38
B 16								
I	74	76	59	3	9	20	15	13
C(rat)	1.00	0.81	0.59	0.03	0.02	0.03	0.02	0.01
C(at%)	39.52	32.11	23.44	1.33	0.90	1.37	0.86	0.47
B 18								
I	72	74	62	6	9	23	22	12
C(rat)	1.00	0.81	0.64	0.07	0.02	0.04	0.03	0.01
C(at%)	38.00	30.90	24.35	2.63	0.89	1.56	1.24	0.43
B 20								
I	72	66	59	4	13	15	18	10
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
B 25								
I	67	59	57	2	9	22	20	10
C(rat)	1.08	0.75	0.68	0.03	0.03	0.05	0.03	0.01
C(at%)	37.56	28.28	25.69	1.01	1.03	1.71	1.30	0.41
B 30								
I	59	41	49	3	8	19	13	12
C(rat)	1.11	0.61	0.69	0.05	0.03	0.05	0.03	0.02
C(at%)	38.82	23.76	26.70	1.82	1.10	1.79	1.02	0.60



Yiy Pan 2/18/95

This foil RP, aging treated at 700°C/101hr, was electropolished with a perchloric acid solution. Chemical concentration profiles were measured across two grain boundary regions. The results are presented below.

Profile RP1

RP1	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	143	152	103	4	15	18	16	14
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.68	0.85	1.65	0.32	0.21	0.24	0.10
PPT R								
I	106	96	213	10	10	14	11	9
C(rat)	1.00	0.62	1.70	0.16	0.03	0.03	0.02	0.01
C(at%)	28.04	17.32	47.69	4.36	0.86	0.79	0.70	0.23
PPT L								
I	54	68	292	13	9	7	10	10
C(rat)	1.00	0.86	4.58	0.40	0.05	0.03	0.04	0.02
C(at%)	14.33	12.31	65.59	5.69	0.77	0.39	0.63	0.26
GB								
I	123	74	47	5	11	49	12	11
C(rat)	1.00	0.41	0.32	0.07	0.03	0.08	0.02	0.01
C(at%)	51.38	21.09	16.62	3.44	1.49	4.35	1.20	0.44
T 1								
I	128	89	53	4	15	36	9	8
C(rat)	1.00	0.47	0.35	0.05	0.04	0.06	0.02	0.01
C(at%)	50.08	23.76	17.55	2.58	1.90	3.00	0.84	0.30
T 2								
I	126	85	51	3	13	35	13	13
C(rat)	1.00	0.46	0.34	0.04	0.03	0.06	0.02	0.01
C(at%)	50.78	23.37	17.40	1.99	1.70	3.00	1.25	0.50
T 3								
I	129	70	49	5	10	36	9	9
C(rat)	1.00	0.37	0.32	0.06	0.03	0.06	0.02	0.01
C(at%)	53.66	19.86	17.25	3.43	1.35	3.18	0.90	0.36
T 4								
I	138	86	56	5	11	29	12	9
C(rat)	1.00	0.43	0.34	0.06	0.03	0.04	0.02	0.01
C(at%)	51.92	22.07	17.83	3.10	1.34	2.32	1.08	0.33
T 5								
I	141	88	63	4	10	31	11	11
C(rat)	1.00	0.43	0.38	0.05	0.02	0.05	0.02	0.01
C(at%)	51.37	21.87	19.43	2.40	1.18	2.40	0.96	0.39
T 6								
I	141	96	65	4	10	24	14	8
C(rat)	1.00	0.46	0.39	0.05	0.02	0.04	0.02	0.01
C(at%)	50.26	23.35	19.61	2.35	1.15	1.82	1.19	0.27

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T 8								
I	137	118	77	4	11	17	16	10
C(rat)	1.00	0.59	0.48	0.05	0.03	0.03	0.03	0.01
C(at%)	45.48	26.72	21.64	2.19	1.18	1.20	1.27	0.32
T 10								
I	155	134	91	4	13	19	11	14
C(rat)	1.00	0.59	0.50	0.04	0.03	0.03	0.02	0.01
C(at%)	45.29	26.71	22.51	1.93	1.23	1.18	0.77	0.39
T 12								
I	141	136	97	4	18	21	16	13
C(rat)	1.00	0.66	0.58	0.05	0.04	0.03	0.03	0.01
C(at%)	41.73	27.46	24.30	1.95	1.72	1.32	1.13	0.37
T 14								
I	145	122	93	4	13	24	16	10
C(rat)	1.00	0.57	0.54	0.05	0.03	0.04	0.03	0.01
C(at%)	44.26	25.41	24.03	2.01	1.28	1.56	1.17	0.29
T 16								
I	141	123	100	4	19	25	17	10
C(rat)	1.00	0.60	0.60	0.05	0.04	0.04	0.03	0.01
C(at%)	42.39	25.23	25.45	1.98	1.85	1.60	1.22	0.29
T 18								
I	148	135	108	4	11	22	16	12
C(rat)	1.00	0.62	0.62	0.04	0.02	0.03	0.03	0.01
C(at%)	42.13	26.22	26.02	1.88	1.01	1.33	1.09	0.33
T 20								
I	154	136	106	5	14	21	18	13
C(rat)	1.00	0.60	0.58	0.05	0.03	0.03	0.03	0.01
C(at%)	42.86	25.82	24.97	2.29	1.26	1.24	1.20	0.35
T 25								
I	143	152	103	4	15	18	16	14
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
T 30								
I	158	166	105	4	11	18	20	14
C(rat)	1.00	0.72	0.56	0.04	0.02	0.02	0.03	0.01
C(at%)	41.55	29.78	23.37	1.73	0.94	1.01	1.26	0.35
B 1								
I	105	79	43	6	9	28	13	8
C(rat)	1.00	0.51	0.35	0.09	0.03	0.06	0.03	0.01
C(at%)	48.18	24.73	16.70	4.54	1.34	2.73	1.43	0.35
B 2								
I	99	84	42	3	13	29	9	11
C(rat)	1.00	0.58	0.36	0.05	0.04	0.06	0.02	0.01
C(at%)	47.06	27.24	16.90	2.35	2.00	2.93	1.02	0.50
B 3								
I	100	83	46	4	9	19	20	15
C(rat)	1.00	0.57	0.39	0.07	0.03	0.04	0.05	0.01
C(at%)	46.44	26.30	18.08	3.06	1.35	1.88	2.22	0.67
B 4								
I	109	79	46	3	8	13	15	13
C(rat)	1.00	0.49	0.36	0.05	0.02	0.03	0.03	0.01
C(at%)	50.24	24.84	17.95	2.28	1.19	1.27	1.65	0.58

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B 5								
I	108	88	56	3	13	16	9	7
C(rat)	1.00	0.56	0.44	0.05	0.04	0.03	0.02	0.01
C(at%)	46.79	26.01	20.54	2.14	1.82	1.47	0.93	0.29
B 6								
I	98	73	51	4	9	15	15	11
C(rat)	1.00	0.51	0.44	0.07	0.03	0.03	0.04	0.01
C(at%)	47.05	23.91	20.72	3.16	1.40	1.53	1.72	0.51
B 8								
I	109	79	53	4	12	17	14	12
C(rat)	1.00	0.49	0.41	0.06	0.04	0.03	0.03	0.01
C(at%)	48.16	23.81	19.82	2.91	1.72	1.60	1.48	0.51
B 10								
I	119	92	61	4	12	18	8	11
C(rat)	1.00	0.53	0.43	0.06	0.03	0.03	0.02	0.01
C(at%)	47.47	25.04	20.60	2.63	1.55	1.53	0.76	0.42
B 12								
I	109	95	52	4	8	14	14	11
C(rat)	1.00	0.59	0.40	0.06	0.02	0.03	0.03	0.01
C(at%)	46.50	27.65	18.78	2.81	1.10	1.27	1.43	0.45
B 14								
I	109	87	53	2	10	19	13	8
C(rat)	1.00	0.54	0.41	0.03	0.03	0.04	0.03	0.01
C(at%)	47.88	26.07	19.71	1.45	1.42	1.77	1.37	0.34
B 16								
I	109	98	62	4	9	13	12	11
C(rat)	1.00	0.61	0.48	0.06	0.03	0.03	0.03	0.01
C(at%)	44.57	27.34	21.46	2.70	1.19	1.13	1.17	0.43
B 18								
I	88	75	53	4	8	14	12	10
C(rat)	1.00	0.58	0.51	0.07	0.03	0.03	0.03	0.01
C(at%)	44.00	25.58	22.43	3.30	1.29	1.49	1.44	0.48
B 20								
I	92	82	58	2	11	14	11	9
C(rat)	1.00	0.61	0.53	0.04	0.04	0.03	0.03	0.01
C(at%)	43.73	26.59	23.34	1.57	1.69	1.42	1.25	0.41
B 25								
I	86	86	58	4	11	15	15	10
C(rat)	1.00	0.68	0.57	0.08	0.04	0.04	0.04	0.01
C(at%)	40.63	27.72	23.19	3.11	1.68	1.51	1.70	0.45
B 30								
I	98	86	66	2	6	18	12	9
C(rat)	1.00	0.60	0.57	0.03	0.02	0.04	0.03	0.01
C(at%)	43.49	26.04	24.79	1.46	0.86	1.70	1.27	0.38

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Profile RP2

RP2	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	193	181	147	6	20	29	35	25
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.77	0.80	1.48	0.33	0.18	0.15	0.07
PPT R								
I	74	112	415	12	13	14	10	9
C(rat)	1.00	1.17	4.49	0.24	0.06	0.03	0.02	0.01
C(at%)	14.25	16.68	63.97	3.43	0.82	0.48	0.28	0.13
PPT L								
I	71	105	382	10	11	13	13	9
C(rat)	1.00	1.14	4.31	0.21	0.05	0.03	0.03	0.01
C(at%)	14.75	16.87	63.52	3.08	0.75	0.48	0.40	0.14
GB								
I	176	146	76	4	16	16	14	8
C(rat)	1.00	0.64	0.35	0.03	0.03	0.02	0.01	0.00
C(at%)	48.04	30.81	16.60	1.62	1.43	0.78	0.56	0.16
T 1								
I	175	136	84	5	17	17	15	10
C(rat)	1.00	0.60	0.38	0.04	0.03	0.02	0.01	0.00
C(at%)	47.77	28.71	18.35	2.02	1.52	0.83	0.60	0.20
T 2								
I	151	124	77	4	21	18	16	14
C(rat)	1.00	0.63	0.41	0.04	0.05	0.02	0.02	0.01
C(at%)	46.05	29.24	18.80	1.81	2.10	0.98	0.72	0.31
T 3								
I	158	139	88	5	17	24	15	12
C(rat)	1.00	0.68	0.45	0.05	0.04	0.03	0.01	0.01
C(at%)	44.35	30.17	19.77	2.08	1.56	1.20	0.62	0.24
T 4								
I	144	128	84	5	12	18	12	9
C(rat)	1.00	0.69	0.47	0.05	0.03	0.02	0.01	0.00
C(at%)	44.01	30.25	20.55	2.27	1.20	0.98	0.54	0.20
T 5								
I	138	118	84	4	14	17	15	10
C(rat)	1.00	0.66	0.49	0.04	0.03	0.02	0.02	0.01
C(at%)	44.09	29.15	21.48	1.89	1.47	0.97	0.71	0.23
T 6								
I	120	108	80	5	10	20	19	13
C(rat)	1.00	0.70	0.53	0.06	0.03	0.03	0.02	0.01
C(at%)	42.02	29.24	22.42	2.60	1.15	1.25	0.98	0.33
T 8								
I	123	113	81	6	10	17	20	12
C(rat)	1.00	0.71	0.53	0.07	0.03	0.02	0.02	0.01
C(at%)	41.80	29.69	22.03	3.02	1.11	1.03	1.00	0.30
T 10								
I	121	110	82	4	15	18	19	14
C(rat)	1.00	0.70	0.54	0.05	0.04	0.03	0.02	0.01
C(at%)	41.79	29.38	22.67	2.05	1.70	1.11	0.97	0.35

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T 12								
I	130	113	94	5	12	18	17	15
C(rat)	1.00	0.67	0.58	0.06	0.03	0.02	0.02	0.01
C(at%)	41.83	28.11	24.21	2.39	1.27	1.03	0.81	0.35
T 14								
I	122	117	91	5	14	21	19	13
C(rat)	1.00	0.74	0.60	0.06	0.04	0.03	0.02	0.01
C(at%)	40.03	29.68	23.90	2.43	1.51	1.23	0.92	0.31
T 16								
I	121	108	93	6	12	22	19	13
C(rat)	1.00	0.69	0.62	0.07	0.03	0.03	0.02	0.01
C(at%)	40.41	27.89	24.86	2.97	1.31	1.31	0.94	0.32
T 18								
I	119	106	89	5	11	19	18	14
C(rat)	1.00	0.69	0.60	0.06	0.03	0.03	0.02	0.01
C(at%)	41.00	28.24	24.54	2.55	1.24	1.17	0.92	0.35
T 20								
I	116	100	85	5	11	20	18	16
C(rat)	1.00	0.67	0.59	0.06	0.03	0.03	0.02	0.01
C(at%)	41.46	27.64	24.32	2.65	1.29	1.27	0.95	0.42
T 25								
I	117	104	90	5	12	16	16	12
C(rat)	1.00	0.69	0.62	0.06	0.03	0.02	0.02	0.01
C(at%)	40.78	28.03	25.11	2.58	1.37	0.99	0.82	0.30
T 30								
I	119	100	88	4	10	16	20	17
C(rat)	1.00	0.65	0.59	0.05	0.03	0.02	0.02	0.01
C(at%)	42.05	27.32	24.89	2.10	1.16	1.01	1.04	0.44
B 1								
I	166	135	74	4	14	22	18	12
C(rat)	1.00	0.63	0.36	0.04	0.03	0.02	0.02	0.01
C(at%)	47.76	30.03	17.04	1.71	1.32	1.13	0.76	0.25
B 2								
I	176	134	82	6	16	30	11	13
C(rat)	1.00	0.59	0.37	0.05	0.03	0.03	0.01	0.01
C(at%)	47.92	28.21	17.87	2.42	1.43	1.46	0.44	0.26
B 3								
I	182	138	86	5	15	22	18	11
C(rat)	1.00	0.59	0.38	0.04	0.03	0.02	0.01	0.00
C(at%)	48.24	28.28	18.25	1.97	1.30	1.04	0.70	0.21
B 4								
I	173	142	97	5	14	25	24	12
C(rat)	1.00	0.63	0.45	0.04	0.03	0.03	0.02	0.01
C(at%)	45.37	28.80	20.36	1.94	1.20	1.17	0.93	0.23
B 5								
I	170	130	96	3	18	28	17	19
C(rat)	1.00	0.59	0.45	0.03	0.03	0.03	0.01	0.01
C(at%)	46.37	27.42	20.96	1.21	1.61	1.36	0.68	0.38
B 6								
I	158	134	93	6	19	28	21	12
C(rat)	1.00	0.66	0.47	0.06	0.04	0.03	0.02	0.01
C(at%)	43.87	28.77	20.67	2.47	1.73	1.38	0.86	0.24

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B 8								
I	184	151	102	6	20	28	17	17
C(rat)	1.00	0.63	0.44	0.05	0.04	0.03	0.01	0.01
C(at%)	45.25	28.71	20.08	2.19	1.61	1.23	0.62	0.30
B 10								
I	181	169	108	7	16	24	19	15
C(rat)	1.00	0.72	0.48	0.06	0.03	0.02	0.02	0.01
C(at%)	42.90	30.97	20.49	2.46	1.24	1.01	0.66	0.26
B 12								
I	189	174	112	7	19	27	21	17
C(rat)	1.00	0.71	0.47	0.05	0.03	0.03	0.02	0.01
C(at%)	43.06	30.65	20.42	2.36	1.42	1.10	0.71	0.28
B 14								
I	182	168	111	6	18	26	18	17
C(rat)	1.00	0.71	0.49	0.05	0.03	0.03	0.01	0.01
C(at%)	42.92	30.63	20.95	2.10	1.39	1.09	0.63	0.29
B 16								
I	191	176	138	6	19	31	20	20
C(rat)	1.00	0.71	0.58	0.05	0.03	0.03	0.02	0.01
C(at%)	41.29	29.42	23.88	1.92	1.35	1.19	0.64	0.31
B 18								
I	189	174	132	7	21	30	19	19
C(rat)	1.00	0.71	0.56	0.05	0.04	0.03	0.01	0.01
C(at%)	41.45	29.51	23.17	2.28	1.51	1.17	0.62	0.30
B 20								
I	199	176	157	7	22	33	22	23
C(rat)	1.00	0.68	0.63	0.05	0.04	0.03	0.02	0.01
C(at%)	40.68	27.82	25.69	2.12	1.47	1.20	0.66	0.34
B 25								
I	193	181	147	6	20	29	35	25
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
B 30								
I	201	179	145	5	16	33	31	19
C(rat)	1.00	0.69	0.58	0.04	0.03	0.03	0.02	0.01
C(at%)	41.88	28.84	24.18	1.54	1.09	1.22	0.95	0.29

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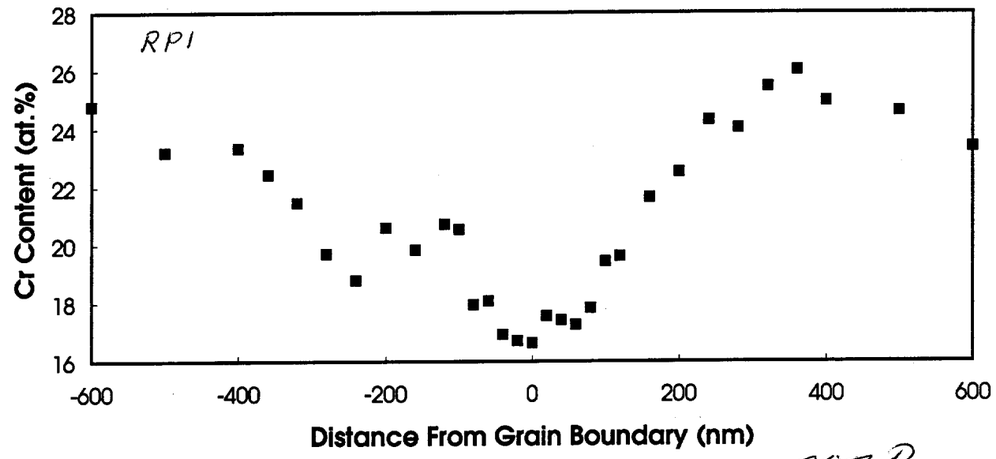

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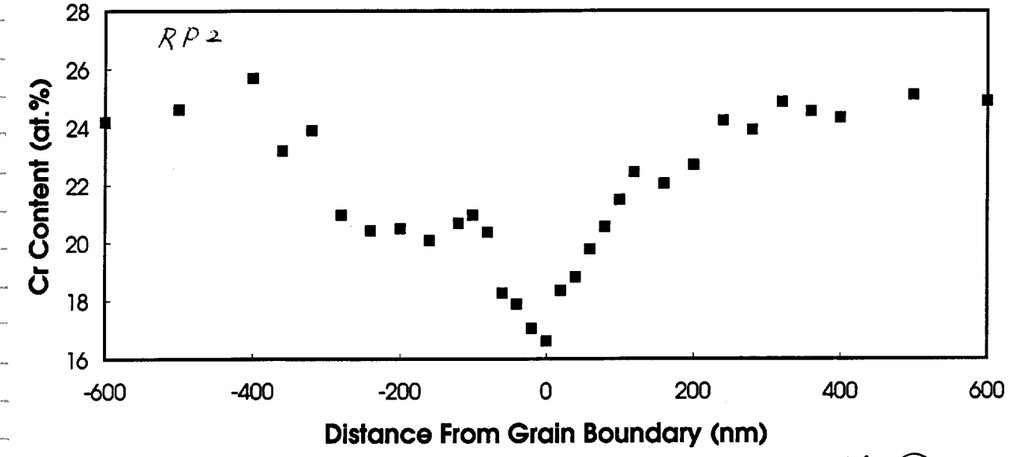

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Chemical Profile Analysis of Sample FGP Aged at 700°C/15hr

Thin foil FGP3, aging treated at 700°C/15hr, was electropolished with a perchloric acid solution. Chemical profile was measured across a grain boundary region. The results are presented below.

FGP31	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	242	205	187	7	26	41	36	22
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.86	0.79	1.59	0.32	0.16	0.18	0.10
PPT R								
I	74	63	216	6	9	16	11	10
C(rat)	1.00	0.73	2.30	0.13	0.04	0.03	0.03	0.01
C(at%)	23.40	17.05	53.89	3.02	0.90	0.80	0.63	0.33
PPT L								
I	60	62	144	6	13	11	9	8
C(rat)	1.00	0.88	1.89	0.16	0.07	0.03	0.03	0.01
C(at%)	24.54	21.71	46.47	3.91	1.68	0.71	0.66	0.34
GB								
I	72	66	33	2	10	5	4	4
C(rat)	1.00	0.78	0.36	0.04	0.04	0.01	0.01	0.01
C(at%)	44.22	34.70	15.99	1.96	1.94	0.49	0.44	0.25
T 1								
I	66	53	35	2	9	10	5	4
C(rat)	1.00	0.69	0.42	0.05	0.04	0.02	0.01	0.01
C(at%)	44.62	30.67	18.67	2.15	1.92	1.07	0.61	0.28
T 2								
I	74	64	48	3	14	7	7	5
C(rat)	1.00	0.74	0.51	0.06	0.06	0.01	0.02	0.01
C(at%)	41.40	30.65	21.19	2.67	2.48	0.62	0.70	0.29
T 3								
I	80	58	46	3	9	11	8	6
C(rat)	1.00	0.62	0.45	0.06	0.04	0.02	0.02	0.01
C(at%)	45.10	27.99	20.46	2.70	1.60	0.98	0.81	0.35
T 4								
I	94	74	63	2	10	10	5	9
C(rat)	1.00	0.67	0.53	0.03	0.03	0.02	0.01	0.01
C(at%)	43.36	29.22	22.93	1.47	1.46	0.73	0.41	0.43
T 5								
I	93	74	58	5	13	15	11	8
C(rat)	1.00	0.68	0.49	0.09	0.04	0.03	0.02	0.01
C(at%)	42.40	28.88	20.86	3.63	1.87	1.08	0.90	0.38
T 6								
I	109	95	72	5	11	21	9	8
C(rat)	1.00	0.75	0.52	0.07	0.03	0.03	0.01	0.01
C(at%)	41.23	30.76	21.49	3.01	1.31	1.25	0.61	0.31
T 8								
I	111	106	85	5	12	18	8	7
C(rat)	1.00	0.82	0.60	0.07	0.03	0.03	0.01	0.01
C(at%)	38.87	31.78	23.48	2.79	1.33	1.00	0.50	0.25

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T 10								
I	125	108	96	7	13	15	14	12
C(rat)	1.00	0.74	0.61	0.09	0.03	0.02	0.02	0.01
C(at%)	39.73	29.38	24.07	3.55	1.31	0.75	0.80	0.40
T 12								
I	116	110	94	5	12	20	12	14
C(rat)	1.00	0.81	0.64	0.07	0.03	0.03	0.02	0.01
C(at%)	38.30	31.09	24.49	2.63	1.25	1.04	0.71	0.48
T 14								
I	119	118	95	7	16	24	15	8
C(rat)	1.00	0.85	0.63	0.09	0.04	0.03	0.02	0.01
C(at%)	37.36	31.71	23.53	3.50	1.59	1.19	0.85	0.26
T 16								
I	115	112	91	7	13	20	15	11
C(rat)	1.00	0.83	0.62	0.10	0.04	0.03	0.02	0.01
C(at%)	37.71	31.44	23.54	3.66	1.35	1.04	0.88	0.37
T 18								
I	126	97	101	5	16	20	12	10
C(rat)	1.00	0.66	0.63	0.06	0.04	0.03	0.02	0.01
C(at%)	40.90	26.95	25.87	2.59	1.64	1.03	0.70	0.34
T 20								
I	130	105	99	8	15	19	11	9
C(rat)	1.00	0.69	0.60	0.10	0.04	0.02	0.02	0.01
C(at%)	40.45	27.97	24.30	3.97	1.47	0.93	0.62	0.29
T 25								
I	114	99	96	5	14	24	12	10
C(rat)	1.00	0.74	0.66	0.07	0.04	0.03	0.02	0.01
C(at%)	38.79	28.84	25.77	2.71	1.51	1.29	0.73	0.35
T 30								
I	133	100	101	5	12	21	10	11
C(rat)	1.00	0.64	0.60	0.06	0.03	0.02	0.01	0.01
C(at%)	42.05	27.06	25.19	2.52	1.20	1.05	0.57	0.36
B 1								
I	90	83	47	5	11	15	10	8
C(rat)	1.00	0.79	0.41	0.09	0.04	0.03	0.02	0.01
C(at%)	41.94	33.11	17.28	3.71	1.62	1.10	0.84	0.39
B 2								
I	94	85	55	3	13	14	10	11
C(rat)	1.00	0.77	0.46	0.05	0.04	0.02	0.02	0.01
C(at%)	41.93	32.46	19.36	2.13	1.83	0.99	0.80	0.51
B 3								
I	112	97	65	5	14	20	22	15
C(rat)	1.00	0.74	0.46	0.07	0.04	0.03	0.04	0.01
C(at%)	41.89	31.06	19.18	2.98	1.65	1.18	1.48	0.58
B 4								
I	129	108	84	4	14	23	19	14
C(rat)	1.00	0.72	0.51	0.05	0.03	0.03	0.03	0.01
C(at%)	42.02	30.11	21.59	2.08	1.44	1.18	1.11	0.47
B 5								
I	138	131	87	6	14	24	22	17
C(rat)	1.00	0.81	0.50	0.07	0.03	0.03	0.03	0.01
C(at%)	40.32	32.76	20.06	2.79	1.29	1.11	1.16	0.51
B 6								
I	156	160	105	5	16	34	28	22
C(rat)	1.00	0.88	0.53	0.05	0.03	0.03	0.03	0.01
C(at%)	38.85	34.11	20.63	1.98	1.26	1.34	1.25	0.57

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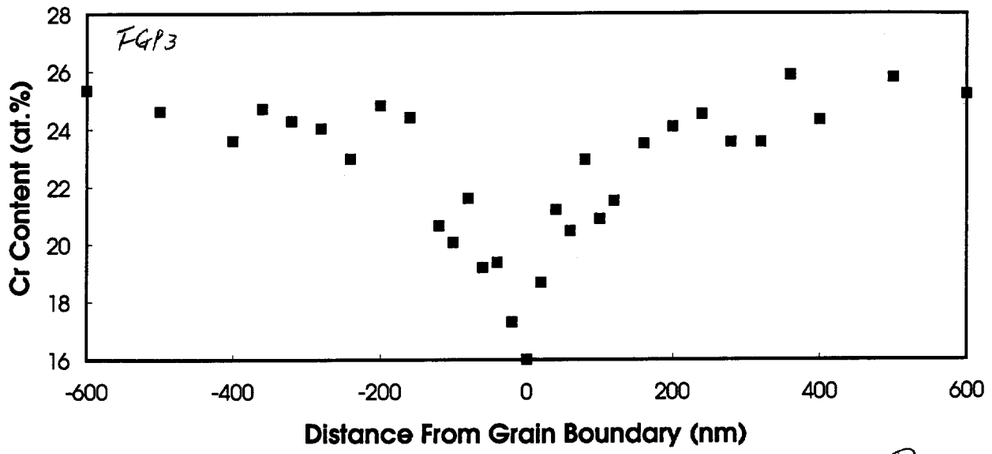
B 8								
I	167	156	135	6	22	37	29	20
C(rat)	1.00	0.80	0.64	0.06	0.04	0.04	0.03	0.01
C(at%)	38.24	30.58	24.39	2.19	1.59	1.34	1.19	0.47
B 10								
I	214	179	167	7	25	36	30	19
C(rat)	1.00	0.72	0.62	0.05	0.04	0.03	0.03	0.01
C(at%)	40.29	28.85	24.81	2.10	1.49	1.07	1.02	0.37
B 12								
I	239	217	176	9	31	41	43	28
C(rat)	1.00	0.78	0.58	0.06	0.04	0.03	0.03	0.01
C(at%)	39.51	30.71	22.96	2.37	1.62	1.07	1.28	0.48
B 14								
I	244	213	188	10	27	43	49	27
C(rat)	1.00	0.75	0.61	0.07	0.03	0.03	0.04	0.01
C(at%)	39.51	29.52	24.02	2.58	1.38	1.10	1.43	0.45
B 16								
I	253	224	195	7	29	36	35	32
C(rat)	1.00	0.76	0.61	0.04	0.04	0.02	0.02	0.01
C(at%)	39.89	30.23	24.26	1.76	1.44	0.90	0.99	0.52
B 18								
I	230	211	186	8	30	34	39	24
C(rat)	1.00	0.79	0.64	0.06	0.04	0.02	0.03	0.01
C(at%)	38.69	30.38	24.69	2.14	1.59	0.90	1.18	0.42
B 20								
I	234	215	178	8	26	39	41	25
C(rat)	1.00	0.79	0.60	0.05	0.04	0.03	0.03	0.01
C(at%)	39.29	30.90	23.58	2.14	1.38	1.03	1.24	0.43
B 25								
I	242	205	187	7	26	41	36	22
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
B 30								
I	254	231	211	8	28	47	37	28
C(rat)	1.00	0.78	0.66	0.05	0.03	0.03	0.03	0.01
C(at%)	38.67	30.11	25.34	1.94	1.35	1.13	1.01	0.44



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Second profile for the 700°C/15hr aged sample:

FGP32	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	133	119	104	6	11	26	37	25
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.81	0.78	1.02	0.41	0.14	0.10	0.05
PPT L								
I	51	60	245	9	7	22	17	15
C(rat)	1.00	0.95	3.75	0.18	0.06	0.06	0.03	0.01
C(at%)	16.55	15.78	61.99	2.98	0.93	0.98	0.53	0.24
GB								
I	108	90	51	4	11	24	13	8
C(rat)	1.00	0.68	0.37	0.04	0.04	0.03	0.01	0.00
C(at%)	46.11	31.14	16.98	1.75	1.93	1.40	0.53	0.17
T 1								
I	126	101	60	5	9	27	17	13
C(rat)	1.00	0.65	0.37	0.04	0.03	0.03	0.01	0.01
C(at%)	46.77	30.38	17.36	1.90	1.37	1.37	0.61	0.24
T 2								
I	108	89	60	3	12	20	21	16
C(rat)	1.00	0.67	0.43	0.03	0.05	0.03	0.02	0.01
C(at%)	44.91	29.99	19.45	1.27	2.05	1.14	0.84	0.33
T 3								
I	111	100	64	3	5	21	21	15
C(rat)	1.00	0.63	0.45	0.03	0.02	0.03	0.02	0.01
C(at%)	45.98	28.89	20.67	1.27	0.85	1.19	0.84	0.31
T 4								
I	97	83	68	6	10	21	28	16
C(rat)	1.00	0.69	0.55	0.06	0.04	0.03	0.03	0.01
C(at%)	41.47	28.76	22.67	2.62	1.76	1.23	1.15	0.34
T 5								
I	116	103	78	4	9	21	25	26
C(rat)	1.00	0.72	0.52	0.04	0.03	0.02	0.02	0.01
C(at%)	42.23	30.39	22.14	1.49	1.35	1.05	0.88	0.47
T 6								
I	128	102	83	4	11	25	32	20
C(rat)	1.00	0.65	0.51	0.03	0.04	0.03	0.02	0.01
C(at%)	43.91	28.36	22.20	1.40	1.55	1.17	1.06	0.34
T 8								
I	155	135	118	5	11	27	43	28
C(rat)	1.00	0.71	0.59	0.03	0.03	0.02	0.03	0.01
C(at%)	41.30	29.15	24.51	1.36	1.20	0.99	1.10	0.37
T 10								
I	140	117	109	6	13	29	43	25
C(rat)	1.00	0.68	0.61	0.04	0.04	0.03	0.03	0.01
C(at%)	41.10	27.84	24.95	1.80	1.57	1.17	1.21	0.37
T 12								
I	136	128	110	7	15	28	40	26
C(rat)	1.00	0.76	0.63	0.05	0.05	0.03	0.03	0.01
C(at%)	39.10	29.83	24.66	2.06	1.77	1.10	1.11	0.37

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T 14								
I	152	122	124	7	18	30	42	30
C(rat)	1.00	0.65	0.64	0.05	0.05	0.03	0.03	0.01
C(at%)	40.89	26.60	26.01	1.92	1.99	1.10	1.09	0.40

T 16								
I	167	133	128	5	15	27	31	23
C(rat)	1.00	0.65	0.60	0.03	0.04	0.02	0.02	0.01
C(at%)	42.42	27.38	25.35	1.30	1.56	0.94	0.76	0.29

T 18								
I	156	119	115	5	13	25	36	28
C(rat)	1.00	0.62	0.57	0.03	0.03	0.02	0.02	0.01
C(at%)	43.23	26.73	24.85	1.42	1.48	0.95	0.96	0.39

T 20								
I	140	124	116	6	12	33	43	26
C(rat)	1.00	0.72	0.65	0.04	0.04	0.03	0.03	0.01
C(at%)	39.78	28.56	25.70	1.74	1.40	1.28	1.18	0.37

T 25								
I	133	119	104	6	11	26	37	25
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

T 30								
I	135	110	114	4	13	24	35	26
C(rat)	1.00	0.66	0.66	0.03	0.04	0.02	0.02	0.01
C(at%)	40.86	26.98	26.90	1.24	1.62	0.99	1.02	0.39

B 1								
I	122	98	60	4	11	26	19	12
C(rat)	1.00	0.65	0.38	0.03	0.04	0.03	0.01	0.00
C(at%)	46.42	30.22	17.80	1.56	1.72	1.35	0.70	0.23

B 2								
I	104	84	54	3	14	16	14	8
C(rat)	1.00	0.65	0.40	0.03	0.06	0.02	0.01	0.00
C(at%)	45.83	30.00	18.55	1.35	2.53	0.97	0.59	0.18

B 3								
I	119	91	73	4	8	20	14	15
C(rat)	1.00	0.62	0.48	0.03	0.03	0.02	0.01	0.01
C(at%)	45.44	28.16	21.73	1.56	1.25	1.05	0.51	0.29

B 4								
I	98	80	63	5	10	16	17	15
C(rat)	1.00	0.66	0.50	0.05	0.04	0.02	0.02	0.01
C(at%)	43.41	28.72	21.76	2.26	1.82	0.97	0.72	0.33

B 5								
I	117	112	77	6	12	27	20	16
C(rat)	1.00	0.78	0.51	0.05	0.04	0.03	0.02	0.01
C(at%)	41.01	31.82	21.04	2.15	1.73	1.30	0.67	0.28

B 6								
I	120	127	93	4	15	22	21	15
C(rat)	1.00	0.86	0.60	0.03	0.05	0.03	0.02	0.01
C(at%)	38.53	33.05	23.28	1.31	1.98	0.97	0.65	0.24

B 8								
I	155	144	123	5	14	28	33	19
C(rat)	1.00	0.75	0.62	0.03	0.04	0.02	0.02	0.01
C(at%)	40.11	30.20	24.82	1.32	1.49	0.99	0.82	0.25

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B 10								
I	148	133	116	6	12	29	26	20
C(rat)	1.00	0.73	0.61	0.04	0.03	0.03	0.02	0.01
C(at%)	40.57	29.55	24.79	1.68	1.35	1.09	0.69	0.27

B 12								
I	156	138	126	5	17	32	37	22
C(rat)	1.00	0.72	0.63	0.03	0.04	0.03	0.02	0.01
C(at%)	40.29	28.89	25.37	1.32	1.80	1.13	0.92	0.28

B 14								
I	156	152	130	5	15	26	30	27
C(rat)	1.00	0.79	0.65	0.03	0.04	0.02	0.02	0.01
C(at%)	39.04	30.83	25.37	1.28	1.54	0.89	0.72	0.34

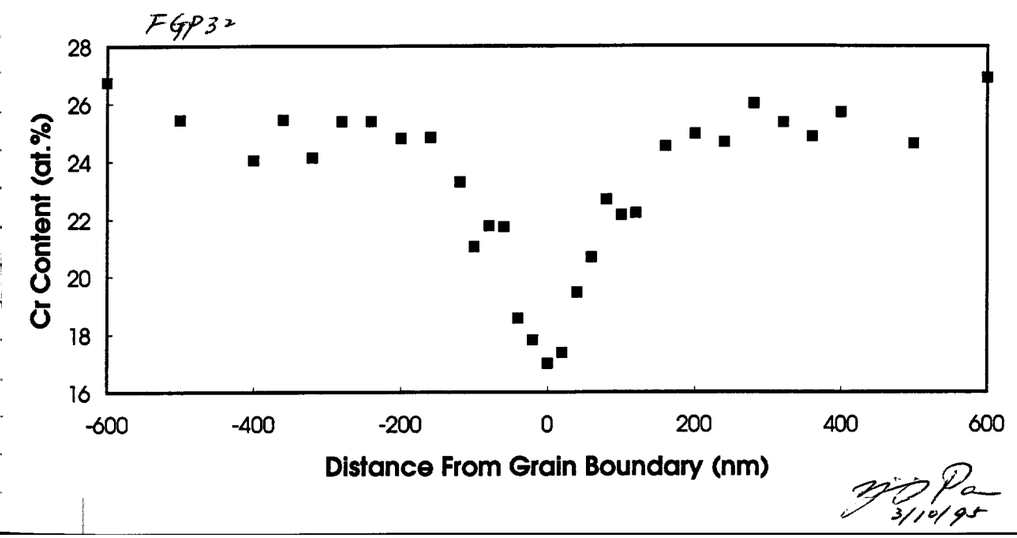
B 16								
I	186	157	136	6	15	27	28	29
C(rat)	1.00	0.68	0.57	0.03	0.03	0.02	0.01	0.01
C(at%)	42.33	28.96	24.13	1.40	1.40	0.84	0.61	0.33

B 18								
I	187	146	143	5	18	30	39	26
C(rat)	1.00	0.63	0.60	0.03	0.04	0.02	0.02	0.01
C(at%)	42.65	26.99	25.43	1.17	1.69	0.94	0.86	0.30

B 20								
I	209	166	149	6	19	36	35	28
C(rat)	1.00	0.64	0.56	0.03	0.04	0.02	0.02	0.01
C(at%)	43.24	27.83	24.03	1.27	1.61	1.02	0.70	0.29

B 25								
I	185	156	147	8	18	34	32	22
C(rat)	1.00	0.68	0.62	0.04	0.04	0.03	0.02	0.01
C(at%)	41.07	28.07	25.44	1.81	1.64	1.03	0.68	0.24

B 30								
I	197	168	170	11	20	37	41	31
C(rat)	1.00	0.69	0.67	0.06	0.04	0.03	0.02	0.01
C(at%)	39.74	27.47	26.74	2.27	1.66	1.02	0.80	0.31



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STEM Results for Final Project Report

The following figures have been prepared using the STEM data for the final project report.

Fig. 1 Effect of electropolish on chromium depletion

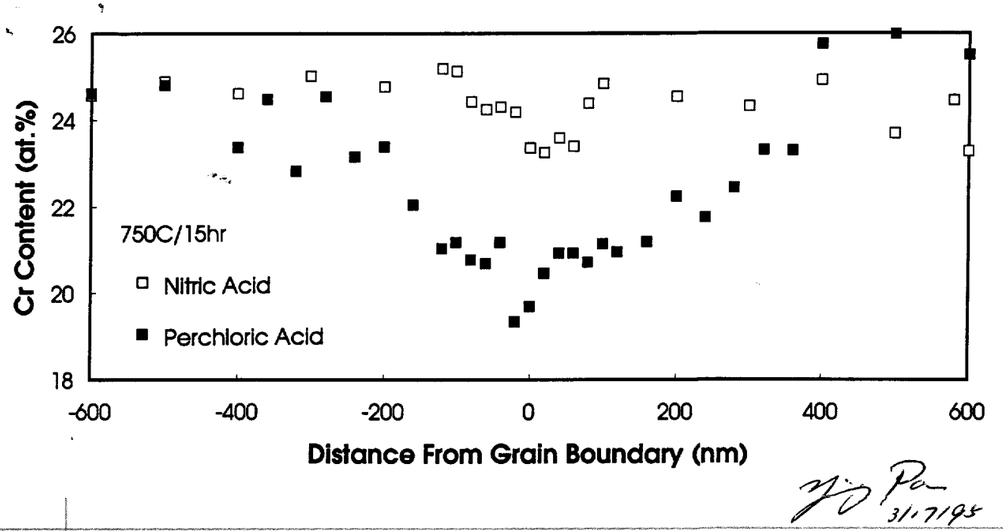

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Fig. 2 Effect of aging time period on chromium depletion

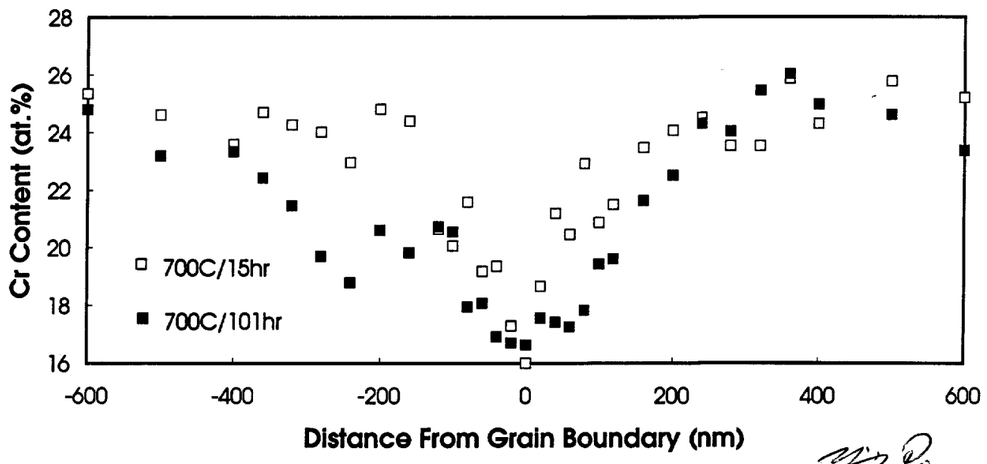

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Fig. 3 Effect of temperature on chromium depletion

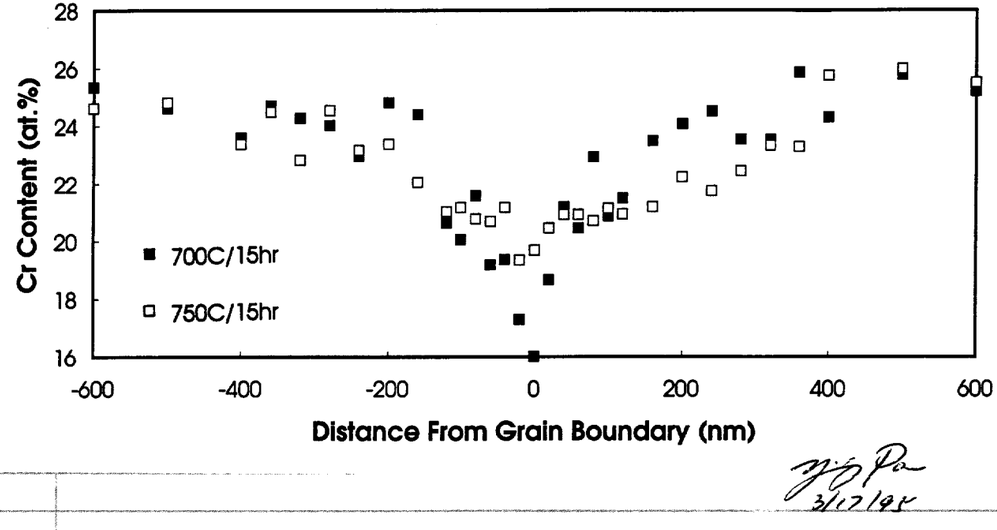

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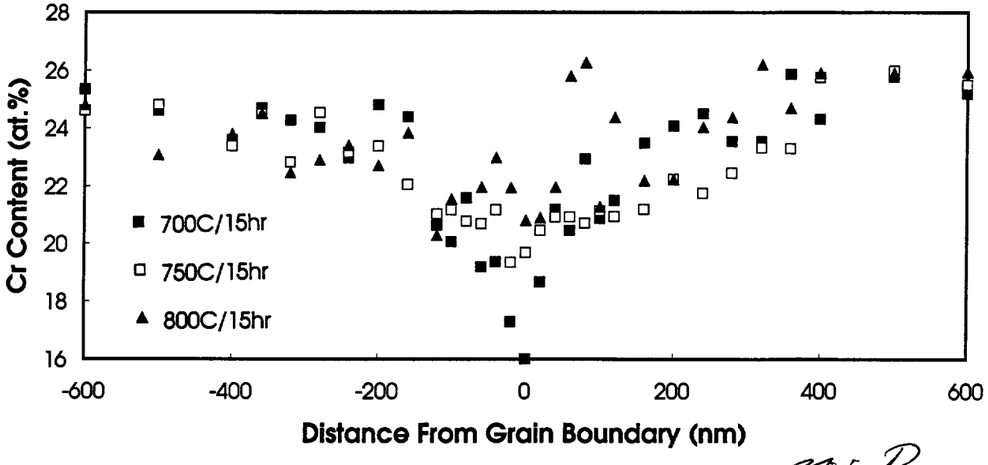
Fig. 4 Effect temperature on chromium depletion



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Chemical Profile Analysis of Sample A6b Aged at 640°C/15hr

Chemical profile was measured across a grain boundary region of thin foil A6b aged at 640°C for 15 hr and electropolished with a perchloric acid solution.

A6b	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
R 16								
I	120	102	97	5	36	20	15	12
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.85	0.75	1.11	0.11	0.16	0.21	0.09
GB								
I	113	97	80	6	30	12	7	4
C(rat)	1.00	0.73	0.53	0.06	0.03	0.02	0.01	0.00
C(at%)	41.86	30.66	22.35	2.46	1.26	0.71	0.56	0.14
R 1								
I	213	180	158	7	56	23	15	16
C(rat)	1.00	0.72	0.56	0.04	0.03	0.02	0.02	0.01
C(at%)	41.91	30.21	23.45	1.52	1.25	0.73	0.63	0.30
R 2								
I	186	159	141	6	49	33	18	18
C(rat)	1.00	0.73	0.57	0.04	0.03	0.03	0.02	0.01
C(at%)	41.24	30.08	23.58	1.47	1.23	1.18	0.85	0.38
R 3								
I	184	162	150	6	48	31	20	24
C(rat)	1.00	0.75	0.61	0.04	0.03	0.03	0.02	0.01
C(at%)	40.09	30.11	24.65	1.45	1.18	1.08	0.93	0.49
R 4								
I	186	167	150	8	46	26	19	16
C(rat)	1.00	0.77	0.61	0.05	0.03	0.02	0.02	0.01
C(at%)	39.96	30.61	24.31	1.90	1.12	0.90	0.87	0.32
R 5								
I	187	167	155	7	46	30	20	20
C(rat)	1.00	0.76	0.63	0.04	0.03	0.03	0.02	0.01
C(at%)	39.76	30.29	24.86	1.65	1.11	1.02	0.91	0.40
R 6								
I	186	166	152	7	49	33	19	18
C(rat)	1.00	0.76	0.62	0.04	0.03	0.03	0.02	0.01
C(at%)	39.86	30.35	24.57	1.66	1.19	1.14	0.87	0.36
R 8								
I	198	156	158	7	48	30	22	20
C(rat)	1.00	0.67	0.60	0.04	0.03	0.02	0.02	0.01
C(at%)	41.70	28.03	25.10	1.63	1.14	1.01	0.99	0.40
R 10								
I	177	155	145	5	43	32	21	16
C(rat)	1.00	0.75	0.62	0.03	0.03	0.03	0.03	0.01
C(at%)	40.21	30.04	24.84	1.26	1.11	1.17	1.02	0.34
R 12								
I	155	130	124	5	35	32	16	16
C(rat)	1.00	0.72	0.60	0.04	0.03	0.03	0.02	0.01
C(at%)	40.90	29.26	24.68	1.46	1.05	1.36	0.90	0.40
R 14								
I	130	114	106	6	34	26	17	16
C(rat)	1.00	0.75	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	39.75	29.74	24.45	2.03	1.18	1.28	1.11	0.46

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R 16								
I	120	102	97	5	36	20	15	12
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
R 18								
I	118	94	95	6	35	21	15	9
C(rat)	1.00	0.68	0.61	0.06	0.03	0.03	0.03	0.01
C(at%)	40.99	27.86	24.89	2.31	1.38	1.17	1.12	0.29
R 20								
I	133	116	104	5	38	27	17	11
C(rat)	1.00	0.74	0.59	0.04	0.03	0.03	0.03	0.01
C(at%)	40.40	30.06	23.83	1.68	1.31	1.32	1.11	0.31
R 25								
I	177	147	145	8	46	36	21	23
C(rat)	1.00	0.71	0.62	0.05	0.03	0.03	0.03	0.01
C(at%)	40.39	28.62	24.96	2.02	1.19	1.32	1.03	0.49
R 30								
I	157	137	124	6	45	23	24	18
C(rat)	1.00	0.74	0.60	0.04	0.03	0.02	0.03	0.01
C(at%)	40.29	29.99	24.00	1.70	1.31	0.95	1.32	0.44
L 1								
I	91	85	66	3	21	13	14	8
C(rat)	1.00	0.80	0.55	0.04	0.03	0.02	0.03	0.01
C(at%)	40.48	32.26	22.14	1.48	1.06	0.93	1.33	0.34
L 2								
I	70	68	55	3	26	13	11	8
C(rat)	1.00	0.83	0.59	0.05	0.04	0.03	0.03	0.01
C(at%)	38.68	32.06	22.92	1.83	1.63	1.15	1.30	0.42
L 3								
I	67	56	55	3	22	16	13	10
C(rat)	1.00	0.71	0.62	0.05	0.04	0.04	0.04	0.01
C(at%)	39.80	28.38	24.64	1.97	1.48	1.53	1.65	0.56
L 4								
I	62	54	50	3	20	14	10	9
C(rat)	1.00	0.74	0.61	0.05	0.04	0.04	0.03	0.01
C(at%)	39.59	29.42	24.08	2.12	1.45	1.44	1.37	0.54
L 5								
I	58	52	49	2	20	12	10	10
C(rat)	1.00	0.76	0.64	0.04	0.04	0.03	0.04	0.02
C(at%)	38.98	29.81	24.84	1.49	1.52	1.30	1.44	0.63
L 6								
I	65	50	53	3	15	9	14	8
C(rat)	1.00	0.66	0.61	0.05	0.03	0.02	0.05	0.01
C(at%)	41.18	27.02	25.33	2.10	1.08	0.92	1.90	0.48
L 8								
I	69	49	57	5	18	15	14	9
C(rat)	1.00	0.61	0.62	0.08	0.03	0.03	0.04	0.01
C(at%)	41.17	25.12	25.84	3.32	1.22	1.45	1.80	0.51
L 10								
I	62	50	52	2	21	13	11	6
C(rat)	1.00	0.69	0.63	0.04	0.04	0.03	0.04	0.01
C(at%)	40.40	27.80	25.56	1.44	1.55	1.36	1.53	0.37

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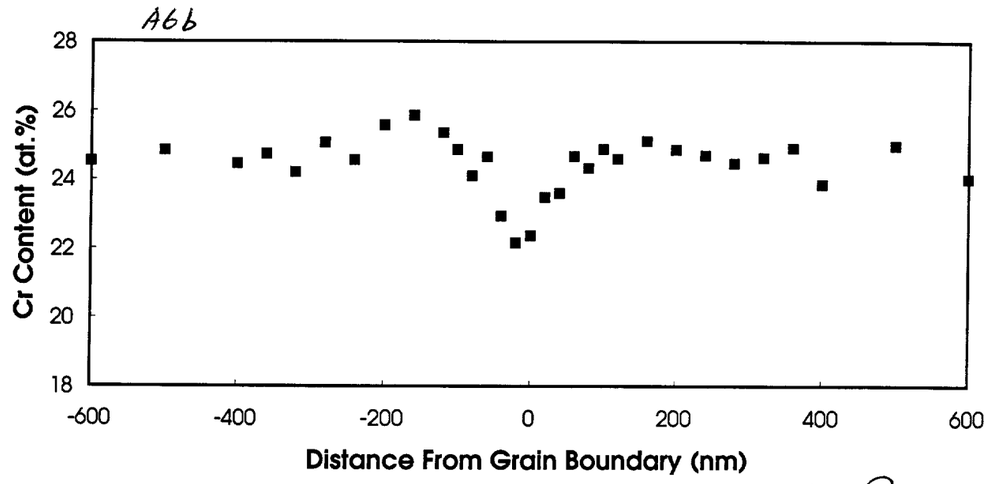
L 12								
I	68	57	56	4	23	15	14	8
C(rat)	1.00	0.72	0.62	0.07	0.04	0.04	0.04	0.01
C(at%)	39.52	28.26	24.55	2.57	1.51	1.40	1.74	0.44
L 14								
I	63	51	52	3	19	14	11	8
C(rat)	1.00	0.69	0.62	0.05	0.03	0.04	0.04	0.01
C(at%)	40.24	27.79	25.05	2.12	1.37	1.44	1.50	0.48
L 16								
I	61	52	49	3	22	12	10	6
C(rat)	1.00	0.73	0.61	0.05	0.04	0.03	0.04	0.01
C(at%)	39.93	29.04	24.19	2.17	1.63	1.26	1.40	0.37
L 18								
I	61	53	51	3	20	14	11	8
C(rat)	1.00	0.74	0.63	0.05	0.04	0.04	0.04	0.01
C(at%)	39.20	29.06	24.72	2.13	1.45	1.44	1.51	0.48
L 20								
I	57	48	46	2	18	12	11	8
C(rat)	1.00	0.72	0.61	0.04	0.04	0.03	0.04	0.01
C(at%)	40.16	28.85	24.44	1.56	1.44	1.36	1.66	0.53
L 25								
I	57	49	48	3	21	13	10	9
C(rat)	1.00	0.73	0.64	0.06	0.04	0.04	0.04	0.01
C(at%)	39.10	28.68	24.83	2.28	1.63	1.43	1.47	0.58
L 30								
I	51	45	42	2	16	9	10	6
C(rat)	1.00	0.75	0.62	0.04	0.04	0.03	0.04	0.01
C(at%)	39.46	29.70	24.51	1.71	1.40	1.12	1.66	0.44

A6b



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Second profile for thin foil A6a aged at 640°C for 1 hr.

A6a2	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
R 30								
I	68	74	69	6	38	25	20	13
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.67	0.60	0.52	0.06	0.07	0.09	0.05
GB								
I	55	51	40	2	27	8	10	4
C(rat)	1.00	0.62	0.44	0.02	0.03	0.01	0.02	0.00
C(at%)	46.85	28.95	20.47	0.89	1.40	0.50	0.78	0.17
R 1								
I	64	60	49	4	39	16	14	9
C(rat)	1.00	0.62	0.46	0.03	0.04	0.02	0.02	0.01
C(at%)	45.47	28.41	20.92	1.48	1.68	0.83	0.91	0.31
R 2								
I	71	67	56	6	43	21	17	12
C(rat)	1.00	0.63	0.47	0.04	0.04	0.02	0.02	0.01
C(at%)	44.74	28.13	21.20	1.98	1.65	0.96	0.97	0.37
R 3								
I	61	59	54	5	36	19	15	10
C(rat)	1.00	0.64	0.53	0.04	0.04	0.02	0.02	0.01
C(at%)	43.32	27.92	23.04	1.86	1.55	0.98	0.97	0.35
R 4								
I	66	62	63	6	41	23	21	12
C(rat)	1.00	0.63	0.57	0.05	0.04	0.03	0.03	0.01
C(at%)	42.59	26.66	24.43	2.02	1.61	1.08	1.23	0.38
R 5								
I	67	66	68	5	39	21	19	13
C(rat)	1.00	0.66	0.61	0.04	0.04	0.02	0.03	0.01
C(at%)	41.69	27.37	25.42	1.63	1.47	0.95	1.08	0.40
R 6								
I	66	65	64	5	35	21	17	13
C(rat)	1.00	0.66	0.58	0.04	0.03	0.02	0.02	0.01
C(at%)	42.25	27.73	24.62	1.67	1.36	0.98	0.99	0.41
R 8								
I	61	62	59	4	32	19	17	11
C(rat)	1.00	0.68	0.58	0.03	0.03	0.02	0.03	0.01
C(at%)	41.99	28.44	24.40	1.44	1.34	0.95	1.06	0.37
R 10								
I	62	64	62	5	34	17	15	12
C(rat)	1.00	0.69	0.60	0.04	0.03	0.02	0.02	0.01
C(at%)	41.40	28.48	24.87	1.74	1.38	0.83	0.91	0.39
R 12								
I	60	62	61	5	31	19	16	12
C(rat)	1.00	0.69	0.61	0.04	0.03	0.02	0.02	0.01
C(at%)	41.13	28.32	25.12	1.79	1.29	0.95	1.00	0.41
R 14								
I	60	67	64	5	32	23	20	15
C(rat)	1.00	0.74	0.64	0.04	0.03	0.03	0.03	0.01
C(at%)	39.50	29.39	25.31	1.72	1.28	1.10	1.20	0.49

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R 16								
I	66	70	68	7	38	25	21	13
C(rat)	1.00	0.71	0.62	0.06	0.03	0.03	0.03	0.01
C(at%)	40.28	28.47	24.93	2.23	1.41	1.11	1.17	0.39
R 18								
I	74	76	73	9	45	27	23	15
C(rat)	1.00	0.68	0.59	0.06	0.04	0.03	0.03	0.01
C(at%)	40.94	28.02	24.27	2.60	1.51	1.09	1.16	0.41
R 20								
I	58	64	60	5	31	21	16	12
C(rat)	1.00	0.74	0.62	0.05	0.03	0.03	0.03	0.01
C(at%)	40.06	29.46	24.90	1.80	1.30	1.06	1.01	0.41
R 25								
I	67	71	68	6	36	26	19	13
C(rat)	1.00	0.71	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.67	28.72	24.80	1.90	1.33	1.15	1.05	0.39
R 30								
I	68	74	69	6	38	25	20	13
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
L 1								
I	48	48	37	2	23	12	11	7
C(rat)	1.00	0.67	0.46	0.02	0.03	0.02	0.02	0.01
C(at%)	44.91	29.93	20.80	0.98	1.31	0.82	0.94	0.32
L 2								
I	42	36	34	2	27	12	8	6
C(rat)	1.00	0.57	0.49	0.02	0.04	0.02	0.02	0.01
C(at%)	46.15	26.36	22.45	1.15	1.80	0.96	0.80	0.32
L 3								
I	39	29	35	2	24	14	7	7
C(rat)	1.00	0.50	0.54	0.03	0.04	0.03	0.02	0.01
C(at%)	46.51	23.05	25.08	1.25	1.74	1.22	0.76	0.41
L 4								
I	37	35	36	2	23	10	10	5
C(rat)	1.00	0.63	0.58	0.03	0.04	0.02	0.02	0.01
C(at%)	42.88	27.03	25.07	1.21	1.62	0.84	1.05	0.29
L 5								
I	31	32	30	2	18	13	8	8
C(rat)	1.00	0.69	0.58	0.03	0.04	0.03	0.02	0.01
C(at%)	41.58	28.60	24.18	1.40	1.47	1.27	0.98	0.53
L 6								
I	32	32	30	2	22	12	5	8
C(rat)	1.00	0.67	0.56	0.03	0.04	0.03	0.01	0.01
C(at%)	42.41	28.08	23.74	1.38	1.76	1.15	0.60	0.52
L 8								
I	36	40	35	1	27	12	9	10
C(rat)	1.00	0.74	0.58	0.01	0.05	0.02	0.02	0.01
C(at%)	40.89	30.27	23.89	0.59	1.86	0.99	0.93	0.56
L 10								
I	29	25	27	1	24	10	11	9
C(rat)	1.00	0.57	0.56	0.02	0.05	0.03	0.03	0.02
C(at%)	43.92	25.23	24.57	0.79	2.21	1.10	1.52	0.67

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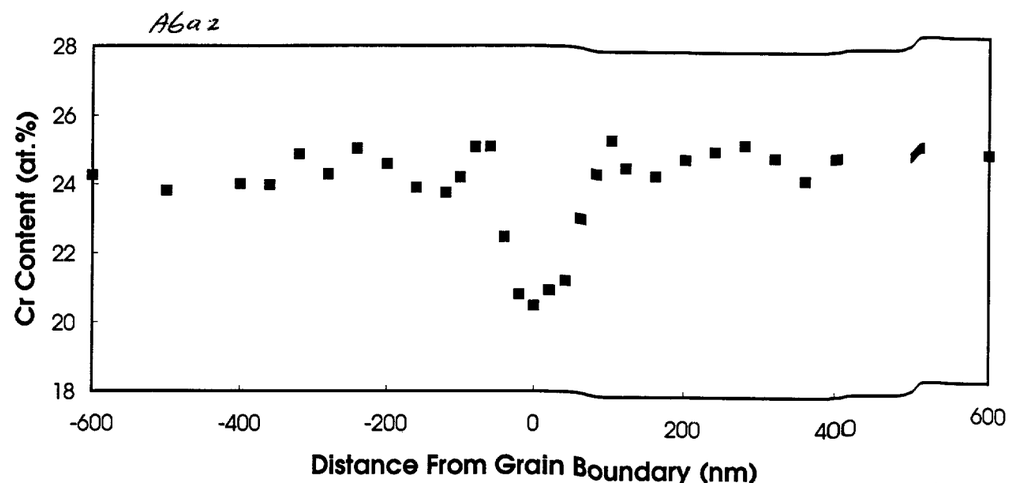
L 12								
I	30	32	31	2	22	12	9	8
C(rat)	1.00	0.71	0.62	0.03	0.04	0.03	0.03	0.01
C(at%)	40.31	28.65	25.03	1.40	1.80	1.17	1.10	0.53
L 14								
I	29	30	28	1	19	10	8	7
C(rat)	1.00	0.69	0.58	0.02	0.04	0.03	0.03	0.01
C(at%)	41.85	28.85	24.28	0.75	1.67	1.05	1.05	0.50
L 16								
I	26	29	27	1	18	12	9	8
C(rat)	1.00	0.74	0.62	0.02	0.04	0.03	0.03	0.02
C(at%)	39.85	29.62	24.86	0.80	1.68	1.34	1.26	0.60
L 18								
I	29	32	29	2	22	16	11	9
C(rat)	1.00	0.74	0.60	0.04	0.05	0.04	0.03	0.02
C(at%)	39.87	29.32	23.96	1.44	1.84	1.60	1.38	0.61
L 20								
I	25	30	26	2	21	16	8	6
C(rat)	1.00	0.80	0.62	0.04	0.05	0.05	0.03	0.01
C(at%)	38.39	30.70	23.99	1.60	1.96	1.79	1.12	0.45
L 25								
I	26	32	27	2	22	14	9	8
C(rat)	1.00	0.82	0.62	0.04	0.05	0.04	0.03	0.02
C(at%)	38.15	31.29	23.80	1.53	1.96	1.50	1.20	0.58
L 30								
I	22	25	23	2	20	15	9	7
C(rat)	1.00	0.76	0.63	0.05	0.06	0.05	0.04	0.02
C(at%)	38.60	29.23	24.25	1.83	2.13	1.92	1.44	0.61



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Chemical Profile Analysis of 1 Sample FP3 ~~Aged at 750°C/1 hr~~ solution-annealed 1 hr/WQ

Preliminary chemical analysis was performed on the ~~750°C/1 hr aged~~ solution-annealed thin foil FP3 electropolished with a perchloric acid solution.

Samp FP3	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
T 21								
I	263	233	223	8	31	31	18	19
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.82	0.72	1.52	0.29	0.23	0.39	0.13
GB 1								
I	288	234	191	7	22	20	19	11
C(rat)	1.00	0.67	0.48	0.04	0.02	0.02	0.03	0.00
C(at%)	44.50	29.59	21.22	1.64	0.98	0.70	1.15	0.22
GB 2								
I	271	218	197	7	31	39	30	24
C(rat)	1.00	0.66	0.52	0.04	0.03	0.03	0.04	0.01
C(at%)	42.72	28.13	22.33	1.67	1.41	1.40	1.85	0.49
GB 3								
I	249	222	206	6	22	37	26	26
C(rat)	1.00	0.73	0.59	0.04	0.03	0.03	0.04	0.01
C(at%)	40.41	29.49	24.04	1.48	1.03	1.36	1.65	0.55
T 1								
I	297	254	211	10	28	18	27	12
C(rat)	1.00	0.70	0.51	0.05	0.03	0.01	0.04	0.01
C(at%)	42.67	29.87	21.80	2.18	1.16	0.59	1.52	0.22
T 2								
I	306	235	217	8	25	15	24	14
C(rat)	1.00	0.63	0.51	0.04	0.02	0.01	0.03	0.01
C(at%)	44.46	27.95	22.67	1.76	1.05	0.49	1.36	0.27
T 5								
I	342	261	248	13	27	24	22	15
C(rat)	1.00	0.62	0.52	0.06	0.02	0.02	0.03	0.01
C(at%)	43.99	27.48	22.94	2.53	1.00	0.70	1.11	0.25
T 10								
I	314	273	236	11	25	30	22	18
C(rat)	1.00	0.71	0.54	0.05	0.02	0.02	0.03	0.01
C(at%)	41.93	29.84	22.66	2.23	0.96	0.91	1.15	0.31
T 20								
I	277	252	244	10	30	28	21	16
C(rat)	1.00	0.74	0.63	0.05	0.03	0.02	0.03	0.01
C(at%)	39.62	29.50	25.09	2.17	1.24	0.91	1.17	0.30
T 21								
I	263	233	223	8	31	31	18	19
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
T 29								
I	216	229	204	6	24	31	19	12
C(rat)	1.00	0.87	0.68	0.04	0.03	0.03	0.03	0.01
C(at%)	37.10	32.19	25.19	1.56	1.19	1.21	1.28	0.27
T 30								
I	224	223	204	7	20	29	23	16
C(rat)	1.00	0.81	0.65	0.05	0.03	0.03	0.04	0.01
C(at%)	38.14	31.08	24.97	1.81	0.98	1.12	1.53	0.36

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B 1								
I	180	165	138	8	14	20	18	18
C(rat)	1.00	0.75	0.55	0.07	0.02	0.03	0.04	0.01
C(at%)	40.51	30.40	22.33	2.73	0.91	1.02	1.58	0.53
B 2								
I	177	153	132	6	17	23	19	15
C(rat)	1.00	0.71	0.54	0.05	0.03	0.03	0.04	0.01
C(at%)	41.57	29.41	22.29	2.14	1.15	1.23	1.75	0.46
B 5								
I	178	153	136	6	17	27	20	11
C(rat)	1.00	0.70	0.55	0.05	0.03	0.03	0.04	0.01
C(at%)	41.36	29.10	22.72	2.11	1.14	1.42	1.82	0.33
B 10								
I	232	205	167	5	19	36	26	22
C(rat)	1.00	0.72	0.52	0.03	0.02	0.04	0.04	0.01
C(at%)	41.87	30.28	21.67	1.37	0.99	1.48	1.84	0.52
B 20								
I	266	237	214	7	25	40	26	19
C(rat)	1.00	0.73	0.58	0.04	0.03	0.03	0.04	0.01
C(at%)	40.71	29.69	23.55	1.62	1.10	1.39	1.56	0.38
B 30								
I	195	165	144	6	19	30	20	19
C(rat)	1.00	0.69	0.53	0.05	0.03	0.03	0.04	0.01
C(at%)	41.91	29.03	22.25	1.95	1.18	1.46	1.68	0.53

FD Po
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First chromium depletion profile. (FP31)

Samp FP31	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
B 20								
I	266	237	214	7	25	40	26	19
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.52	24.82	1.88	1.38	1.09	1.09	0.38
k	1.00	0.81	0.76	1.75	0.36	0.18	0.27	0.13
GB 1								
I	288	234	191	7	22	20	19	11
C(rat)	1.00	0.66	0.50	0.04	0.03	0.01	0.02	0.01
C(at%)	44.06	29.14	22.14	1.88	1.22	0.54	0.80	0.22
GB 2								
I	271	218	197	7	31	39	30	24
C(rat)	1.00	0.65	0.55	0.05	0.04	0.03	0.03	0.01
C(at%)	42.38	27.75	23.35	1.92	1.75	1.09	1.28	0.49
GB 3								
I	249	222	206	6	22	37	26	26
C(rat)	1.00	0.73	0.63	0.04	0.03	0.03	0.03	0.01
C(at%)	40.07	29.08	25.12	1.69	1.28	1.06	1.15	0.55
T 1								
I	297	254	211	10	28	18	27	12
C(rat)	1.00	0.70	0.54	0.06	0.03	0.01	0.02	0.01
C(at%)	42.22	29.39	22.73	2.49	1.44	0.46	1.05	0.22
T 2								
I	306	235	217	8	25	15	24	14
C(rat)	1.00	0.63	0.54	0.05	0.03	0.01	0.02	0.01
C(at%)	43.98	27.49	23.63	2.01	1.30	0.38	0.94	0.27
T 5								
I	342	261	248	13	27	24	22	15
C(rat)	1.00	0.62	0.55	0.07	0.03	0.01	0.02	0.01
C(at%)	43.45	26.99	23.88	2.89	1.24	0.54	0.77	0.25
T 10								
I	314	273	236	11	25	30	22	18
C(rat)	1.00	0.71	0.57	0.06	0.03	0.02	0.02	0.01
C(at%)	41.48	29.35	23.63	2.55	1.19	0.71	0.80	0.31
T 20								
I	277	252	244	10	30	28	21	16
C(rat)	1.00	0.74	0.67	0.06	0.04	0.02	0.02	0.01
C(at%)	39.11	28.96	26.11	2.47	1.53	0.70	0.81	0.30
T 21								
I	263	233	223	8	31	31	18	19
C(rat)	1.00	0.72	0.64	0.05	0.04	0.02	0.02	0.01
C(at%)	39.86	28.74	25.61	2.12	1.70	0.84	0.75	0.38
T 29								
I	216	229	204	6	24	31	19	12
C(rat)	1.00	0.86	0.72	0.05	0.04	0.03	0.02	0.01
C(at%)	36.71	31.68	26.27	1.79	1.47	0.94	0.88	0.27
T 30								
I	224	223	204	7	20	29	23	16
C(rat)	1.00	0.81	0.69	0.05	0.03	0.02	0.03	0.01
C(at%)	37.76	30.60	26.06	2.07	1.22	0.87	1.06	0.36

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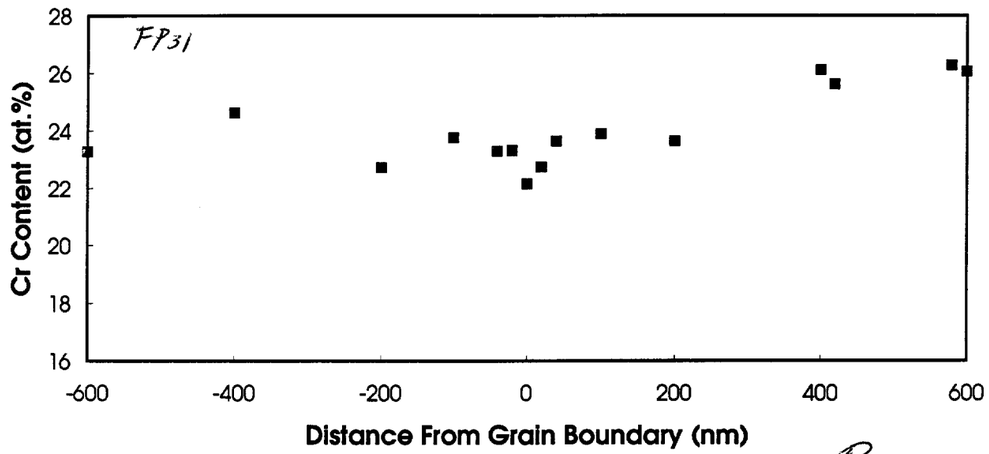
B 1								
I	180	165	138	8	14	20	18	18
C(rat)	1.00	0.75	0.58	0.08	0.03	0.02	0.03	0.01
C(at%)	40.11	29.92	23.30	3.12	1.13	0.79	1.10	0.53
B 2								
I	177	153	132	6	17	23	19	15
C(rat)	1.00	0.70	0.57	0.06	0.03	0.02	0.03	0.01
C(at%)	41.21	28.99	23.29	2.45	1.43	0.95	1.21	0.46
B 5								
I	178	153	136	6	17	27	20	11
C(rat)	1.00	0.70	0.58	0.06	0.03	0.03	0.03	0.01
C(at%)	41.02	28.70	23.75	2.42	1.42	1.11	1.26	0.33
B 10								
I	232	205	167	5	19	36	26	22
C(rat)	1.00	0.72	0.55	0.04	0.03	0.03	0.03	0.01
C(at%)	41.62	29.93	22.70	1.57	1.23	1.15	1.28	0.52
B 20								
I	266	237	214	7	25	40	26	19
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
B 30								
I	195	165	144	6	19	30	20	19
C(rat)	1.00	0.69	0.56	0.05	0.04	0.03	0.03	0.01
C(at%)	41.57	28.63	23.26	2.24	1.46	1.14	1.17	0.53



YP 4/21/95

Second chromium profile: (FP32)

Samp FP32	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
B 20								
I	230	185	188	6	22	35	24	20
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.90	0.75	1.77	0.35	0.18	0.26	0.11
GB 1								
I	164	140	139	6	17	19	23	11
C(rat)	1.00	0.77	0.63	0.06	0.04	0.02	0.04	0.01
C(at%)	38.96	29.98	24.63	2.52	1.43	0.79	1.40	0.28
GB 2								
I	120	106	95	6	15	16	17	8
C(rat)	1.00	0.80	0.59	0.09	0.04	0.02	0.04	0.01
C(at%)	38.66	30.79	22.83	3.42	1.72	0.91	1.40	0.28
GB 3								
I	115	104	92	6	11	24	15	14
C(rat)	1.00	0.82	0.60	0.09	0.03	0.04	0.03	0.01
C(at%)	38.15	31.10	22.76	3.52	1.30	1.40	1.28	0.50
T 1								
I	163	144	137	7	16	22	13	9
C(rat)	1.00	0.80	0.63	0.08	0.03	0.02	0.02	0.01
C(at%)	38.70	30.82	24.26	2.94	1.35	0.92	0.79	0.23
T 2								
I	157	140	131	6	16	19	16	11
C(rat)	1.00	0.80	0.62	0.07	0.04	0.02	0.03	0.01
C(at%)	38.68	31.10	24.07	2.61	1.40	0.82	1.01	0.29
T 5								
I	179	159	159	6	19	29	23	13
C(rat)	1.00	0.80	0.66	0.06	0.04	0.03	0.03	0.01
C(at%)	38.03	30.45	25.20	2.25	1.43	1.08	1.25	0.30
T 10								
I	179	170	156	8	18	28	23	17
C(rat)	1.00	0.86	0.65	0.08	0.04	0.03	0.03	0.01
C(at%)	37.15	31.81	24.15	2.93	1.33	1.02	1.22	0.38
T 20								
I	195	189	160	8	25	31	18	17
C(rat)	1.00	0.87	0.61	0.07	0.05	0.03	0.02	0.01
C(at%)	37.53	32.79	22.97	2.72	1.71	1.05	0.89	0.35
T 30								
I	215	182	169	6	27	26	20	19
C(rat)	1.00	0.76	0.59	0.05	0.04	0.02	0.02	0.01
C(at%)	40.03	30.55	23.47	1.97	1.78	0.85	0.96	0.38
B 1								
I	174	147	136	8	20	22	12	11
C(rat)	1.00	0.76	0.58	0.08	0.04	0.02	0.02	0.01
C(at%)	39.79	30.31	23.20	3.23	1.62	0.83	0.70	0.27
B 2								
I	172	154	135	9	15	25	15	15
C(rat)	1.00	0.81	0.59	0.09	0.03	0.03	0.02	0.01
C(at%)	38.84	31.35	22.74	3.59	1.20	1.03	0.87	0.37

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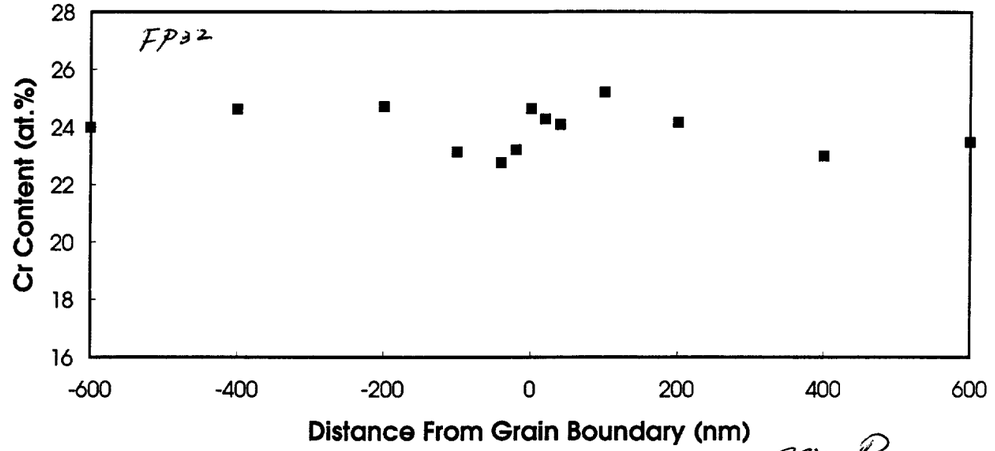
B 5								
I	192	161	149	7	23	28	21	14
C(rat)	1.00	0.76	0.58	0.06	0.04	0.03	0.03	0.01
C(at%)	39.95	30.20	23.12	2.57	1.70	1.02	1.12	0.32
B 10								
I	172	149	146	5	16	26	19	15
C(rat)	1.00	0.78	0.63	0.05	0.03	0.03	0.03	0.01
C(at%)	39.02	30.47	24.70	2.00	1.29	1.04	1.11	0.37
B 20								
I	230	185	188	6	22	35	24	20
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
B 30								
I	255	246	219	8	26	45	28	22
C(rat)	1.00	0.87	0.64	0.06	0.04	0.03	0.03	0.01
C(at%)	37.45	32.57	23.99	2.08	1.36	1.16	1.05	0.35

4/28/95



4/28/95

Review of Electropolish Solution

The use of perchloric acid as electropolish solution was reviewed. Three references were evaluated below. A solution of 60% methanol, 34% ethylene glycol and 6% perchloric acid was selected for thin foil preparation.

Material	Electrolyte / Method	Reference
Ni-16Cr-9Fe alloys (Inconel 600)	Jet polished 10% perchloric acid 70% methanol 20% ethylene glycol	Was and Kruger. Acta Metall., 33(5) 841-854 (1985)
304L stainless steels	Jet polisher 20 v/o perchloric acid in ethanol @ 120 V / -55°C	Carter et al., J. Nucl. Mater. 211, 77-84 (1994)
316LN stainless steels	Jet polisher 20% perchloric acid in methanol @ 25 V / 10-20 mA	Hall and Briant Metall. Trans., 15A, 793-811 (1984).

YDP 5/5/95

TEM Thin Foil Preparation Using Struers Tenupol-3 Jet Polisher

Electrolyte:

- 60 ml perchloric acid
- 300 ml Ethylene glycol
- 600 ml Methanol

Polishing conditions:

-60°C / 100 hr

#1	15 V	#2	15 V
	0.03 A		0.03 A
	-27°C		-23°C
	13 min		12 min
	Sensitivity 10		Sensitivity 6

#3 15 V
0.2 A
-15°C
11 min
Sensitivity 10

-70°C / 100 hr

#1	15 V	#2	15 V
	0.2 A		0.2 A
	-30°C		-15°C
	14 min		11 min

#3 15 V
0.2 A
-40°C
10 min

Observation: the thin foils were well-polished as indicated by mirror-like surfaces but no thin area was observed.

YDP 6/2/95

Discussion of Electrolytic Thinning Process

TO: Dr. ~~Ann Ginyon~~ Anne Guesnier, Struers	**FROM: Yi-Ming Pan** **June 8, 1995**
FAX NO. 011-45-31416544	**FAX NO. 210/522-5122**
PHONE NO. 011-45-36708090	**PHONE NO. 210/522-3781**
	E-mail ypan@swri.edu

Dear Dr. ~~Ginyon~~ Guesnier: (I apologized if I misspelled your name!)

Per my recent conversation with Mr. Bill Thompson, Regional Sales Manager of the Division of Radiometer American Inc. of Struers, I was referred to you to have your technical support on an equipment-on-trial of Tenupol-3. It's my pleasure to have your assistance and I was told that you are the expert of the Struers Tenupol apparatus for electrolytic thinning. Should I describe the experimental details in the following and have your recommendations for further evaluation.

In this trial, alloy 825, a Ni-Fe-Cr-Mo alloy, was selected with the purpose of thin foils preparation for transmission electron microscopy analysis. A solution of 60% methanol, 34% ethylene glycol and 6% perchloric acid was used, which I have success in preparing TEM thin foils previously using an "old" Fischione jet polisher. The Tenupol-3 equipment was calibrated according to the basic adjustment of flowrate as well as photo sensitivity specified in the manual. Then discs of 3 mm diameter and approximately 0.4 mm in thickness were thinned under the operation conditions of 15 V, 0.2 to 0.5 A and -15° to -40° C. The outcome discs were well-polished, indicating an appropriate operation condition; however, no thin area is present. I have tried to slow down the polishing process by adjusting temperature and flowrate, but no significant improvement was made.

Some of my observations may provide clues as to how the polishing defaces were resulted. During the experiments, an intermittent jet flow was noticed judging from the motor sound. In addition, the starting disc thickness was much thicker than what I used in the past (0.4 mm vs. 0.1 mm) in an attempt to reduce the sample preparation time. Hopefully, the above information is enough for you to find remedies.

I can be reached as listed above. Thank you for your assistance.

Very truly yours,

Yi Pan

Yi-Ming Pan, Ph.D.
Southwest Research Institute
San Antonio, Texas
U.S.A.

Yi Pan 6/8/95

Recommendations from Struers Expert

Re. Preparation of alloy 825 on Tenupol-3/your fax dated June 8, 1995

Dear Sir,

I have attentively read your telefax. As the outcome discs are well-polished using the process you described it seems to me, as you mentioned it, that the operation conditions are appropriate. However, I hope that the following recommendations will give you the possibility to improve the thinning results:

1. Temperature of the electrolyte:

Our experience shows that the lower the temperature of the electrolyte is set, the more suitable will be the results obtained generally. However, the electrolyte should not get too thick. I could imagine that the electrolyte you use is quite thick at - 40 degrees celsius (because of its large content of ethylene glycol). I would recommend that you keep the temperature at around -15 degrees celsius during your first trials developing an appropriate preparation method.

2. Regulation of the flowrate:

An intermittent jet flow can indicate, among other things, that the electrolyte is too thick or that the selected flowrate is two low.
- The electrolyte is too thick: see the previous chapter.
- The selected flowrate is two low: After having calibrated Tenupol-3, according to the basic adjustment of flowrate, trials should be carried out with a flowrate varying between 20 and 80 mm. The first trials should be carried out with a flowrate of 80 mm and if this is too high, it should be reduced by steps of 20 mm.

3. Photo sensitivity:

It is usually best to get a hole as small as possible therefore, the highest photo sensitivity is usually used placing the adjusting knob for photo sensitivity on Pos. 10.

4. Thickness of the starting disc:

The best thinning results are obtained with the thinnest starting disc. I would recommend that you again use starting discs of a thickness of 0.1 mm during your first trials developing an appropriate preparation method.

5. You will find enclosed a list of several electrolytes for nickel and nickel alloys which could also be of help. Trials would have to be carried out in order to optimize the voltage and the flow rate.

I hope that this information will of help.

Best Regards
Struers A/S

Anne Guesnier
Tel +45 38 27 37 22

Yi Pan 6/12/95

Chemical Profile Analysis for 1638°C/1000hr Specimens

Profile A1000a

A1000a	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
R 30								
I	2044	2105	2103	89	196	240	82	46
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.70	0.59	1.06	0.35	0.23	0.67	0.42
GB								
I	175	155	145	12	18	28	18	11
C(rat)	1.00	0.62	0.49	0.07	0.04	0.04	0.07	0.03
C(at%)	42.46	26.48	20.85	3.08	1.55	1.55	2.91	1.12
R 1								
I	157	131	129	7	16	24	13	10
C(rat)	1.00	0.59	0.49	0.05	0.04	0.03	0.06	0.03
C(at%)	43.97	25.83	21.41	2.08	1.59	1.53	2.43	1.17
R 2								
I	128	119	117	7	17	19	16	6
C(rat)	1.00	0.65	0.54	0.06	0.05	0.03	0.08	0.02
C(at%)	41.02	26.85	22.22	2.37	1.93	1.39	3.42	0.80
R 3								
I	139	122	123	9	19	24	15	10
C(rat)	1.00	0.62	0.52	0.07	0.05	0.04	0.07	0.03
C(at%)	41.65	25.74	21.84	2.85	2.02	1.64	3.00	1.25
R 4								
I	114	103	109	6	14	18	10	9
C(rat)	1.00	0.64	0.57	0.06	0.04	0.04	0.06	0.03
C(at%)	41.16	26.19	23.32	2.29	1.79	1.48	2.41	1.36
R 5								
I	125	116	119	9	21	19	10	5
C(rat)	1.00	0.65	0.56	0.08	0.06	0.03	0.05	0.02
C(at%)	40.68	26.58	22.95	3.10	2.42	1.41	2.17	0.68
R 6								
I	113	104	100	8	14	22	10	6
C(rat)	1.00	0.65	0.52	0.07	0.04	0.04	0.06	0.02
C(at%)	41.38	26.82	21.70	3.10	1.82	1.84	2.44	0.92
R 8								
I	176	167	161	8	18	31	19	9
C(rat)	1.00	0.67	0.54	0.05	0.04	0.04	0.07	0.02
C(at%)	41.18	27.51	22.32	1.98	1.49	1.65	2.97	0.88
R 10								
I	187	168	160	8	23	27	15	12
C(rat)	1.00	0.63	0.51	0.05	0.04	0.03	0.05	0.03
C(at%)	42.70	27.01	21.65	1.93	1.86	1.41	2.29	1.15
R 12								
I	252	242	240	13	27	40	17	14
C(rat)	1.00	0.68	0.56	0.05	0.04	0.04	0.05	0.02
C(at%)	41.03	27.74	23.16	2.24	1.56	1.48	1.85	0.95

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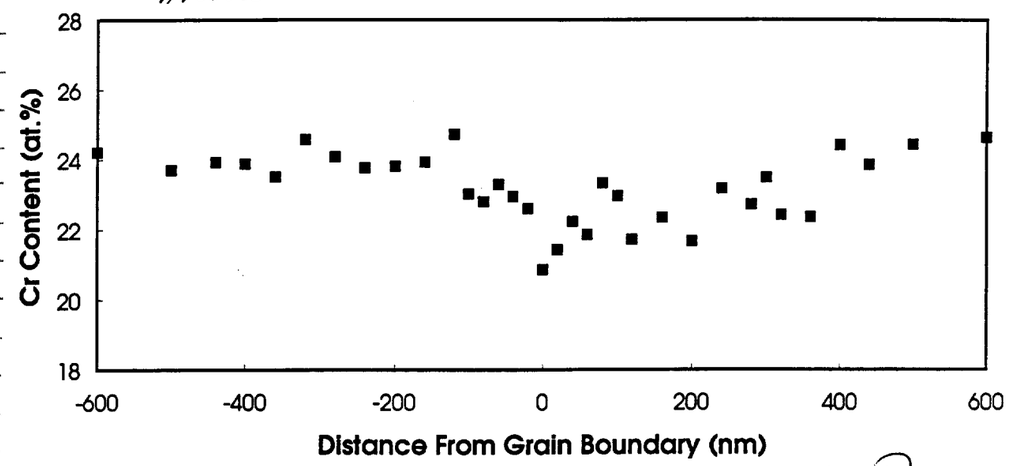
R 14								
I	371	338	333	18	45	45	18	14
C(rat)	1.00	0.64	0.53	0.05	0.04	0.03	0.03	0.02
C(at%)	42.67	27.37	22.69	2.19	1.83	1.18	1.38	0.67
R 15								
I	380	342	356	16	48	47	22	19
C(rat)	1.00	0.63	0.56	0.04	0.04	0.03	0.04	0.02
C(at%)	42.27	26.79	23.47	1.88	1.89	1.19	1.63	0.88
R 16								
I	493	468	444	24	53	66	31	22
C(rat)	1.00	0.67	0.53	0.05	0.04	0.03	0.04	0.02
C(at%)	41.97	28.05	22.40	2.16	1.60	1.28	1.76	0.78
R 18								
I	589	591	538	28	68	68	31	31
C(rat)	1.00	0.71	0.54	0.05	0.04	0.03	0.04	0.02
C(at%)	41.28	29.17	22.34	2.08	1.69	1.09	1.45	0.91
R 20								
I	1101	967	1062	52	103	166	39	31
C(rat)	1.00	0.62	0.57	0.05	0.03	0.03	0.02	0.01
C(at%)	42.68	26.40	24.39	2.13	1.41	1.47	1.01	0.50
R 22								
I	1134	1104	1098	48	105	122	56	36
C(rat)	1.00	0.69	0.57	0.04	0.03	0.02	0.03	0.01
C(at%)	41.53	28.47	23.83	1.86	1.36	1.02	1.37	0.55
R 25								
I	1723	1713	1727	77	163	185	62	40
C(rat)	1.00	0.70	0.59	0.05	0.03	0.02	0.02	0.01
C(at%)	41.10	28.77	24.41	1.94	1.38	1.01	0.99	0.40
R 30								
I	2044	2105	2103	89	196	240	82	46
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
L 1								
I	167	126	143	9	16	21	15	11
C(rat)	1.00	0.53	0.51	0.06	0.03	0.03	0.06	0.03
C(at%)	44.53	23.66	22.59	2.54	1.51	1.28	2.67	1.23
L 2								
I	168	141	153	12	19	23	14	8
C(rat)	1.00	0.59	0.54	0.08	0.04	0.03	0.06	0.02
C(at%)	42.50	25.12	22.94	3.21	1.70	1.33	2.36	0.85
L 3								
I	178	169	171	10	23	20	14	11
C(rat)	1.00	0.67	0.57	0.06	0.05	0.03	0.05	0.03
C(at%)	40.87	27.32	23.27	2.43	1.87	1.05	2.14	1.06
L 4								
I	203	177	184	11	24	24	16	13
C(rat)	1.00	0.61	0.54	0.06	0.04	0.03	0.05	0.03
C(at%)	42.43	26.05	22.79	2.43	1.78	1.14	2.23	1.14

6/23/95

L 5								
I	263	224	237	14	30	27	20	10
C(rat)	1.00	0.60	0.53	0.06	0.04	0.02	0.05	0.02
C(at%)	43.09	25.84	23.01	2.43	1.74	1.01	2.19	0.69
L 6								
I	312	251	302	15	37	37	20	14
C(rat)	1.00	0.57	0.57	0.05	0.04	0.03	0.04	0.02
C(at%)	43.08	24.40	24.71	2.19	1.81	1.16	1.84	0.81
L 8								
I	272	235	259	16	26	38	17	11
C(rat)	1.00	0.61	0.56	0.06	0.03	0.03	0.04	0.02
C(at%)	42.39	25.79	23.92	2.64	1.43	1.35	1.77	0.72
L 10								
I	282	265	275	14	35	38	17	14
C(rat)	1.00	0.66	0.58	0.05	0.04	0.03	0.04	0.02
C(at%)	41.19	27.26	23.80	2.16	1.81	1.27	1.66	0.86
L 12								
I	331	301	318	21	34	35	21	13
C(rat)	1.00	0.64	0.57	0.07	0.04	0.02	0.04	0.02
C(at%)	41.74	26.73	23.76	2.80	1.52	1.01	1.77	0.69
L 14								
I	427	381	413	23	44	43	29	18
C(rat)	1.00	0.63	0.57	0.06	0.04	0.02	0.05	0.02
C(at%)	42.00	26.39	24.07	2.40	1.53	0.96	1.90	0.74
L 16								
I	501	511	523	28	54	57	30	23
C(rat)	1.00	0.72	0.62	0.06	0.04	0.03	0.04	0.02
C(at%)	39.70	28.51	24.56	2.35	1.52	1.03	1.59	0.76
L 18								
I	753	706	707	37	78	88	23	27
C(rat)	1.00	0.66	0.56	0.05	0.04	0.03	0.02	0.02
C(at%)	42.24	27.89	23.50	2.20	1.55	1.13	0.86	0.63
L 20								
I	918	830	868	41	89	91	44	31
C(rat)	1.00	0.64	0.56	0.05	0.03	0.02	0.03	0.01
C(at%)	42.60	27.12	23.87	2.01	1.46	0.96	1.36	0.60
L 22								
I	1000	975	974	45	95	98	50	29
C(rat)	1.00	0.69	0.58	0.05	0.03	0.02	0.03	0.01
C(at%)	41.45	28.46	23.92	1.97	1.39	0.93	1.38	0.50
L 25								
I	1245	1169	1175	62	113	110	44	34
C(rat)	1.00	0.66	0.56	0.05	0.03	0.02	0.02	0.01
C(at%)	42.37	28.01	23.70	2.23	1.36	0.85	1.00	0.48
L 30								
I	1502	1515	1501	63	157	164	61	35
C(rat)	1.00	0.71	0.59	0.04	0.04	0.02	0.03	0.01
C(at%)	40.89	29.04	24.21	1.82	1.51	1.02	1.11	0.40

6/23/95

A/0000a



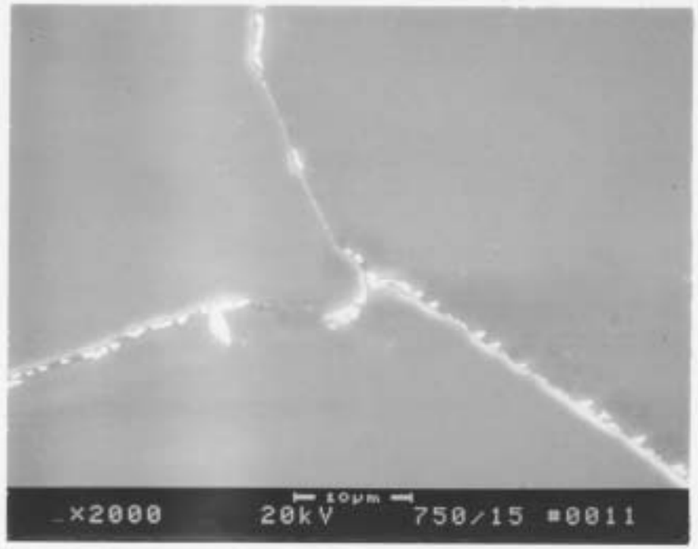
6/23/95

Profile B1000a: Chemical analysis near G.B. area

B1000a	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	508	475	511	30	41	49	15	10
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.78	0.61	0.78	0.42	0.28	0.91	0.48
Thin Area 1								
Dark spot								
I	102	120	145	15	14	22	9	9
C(rat)	1.00	0.91	0.86	0.11	0.06	0.06	0.08	0.04
C(at%)	31.96	29.16	27.54	3.67	1.85	1.91	2.56	1.35
Light spot								
I	73	82	106	11	8	10	9	7
C(rat)	1.00	0.87	0.88	0.12	0.05	0.04	0.11	0.05
C(at%)	32.15	28.01	28.29	3.78	1.48	1.22	3.59	1.47
Right cavity corner								
I	1224	1448	1831	169	134	136	72	77
C(rat)	1.00	0.92	0.91	0.11	0.05	0.03	0.05	0.03
C(at%)	32.34	29.67	29.32	3.49	1.49	1.00	1.72	0.97
Left cavity corner								
I	32	37	40	9	5	6	4	3
C(rat)	1.00	0.90	0.76	0.22	0.07	0.05	0.11	0.04
C(at%)	31.75	28.47	24.05	6.97	2.09	1.65	3.60	1.42
Side edge 1								
I	83	98	109	13	11	14	8	5
C(rat)	1.00	0.92	0.80	0.12	0.06	0.05	0.09	0.03
C(at%)	32.76	30.00	26.08	4.01	1.83	1.53	2.86	0.94
Side edge 2								
I	39	39	46	7	6	4	3	5
C(rat)	1.00	0.78	0.71	0.14	0.06	0.03	0.07	0.06
C(at%)	35.03	27.17	25.04	4.91	2.27	1.00	2.44	2.15
Thin Area 2								
Center								
I	910	1231	1635	205	133	138	74	97
C(rat)	1.00	1.05	1.09	0.18	0.06	0.04	0.07	0.05
C(at%)	28.23	29.62	30.74	4.96	1.74	1.19	2.08	1.44
Around Cavity 1								
Right edge								
I	508	475	511	30	41	49	15	10
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
Left edge								
I	243	234	281	16	27	55	10	7
C(rat)	1.00	0.75	0.70	0.05	0.05	0.06	0.04	0.01
C(at%)	37.60	28.08	26.35	1.93	1.76	2.36	1.40	0.52

6/28/95

750°C/15hr Foil:



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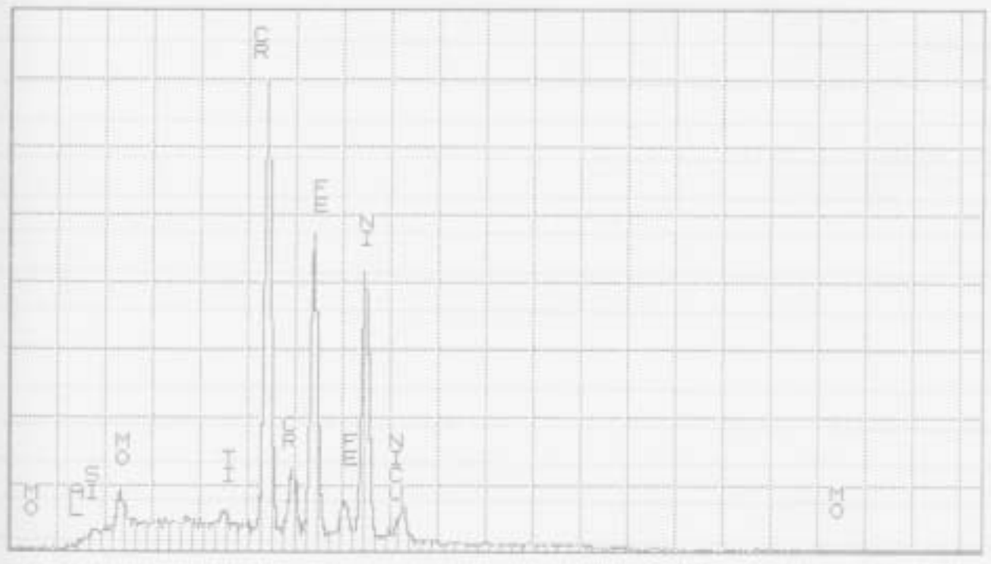
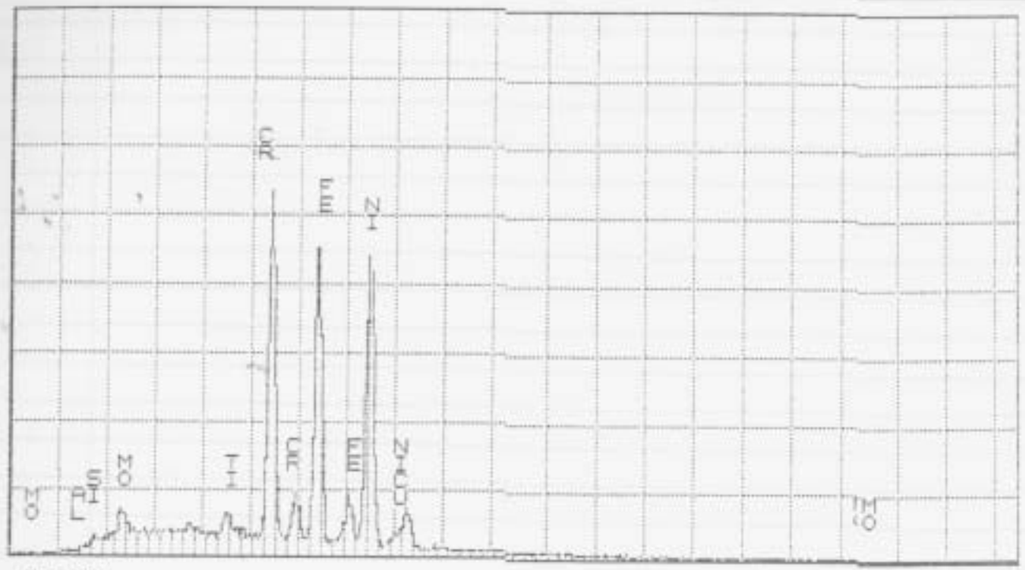
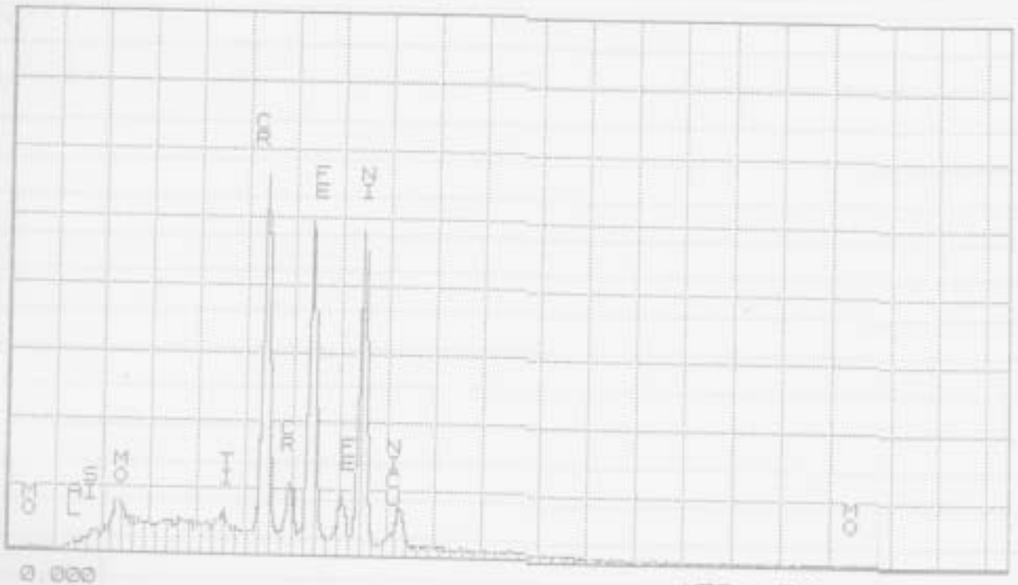


6/30/95



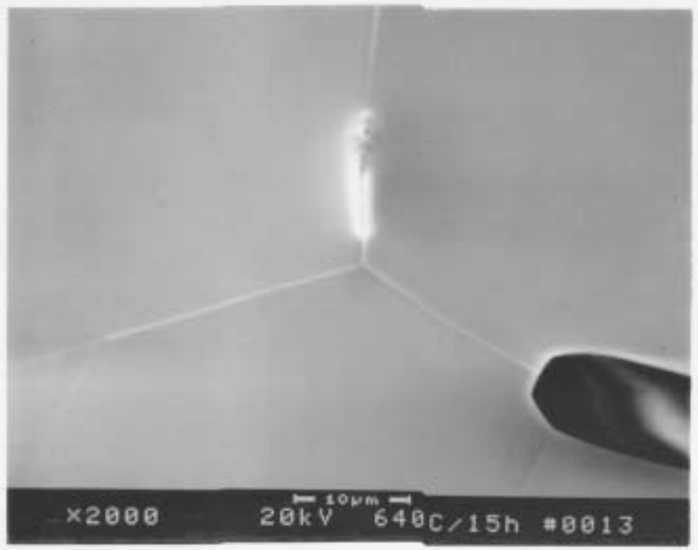
32 ALLOY 625 - 750C/15h - GRAIN BOUNDARY



31 ALLOY 625 - 750C/15h - INSIDE GRAIN

6/30/95

640°C/15hr Foil:



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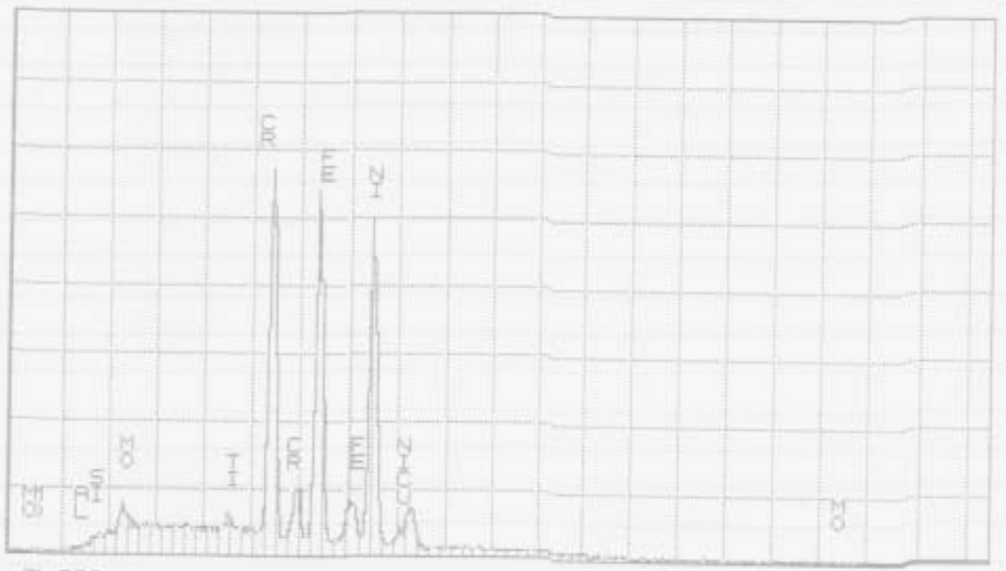
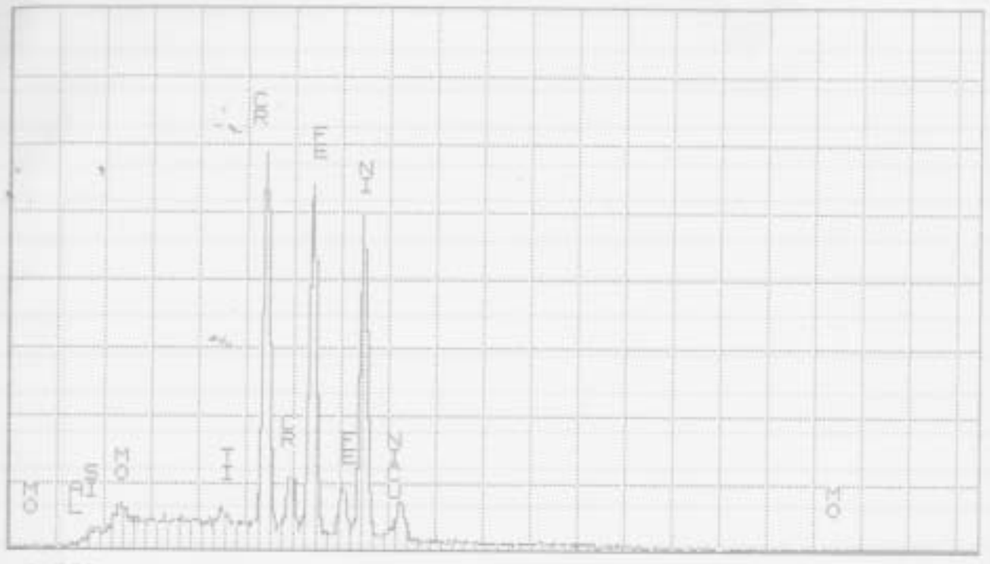


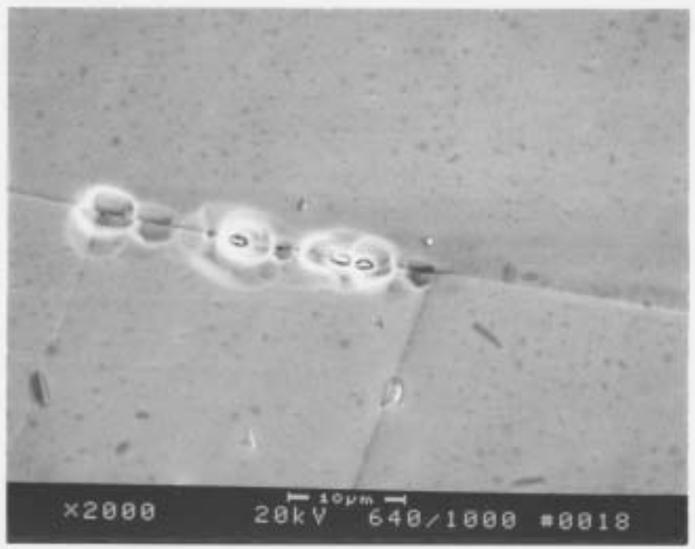
30 ALLOY 625 - 640C/15h - GRAIN BOUNDARY

6/30/95



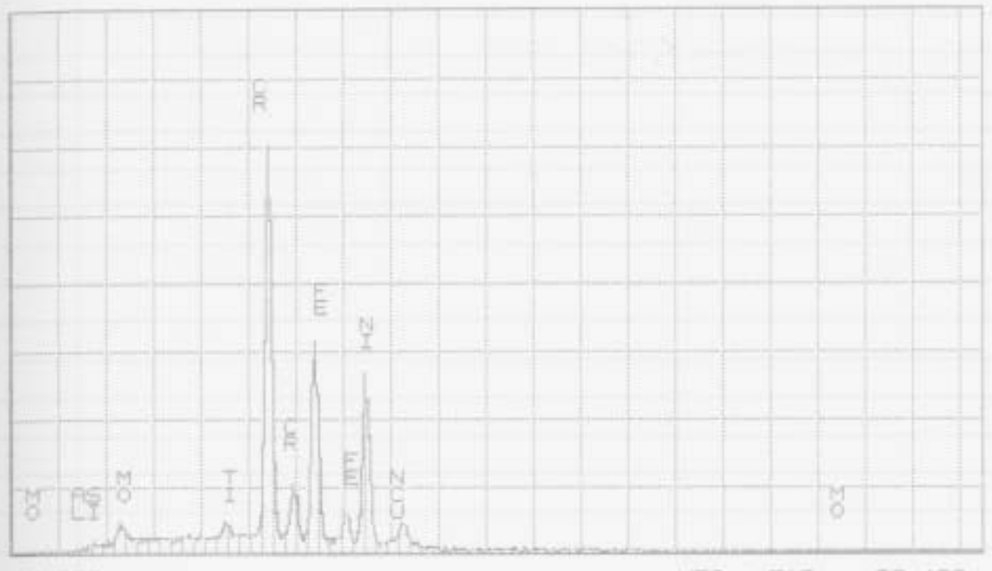
30 ALLOY 825 - 640C/15h - INSIDE GRAIN

640°C/1000 hr Foil:

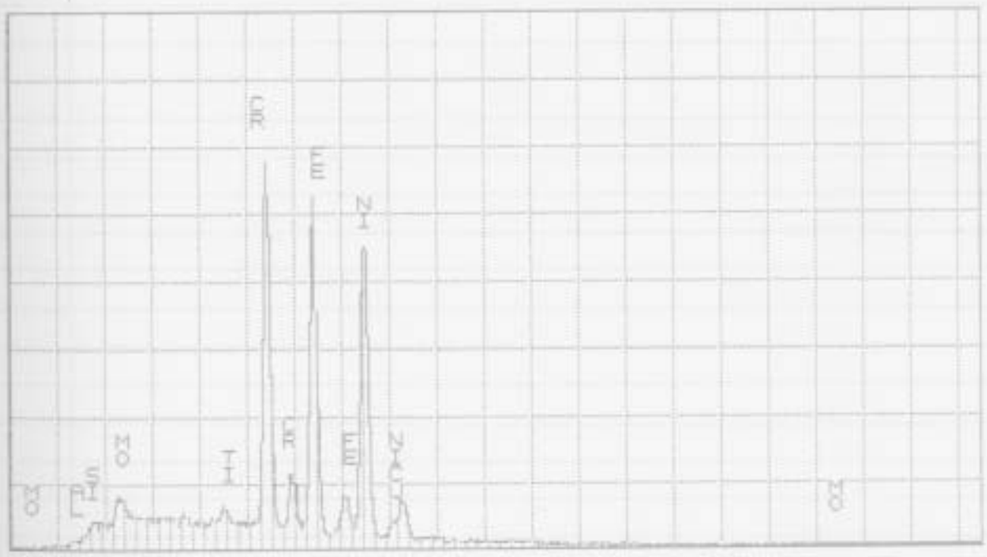


07340 1

6/30/95



30 ALLOY 825 - 640C/1000h - CARBIDE



30 ALLOY 825 - 640C/1000h - GRAIN BOUNDARY

6/30/95

Chemical Profile Analysis of 750C/100hr Sample

Analysis S750H1:

S750H1	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	1064	1107	928	38	114	113	61	44
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.70	0.70	1.29	0.32	0.25	0.47	0.23
GB								
I	610	602	461	19	51	69	52	26
C(rat)	1.00	0.69	0.53	0.04	0.03	0.03	0.04	0.01
C(at%)	42.36	29.14	22.38	1.70	1.12	1.21	1.69	0.41
R 1								
I	720	701	554	24	64	55	54	30
C(rat)	1.00	0.68	0.54	0.04	0.03	0.02	0.04	0.01
C(at%)	42.53	28.86	22.87	1.83	1.20	0.82	1.49	0.40
R 2								
I	706	657	539	18	63	70	51	29
C(rat)	1.00	0.65	0.53	0.03	0.03	0.02	0.03	0.01
C(at%)	43.26	28.06	23.09	1.42	1.22	1.08	1.46	0.40
R 3								
I	690	641	554	24	65	65	48	26
C(rat)	1.00	0.65	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	42.58	27.57	23.90	1.91	1.27	1.01	1.38	0.37
L 1								
I	582	515	445	21	50	73	43	28
C(rat)	1.00	0.62	0.53	0.05	0.03	0.03	0.03	0.01
C(at%)	43.44	26.79	23.22	2.02	1.18	1.37	1.50	0.48

JDP
7/16/95

Profile S750H2:

S750H2	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	1064	1107	928	38	114	113	61	44
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.70	0.70	1.29	0.32	0.25	0.47	0.23
PPT								
I	89	136	973	34	18	19	38	18
C(rat)	1.00	1.07	7.64	0.49	0.06	0.05	0.20	0.05
C(at%)	9.47	10.09	72.37	4.67	0.61	0.51	1.89	0.44
GB								
I	599	587	426	17	64	46	37	19
C(rat)	1.00	0.68	0.50	0.04	0.03	0.02	0.03	0.01
C(at%)	43.36	29.62	21.56	1.59	1.47	0.84	1.25	0.31
R 1								
I	582	506	426	20	56	45	49	22
C(rat)	1.00	0.61	0.51	0.04	0.03	0.02	0.04	0.01
C(at%)	44.25	26.81	22.64	1.96	1.35	0.86	1.74	0.38
R 2								
I	570	526	450	17	60	49	41	19
C(rat)	1.00	0.64	0.55	0.04	0.03	0.02	0.03	0.01
C(at%)	42.92	27.61	23.69	1.65	1.43	0.93	1.44	0.33
R 3								
I	632	623	516	24	66	74	45	29
C(rat)	1.00	0.69	0.57	0.05	0.03	0.03	0.03	0.01
C(at%)	41.44	28.47	23.65	2.03	1.37	1.22	1.38	0.43
R 4								
I	600	549	486	20	53	55	44	25
C(rat)	1.00	0.64	0.57	0.04	0.03	0.02	0.03	0.01
C(at%)	42.70	27.23	24.18	1.84	1.20	0.99	1.46	0.41
R 5								
I	647	596	531	23	57	68	42	27
C(rat)	1.00	0.64	0.57	0.05	0.03	0.03	0.03	0.01
C(at%)	42.45	27.25	24.35	1.95	1.19	1.12	1.29	0.40
R 6								
I	621	548	507	15	68	60	39	21
C(rat)	1.00	0.62	0.57	0.03	0.03	0.02	0.03	0.01
C(at%)	43.23	26.59	24.67	1.35	1.50	1.05	1.27	0.33
R 8								
I	744	672	597	24	70	73	49	23
C(rat)	1.00	0.63	0.56	0.04	0.03	0.02	0.03	0.01
C(at%)	43.02	27.08	24.13	1.79	1.28	1.06	1.32	0.30
R 10								
I	853	765	697	24	71	93	58	31
C(rat)	1.00	0.63	0.57	0.04	0.03	0.03	0.03	0.01
C(at%)	42.98	26.87	24.55	1.56	1.13	1.18	1.36	0.36

JDP
7/16/95

R 12

I	960	966	813	32	89	70	61	28
C(rat)	1.00	0.70	0.59	0.04	0.03	0.02	0.03	0.01
C(at%)	41.32	28.98	24.46	1.78	1.21	0.76	1.23	0.27

R 14

I	989	919	875	27	102	107	69	28
C(rat)	1.00	0.65	0.62	0.04	0.03	0.03	0.03	0.01
C(at%)	41.66	26.98	25.76	1.47	1.36	1.14	1.36	0.27

R 16

I	1133	1007	974	33	100	107	65	33
C(rat)	1.00	0.62	0.60	0.04	0.03	0.02	0.03	0.01
C(at%)	42.68	26.44	25.65	1.60	1.19	1.02	1.14	0.28

R 18

I	1458	1387	1228	42	130	131	86	37
C(rat)	1.00	0.66	0.59	0.04	0.03	0.02	0.03	0.01
C(at%)	42.14	27.94	24.81	1.57	1.19	0.95	1.16	0.24

R 20

I	1476	1410	1254	46	133	124	77	33
C(rat)	1.00	0.67	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	42.03	27.98	24.96	1.69	1.20	0.89	1.02	0.21

R 25

I	1622	1515	1382	46	133	124	77	33
C(rat)	1.00	0.65	0.60	0.04	0.03	0.02	0.02	0.00
C(at%)	42.46	27.64	25.29	1.55	1.10	0.82	0.94	0.20

R 30

I	1960	1935	1781	62	179	180	109	42
C(rat)	1.00	0.69	0.64	0.04	0.03	0.02	0.03	0.00
C(at%)	40.87	28.12	25.96	1.67	1.18	0.95	1.06	0.20

L 1

I	513	432	374	19	48	53	39	17
C(rat)	1.00	0.59	0.51	0.05	0.03	0.03	0.04	0.01
C(at%)	44.58	26.17	22.72	2.13	1.32	1.16	1.58	0.34

L 2

I	468	420	348	21	37	68	38	24
C(rat)	1.00	0.63	0.52	0.06	0.03	0.04	0.04	0.01
C(at%)	43.21	27.03	22.46	2.50	1.08	1.58	1.64	0.50

L 3

I	445	443	351	20	39	51	42	22
C(rat)	1.00	0.69	0.55	0.06	0.03	0.03	0.04	0.01
C(at%)	41.40	28.73	22.83	2.40	1.15	1.20	1.82	0.47

L 4

I	443	423	350	19	44	56	32	23
C(rat)	1.00	0.67	0.55	0.06	0.03	0.03	0.03	0.01
C(at%)	41.98	27.94	23.18	2.32	1.32	1.34	1.42	0.50

L 5

I	453	431	361	16	40	64	36	22
C(rat)	1.00	0.66	0.56	0.05	0.03	0.04	0.04	0.01
C(at%)	42.06	27.89	23.43	1.92	1.18	1.50	1.56	0.47

3/16/95

L 6

I	432	408	341	14	39	48	29	21
C(rat)	1.00	0.66	0.55	0.04	0.03	0.03	0.03	0.01
C(at%)	42.54	28.00	23.47	1.78	1.22	1.19	1.33	0.47

L 8

I	449	439	368	13	48	48	35	22
C(rat)	1.00	0.68	0.57	0.04	0.03	0.03	0.04	0.01
C(at%)	41.66	28.39	23.87	1.56	1.41	1.12	1.52	0.46

L 10

I	449	410	381	16	52	52	40	22
C(rat)	1.00	0.64	0.59	0.05	0.04	0.03	0.04	0.01
C(at%)	41.77	26.58	24.78	1.92	1.53	1.22	1.74	0.47

L 12

I	452	431	373	15	42	58	40	23
C(rat)	1.00	0.66	0.58	0.04	0.03	0.03	0.04	0.01
C(at%)	41.68	27.70	24.04	1.79	1.23	1.35	1.72	0.48

L 14

I	528	498	455	16	56	63	35	26
C(rat)	1.00	0.66	0.60	0.04	0.03	0.03	0.03	0.01
C(at%)	41.59	27.34	25.05	1.63	1.40	1.25	1.29	0.47

L 16

I	597	599	531	22	54	57	42	21
C(rat)	1.00	0.70	0.62	0.05	0.03	0.02	0.03	0.01
C(at%)	40.61	28.40	25.25	1.93	1.16	0.98	1.33	0.33

L 18

I	693	660	590	21	62	65	51	20
C(rat)	1.00	0.66	0.60	0.04	0.03	0.02	0.03	0.01
C(at%)	41.82	27.76	24.89	1.64	1.19	0.99	1.44	0.27

L 20

I	814	786	678	26	84	65	47	27
C(rat)	1.00	0.67	0.58	0.04	0.03	0.02	0.03	0.01
C(at%)	41.95	28.23	24.42	1.73	1.37	0.84	1.13	0.32

L 25

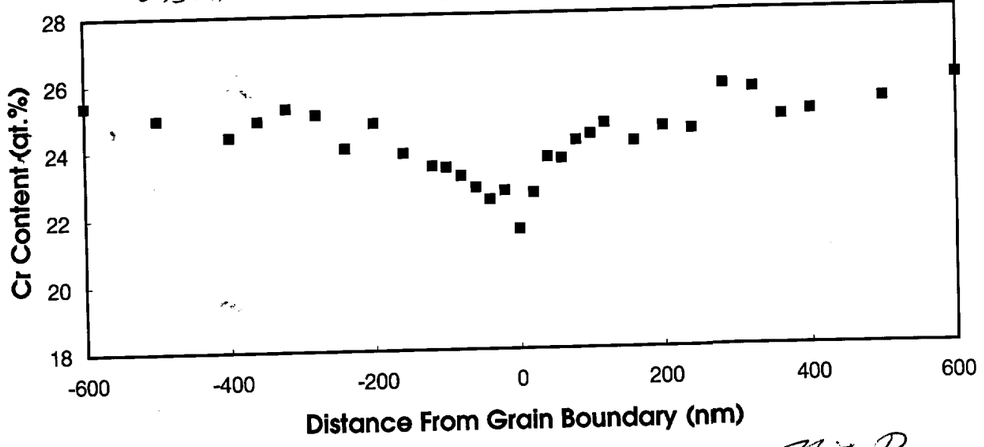
I	1153	1092	974	31	96	90	69	35
C(rat)	1.00	0.66	0.59	0.03	0.03	0.02	0.03	0.01
C(at%)	42.26	27.90	24.95	1.47	1.12	0.83	1.18	0.29

L 30

I	1449	1463	1286	43	120	121	90	36
C(rat)	1.00	0.70	0.62	0.04	0.03	0.02	0.03	0.01
C(at%)	40.91	28.79	25.38	1.57	1.07	0.86	1.19	0.23

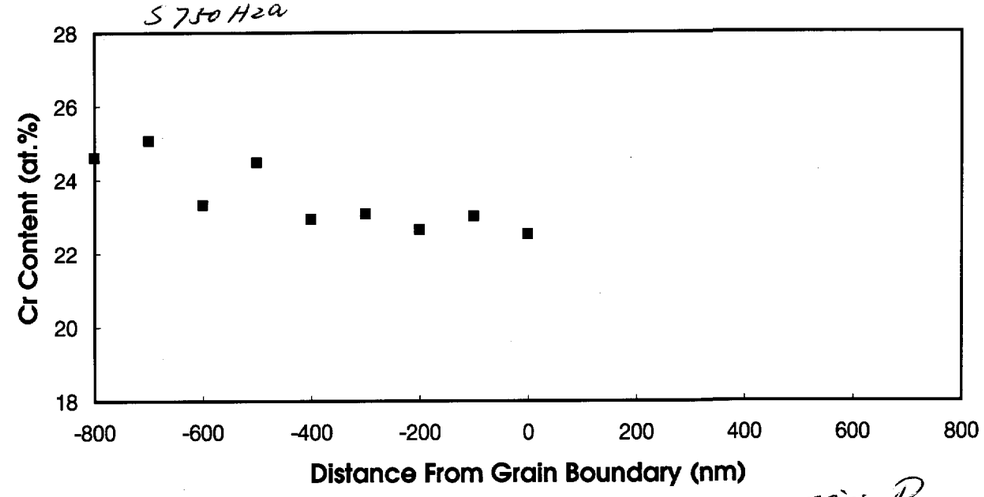
3/16/95

S750 H2



7/6/95

S 750 H2a



7/13/95

Profile verification (S750H2a):

S750H2a	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	737	695	607	21	66	112	47	37
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.77	0.74	1.62	0.38	0.18	0.42	0.19
GB								
I	491	436	352	12	53	73	32	24
C(rat)	1.00	0.68	0.53	0.04	0.04	0.03	0.03	0.01
C(at%)	42.43	28.97	22.52	1.68	1.74	1.11	1.16	0.39
L 5								
I	433	376	320	16	37	69	35	23
C(rat)	1.00	0.67	0.55	0.06	0.03	0.03	0.03	0.01
C(at%)	42.04	28.07	23.00	2.51	1.36	1.18	1.43	0.42
L 10								
I	429	377	309	14	40	55	28	19
C(rat)	1.00	0.68	0.53	0.05	0.04	0.02	0.03	0.01
C(at%)	42.46	28.69	22.64	2.24	1.50	0.96	1.16	0.35
L 15								
I	390	371	303	17	39	64	38	19
C(rat)	1.00	0.73	0.58	0.07	0.04	0.03	0.04	0.01
C(at%)	40.10	29.33	23.06	2.83	1.52	1.16	1.64	0.37
L 20								
I	423	405	323	14	39	68	34	29
C(rat)	1.00	0.74	0.57	0.05	0.03	0.03	0.03	0.01
C(at%)	40.57	29.87	22.93	2.17	1.42	1.15	1.37	0.52
L 25								
I	487	441	394	15	42	71	37	31
C(rat)	1.00	0.70	0.60	0.05	0.03	0.03	0.03	0.01
C(at%)	40.86	28.45	24.47	2.04	1.34	1.05	1.30	0.49
L 30								
I	551	529	429	17	52	83	42	36
C(rat)	1.00	0.74	0.58	0.05	0.04	0.03	0.03	0.01
C(at%)	40.47	29.88	23.32	2.02	1.45	1.07	1.29	0.50
L 35								
I	639	602	546	24	57	98	51	38
C(rat)	1.00	0.72	0.63	0.06	0.03	0.03	0.03	0.01
C(at%)	39.63	28.71	25.07	2.41	1.34	1.07	1.33	0.44
L 40								
I	737	695	607	21	66	112	47	37
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

7/13/95

Thin Foils Preparation for 638°C/1000hr & 750°C/100hr Samples

Electrolyte:

30 ml Perchloric acid
180 ml Ethylene glycol
300 ml Methanol

Polishing Conditions: (Using Fischione jet polisher)

638°C/1000hr:

#1	14 V	#2	9V
	12 mA		9mA
	-20°C		-24°C
	4 min		5 min
#3	9 V	#4	11V
	9 mA		10 mA
	-24°C		-24°C
	4 min		4 min
#5	9 V	#6	6V
	9 mA		6 mA
	-24°C		-24°C
	5 min		7½ min

750°C/100hr

#1	8 V	#2	8V
	8 mA		8mA
	-23°C		-23°C
	4 min		7½ min
#3	8V		
	9 mA		
	-22°C		
	4 min		

JD Pan
8/18/95

Chemical Profile Analysis for 638°C/1000hr specimen

Profile A1000na:

A1000na	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	80	64	60	3	9	13	13	7
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.91	0.81	1.23	0.30	0.16	0.16	0.11
GB 1								
I	166	147	70	3	17	8	12	9
C(rat)	1.00	0.80	0.34	0.02	0.03	0.01	0.01	0.01
C(at%)	44.96	36.09	15.41	1.00	1.39	0.36	0.54	0.26
GB 2								
I	154	94	44	2	11	22	9	7
C(rat)	1.00	0.55	0.23	0.02	0.02	0.02	0.01	0.00
C(at%)	53.73	29.73	12.48	0.86	1.16	1.26	0.52	0.26
GB 3								
I	118	69	37	3	13	20	9	7
C(rat)	1.00	0.53	0.25	0.03	0.03	0.03	0.01	0.01
C(at%)	52.73	27.95	13.44	1.65	1.75	1.47	0.66	0.34
PPT 1								
I	19	28	313	8	5	18	16	10
C(rat)	1.00	1.34	13.39	0.52	0.08	0.16	0.14	0.06
C(at%)	6.00	8.01	80.35	3.11	0.48	0.94	0.83	0.34
PPT 2-1								
I	155	126	154	6	21	20	15	10
C(rat)	1.00	0.74	0.81	0.05	0.04	0.02	0.02	0.01
C(at%)	37.35	27.52	30.17	1.78	1.53	0.79	0.60	0.26
PPT 2-2								
I	43	33	269	9	5	11	11	9
C(rat)	1.00	0.70	5.09	0.26	0.04	0.04	0.04	0.02
C(at%)	13.93	9.69	70.84	3.58	0.49	0.59	0.59	0.31
PPT 2-3								
I	44	39	205	9	4	14	10	8
C(rat)	1.00	0.80	3.79	0.25	0.03	0.05	0.04	0.02
C(at%)	16.73	13.44	63.36	4.21	0.46	0.88	0.63	0.33
R 1								
I	87	73	35	2	6	17	8	7
C(rat)	1.00	0.76	0.33	0.03	0.02	0.03	0.02	0.01
C(at%)	45.61	34.69	14.92	1.29	0.95	1.47	0.69	0.39
R 2								
I	69	58	32	2	9	15	8	8
C(rat)	1.00	0.76	0.38	0.04	0.04	0.04	0.02	0.01
C(at%)	43.83	33.40	16.52	1.56	1.73	1.57	0.84	0.55
R 3								
I	73	68	34	2	10	14	8	10
C(rat)	1.00	0.84	0.38	0.03	0.04	0.03	0.02	0.01
C(at%)	42.33	35.74	16.03	1.43	1.75	1.34	0.76	0.62

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R 4

I	81	68	36	2	5	12	5	7
C(rat)	1.00	0.76	0.36	0.03	0.02	0.02	0.01	0.01
C(at%)	45.14	34.35	16.31	1.37	0.84	1.10	0.46	0.42

R 5

I	71	64	41	3	8	11	10	7
C(rat)	1.00	0.82	0.47	0.05	0.03	0.03	0.02	0.01
C(at%)	41.12	33.60	19.30	2.14	1.40	1.05	0.95	0.44

R 6

I	64	63	42	3	6	14	10	10
C(rat)	1.00	0.89	0.53	0.06	0.03	0.04	0.03	0.02
C(at%)	38.61	34.45	20.60	2.22	1.09	1.39	0.99	0.65

R 8

I	71	69	43	3	9	13	13	7
C(rat)	1.00	0.88	0.49	0.05	0.04	0.03	0.03	0.01
C(at%)	39.46	34.76	19.43	2.05	1.51	1.19	1.19	0.42

R 10

I	68	63	37	2	6	15	14	6
C(rat)	1.00	0.84	0.44	0.04	0.03	0.04	0.03	0.01
C(at%)	41.24	34.63	18.24	1.49	1.10	1.50	1.40	0.39

R 12

I	69	48	42	3	7	12	13	8
C(rat)	1.00	0.63	0.49	0.05	0.03	0.03	0.03	0.01
C(at%)	43.83	27.64	21.69	2.34	1.34	1.26	1.36	0.55

R 14

I	69	53	46	2	10	11	9	8
C(rat)	1.00	0.70	0.54	0.04	0.04	0.03	0.02	0.01
C(at%)	42.06	29.28	22.79	1.50	1.84	1.10	0.90	0.52

R 16

I	70	66	44	3	7	11	13	5
C(rat)	1.00	0.85	0.51	0.05	0.03	0.03	0.03	0.01
C(at%)	39.80	34.01	20.34	2.10	1.20	1.03	1.22	0.31

R 18

I	62	59	40	2	9	10	15	10
C(rat)	1.00	0.86	0.52	0.04	0.04	0.03	0.04	0.02
C(at%)	39.15	33.77	20.53	1.55	1.72	1.04	1.56	0.68

R 20

I	69	54	49	3	7	8	14	7
C(rat)	1.00	0.71	0.58	0.05	0.03	0.02	0.03	0.01
C(at%)	41.08	29.14	23.71	2.20	1.26	0.78	1.37	0.45

R 25

I	61	56	45	4	6	11	12	8
C(rat)	1.00	0.83	0.60	0.08	0.03	0.03	0.03	0.01
C(at%)	38.19	31.78	22.90	3.08	1.13	1.13	1.24	0.54

R 30

I	54	44	42	4	5	9	10	10
C(rat)	1.00	0.74	0.63	0.09	0.03	0.03	0.03	0.02
C(at%)	38.95	28.77	24.63	3.55	1.09	1.07	1.19	0.78

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L 1

I	77	69	32	2	8	14	8	6
C(rat)	1.00	0.81	0.34	0.03	0.03	0.03	0.02	O.01
C(at%)	44.08	35.80	14.89	1.41	1.38	1.32	0.75	O.37

L 2

I	72	65	36	3	6	14	8	7
C(rat)	1.00	0.82	0.41	0.05	0.03	0.03	0.02	O.01
C(at%)	42.34	34.65	17.21	2.17	1.06	1.36	0.77	O.44

L 3

I	94	61	45	2	7	17	7	9
C(rat)	1.00	0.59	0.39	0.03	0.02	0.03	0.01	O.01
C(at%)	48.11	28.30	18.72	1.26	1.08	1.43	0.59	0.50

L 4

I	84	57	42	2	9	15	9	5
C(rat)	1.00	0.62	0.41	0.03	0.03	0.03	0.02	0.01
C(at%)	46.80	28.79	19.02	1.37	1.51	1.38	0.83	0.30

L 5

I	75	64	41	3	9	16	11	7
C(rat)	1.00	0.77	0.44	0.05	0.04	0.04	0.02	0.01
C(at%)	42.15	32.60	18.73	2.07	1.53	1.48	1.02	0.42

L 6

I	75	59	44	2	8	10	14	5
C(rat)	1.00	0.71	0.48	0.03	0.03	0.02	0.03	0.01
C(at%)	43.20	30.80	20.60	1.42	1.39	0.95	1.33	0.31

L 8

I	81	59	43	4	8	10	8	7
C(rat)	1.00	0.66	0.43	0.06	0.03	0.02	0.02	0.01
C(at%)	44.88	29.63	19.37	2.72	1.34	0.91	0.73	0.42

L 10

I	75	58	42	2	6	9	9	6
C(rat)	1.00	0.70	0.46	0.03	0.02	0.02	0.02	0.01
C(at%)	44.22	31.00	20.13	1.45	1.07	0.87	0.87	0.38

L 12

I	71	57	45	3	8	10	11	9
C(rat)	1.00	0.73	0.52	0.05	0.03	0.02	0.03	0.01
C(at%)	41.82	30.43	21.55	2.17	1.42	0.97	1.07	0.57

L 14

I	62	54	39	3	6	11	8	11
C(rat)	1.00	0.79	0.51	0.06	0.03	0.03	0.02	0.02
C(at%)	40.67	32.11	20.80	2.42	1.19	1.19	0.86	0.78

L 16

I	52	41	35	3	6	8	12	7
C(rat)	1.00	0.71	0.55	0.07	0.03	0.03	0.04	0.01
C(at%)	40.89	29.22	22.37	2.90	1.42	1.04	1.55	0.59

L 18

I	62	51	37	2	4	11	9	12
C(rat)	1.00	0.75	0.49	0.04	0.02	0.03	0.02	0.02
C(at%)	42.30	31.54	20.52	1.68	0.82	1.24	1.01	0.88

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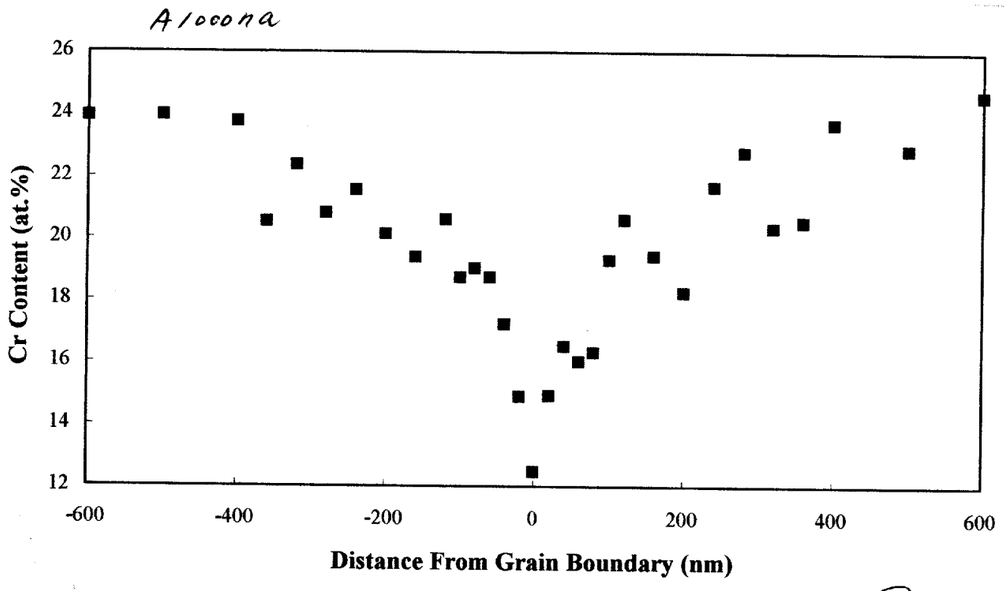
L 20								
I	41	39	32	2	6	7	7	5
C(rat)	1.00	0.86	0.63	0.06	0.04	0.03	0.03	0.01
C(at%)	37.45	32.29	23.76	2.25	1.65	1.05	1.05	0.49
L 25								
I	41	46	35	2	7	7	6	8
C(rat)	1.00	1.02	0.69	0.06	0.05	0.03	0.02	0.02
C(at%)	34.53	35.12	23.96	2.07	1.78	0.97	0.83	0.73
L 30								
I	43	42	34	2	5	7	7	5
C(rat)	1.00	0.89	0.64	0.06	0.04	0.03	0.03	0.01
C(at%)	37.22	32.95	23.92	2.13	1.31	1.00	1.00	0.47

A1000na



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Profile A1000nb

A1000nb	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	80	64	60	3	9	13	13	7
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.91	0.81	1.23	0.30	0.16	0.16	0.11
GB 3-1								
I	101	53	33	3	12	18	6	6
C(rat)	1.00	0.48	0.27	0.04	0.04	0.03	0.01	0.01
C(at%)	53.79	25.59	14.29	1.96	1.93	1.58	0.53	0.34
GB 3-2								
I	81	47	24	2	7	20	8	5
C(rat)	1.00	0.53	0.24	0.03	0.03	0.04	0.02	0.01
C(at%)	53.00	27.88	12.77	1.61	1.38	2.16	0.86	0.35
GB 3-3								
I	53	52	24	2	4	9	7	4
C(rat)	1.00	0.89	0.37	0.05	0.02	0.03	0.02	0.01
C(at%)	41.94	37.30	15.44	1.95	0.96	1.17	0.91	0.34
GB 4-1								
I	162	123	68	4	15	9	12	5
C(rat)	1.00	0.69	0.34	0.03	0.03	0.01	0.01	0.00
C(at%)	47.34	32.58	16.15	1.44	1.32	0.43	0.58	0.16
GB 4-2								
I	242	165	84	4	21	11	16	8
C(rat)	1.00	0.62	0.28	0.02	0.03	0.01	0.01	0.00
C(at%)	50.80	31.40	14.33	1.03	1.33	0.38	0.55	0.18
GB 4-3								
I	204	180	87	4	21	14	16	6
C(rat)	1.00	0.80	0.35	0.02	0.03	0.01	0.01	0.00
C(at%)	44.86	35.88	15.55	1.08	1.39	0.51	0.58	0.14
PPT 3								
I	26	37	319	11	7	16	13	12
C(rat)	1.00	1.29	9.97	0.52	0.08	0.10	0.08	0.05
C(at%)	7.63	9.84	76.10	3.97	0.62	0.77	0.63	0.38
PPT 4								
I	53	46	250	9	19	30	16	14
C(rat)	1.00	0.79	3.83	0.21	0.11	0.09	0.05	0.03
C(at%)	16.37	12.88	62.77	3.42	1.77	1.53	0.81	0.47
R 1								
I	81	43	27	2	7	15	7	6
C(rat)	1.00	0.48	0.27	0.03	0.03	0.03	0.01	0.01
C(at%)	53.73	25.85	14.56	1.63	1.40	1.64	0.76	0.43
R 2								
I	74	49	29	2	6	13	6	6
C(rat)	1.00	0.60	0.32	0.03	0.02	0.03	0.01	0.01
C(at%)	49.32	29.60	15.71	1.64	1.21	1.43	0.66	0.43

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R 3

I	72	63	32	2	8	8	9	8
C(rat)	1.00	0.79	0.36	0.03	0.03	0.02	0.02	0.01
C(at%)	44.00	34.90	15.90	1.50	1.48	0.81	0.91	0.53

R 4

I	76	39	30	2	7	16	8	10
C(rat)	1.00	0.47	0.32	0.03	0.03	0.03	0.02	0.01
C(at%)	52.29	24.32	16.78	1.69	1.45	1.81	0.91	0.74

R 5

I	68	34	26	2	6	18	9	4
C(rat)	1.00	0.45	0.31	0.04	0.03	0.04	0.02	0.01
C(at%)	52.67	23.87	16.37	1.90	1.40	2.30	1.15	0.33

R 6

I	70	54	36	2	10	8	7	7
C(rat)	1.00	0.70	0.42	0.04	0.04	0.02	0.02	0.01
C(at%)	44.61	31.19	18.65	1.57	1.92	0.84	0.73	0.48

R 8

I	73	43	31	2	7	13	7	6
C(rat)	1.00	0.53	0.35	0.03	0.03	0.03	0.02	0.01
C(at%)	50.11	26.76	17.30	1.69	1.45	1.47	0.79	0.44

R 10

I	70	50	36	3	6	8	14	4
C(rat)	1.00	0.65	0.42	0.05	0.03	0.02	0.03	0.01
C(at%)	45.41	29.40	18.98	2.39	1.17	0.85	1.50	0.28

R 12

I	62	55	42	2	6	11	8	7
C(rat)	1.00	0.80	0.55	0.04	0.03	0.03	0.02	0.01
C(at%)	40.22	32.34	22.15	1.59	1.17	1.18	0.85	0.49

R 14

I	69	51	41	3	7	12	9	6
C(rat)	1.00	0.67	0.48	0.05	0.03	0.03	0.02	0.01
C(at%)	43.54	29.17	21.03	2.33	1.33	1.25	0.94	0.41

R 16

I	64	55	41	2	10	13	8	7
C(rat)	1.00	0.78	0.52	0.04	0.05	0.03	0.02	0.01
C(at%)	40.80	31.78	21.25	1.57	1.92	1.37	0.84	0.48

R 18

I	66	58	39	2	9	13	10	6
C(rat)	1.00	0.80	0.48	0.04	0.04	0.03	0.02	0.01
C(at%)	41.28	32.88	19.83	1.54	1.70	1.34	1.03	0.40

R 19

I	62	51	44	2	8	12	11	7
C(rat)	1.00	0.75	0.58	0.04	0.04	0.03	0.03	0.01
C(at%)	40.41	30.13	23.31	1.60	1.57	1.29	1.18	0.49

R 20

I	63	48	47	3	5	10	8	8
C(rat)	1.00	0.69	0.61	0.06	0.02	0.03	0.02	0.01
C(at%)	40.98	28.30	24.85	2.40	0.98	1.07	0.86	0.56

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R 21

I	68	53	45	2	7	12	10	7
C(rat)	1.00	0.71	0.54	0.04	0.03	0.03	0.02	0.01
C(at%)	42.09	29.74	22.64	1.52	1.31	1.22	1.02	0.47

R 25

I	64	49	44	2	6	12	9	7
C(rat)	1.00	0.69	0.56	0.04	0.03	0.03	0.02	0.01
C(at%)	41.92	29.09	23.43	1.61	1.19	1.29	0.97	0.49

R 30

I	49	45	39	2	6	9	7	8
C(rat)	1.00	0.83	0.65	0.05	0.04	0.03	0.02	0.02
C(at%)	37.91	31.56	24.53	1.90	1.40	1.15	0.89	0.67

L 1

I	78	55	32	2	8	14	6	7
C(rat)	1.00	0.64	0.33	0.03	0.03	0.03	0.01	0.01
C(at%)	47.92	30.63	15.98	1.51	1.48	1.42	0.61	0.46

L 2

I	57	43	25	2	6	7	8	6
C(rat)	1.00	0.68	0.36	0.04	0.03	0.02	0.02	0.01
C(at%)	46.08	31.51	16.43	1.99	1.46	0.93	1.07	0.52

L 3

I	45	35	24	2	5	9	7	5
C(rat)	1.00	0.71	0.43	0.05	0.03	0.03	0.03	0.01
C(at%)	43.53	30.69	18.87	2.38	1.46	1.43	1.12	0.52

L 4

I	40	25	19	2	3	10	6	4
C(rat)	1.00	0.57	0.39	0.06	0.02	0.04	0.02	0.01
C(at%)	47.32	26.81	18.27	2.91	1.07	1.95	1.17	0.51

L 5

I	45	38	27	1	5	7	6	5
C(rat)	1.00	0.77	0.49	0.03	0.03	0.03	0.02	0.01
C(at%)	42.13	32.25	20.55	1.15	1.41	1.08	0.93	0.50

L 6

I	40	37	26	2	4	5	7	7
C(rat)	1.00	0.84	0.53	0.06	0.03	0.02	0.03	0.02
C(at%)	39.58	33.19	20.91	2.43	1.19	0.81	1.14	0.75

L 8

I	41	49	28	2	5	9	9	8
C(rat)	1.00	1.08	0.56	0.06	0.04	0.04	0.04	0.02
C(at%)	35.35	38.30	19.62	2.12	1.30	1.28	1.28	0.74

L 10

I	37	37	25	1	7	6	7	5
C(rat)	1.00	0.91	0.55	0.03	0.06	0.03	0.03	0.01
C(at%)	38.19	34.62	20.98	1.27	2.18	1.02	1.19	0.56

L 12

I	42	34	29	3	6	6	10	5
C(rat)	1.00	0.73	0.56	0.09	0.04	0.02	0.04	0.01
C(at%)	39.98	29.34	22.44	3.51	1.72	0.94	1.57	0.51

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L 14								
I	39	26	24	1	4	5	11	7
C(rat)	1.00	0.60	0.50	0.03	0.03	0.02	0.05	0.02
C(at%)	44.37	26.81	22.20	1.40	1.37	0.94	2.06	0.86
L 16								
I	33	25	19	1	5	4	6	4
C(rat)	1.00	0.69	0.47	0.04	0.05	0.02	0.03	0.01
C(at%)	43.47	29.85	20.35	1.62	1.99	0.87	1.30	0.57
L 18								
I	27	23	20	2	3	4	6	4
C(rat)	1.00	0.77	0.60	0.09	0.03	0.02	0.04	0.02
C(at%)	38.82	29.98	23.38	3.53	1.30	0.95	1.42	0.62
L 20								
I	24	16	17	1	2	3	4	4
C(rat)	1.00	0.60	0.58	0.05	0.03	0.02	0.03	0.02
C(at%)	43.06	26.02	24.79	2.21	1.08	0.89	1.18	0.77
L 25								
I	21	16	15	1	3	6	4	5
C(rat)	1.00	0.69	0.58	0.06	0.04	0.05	0.03	0.03
C(at%)	40.37	27.88	23.44	2.36	1.74	1.90	1.27	1.03
L 30								
I	22	18	17	2	2	5	6	5
C(rat)	1.00	0.74	0.63	0.11	0.03	0.04	0.04	0.02
C(at%)	38.23	28.35	24.01	4.27	1.05	1.43	1.72	0.94

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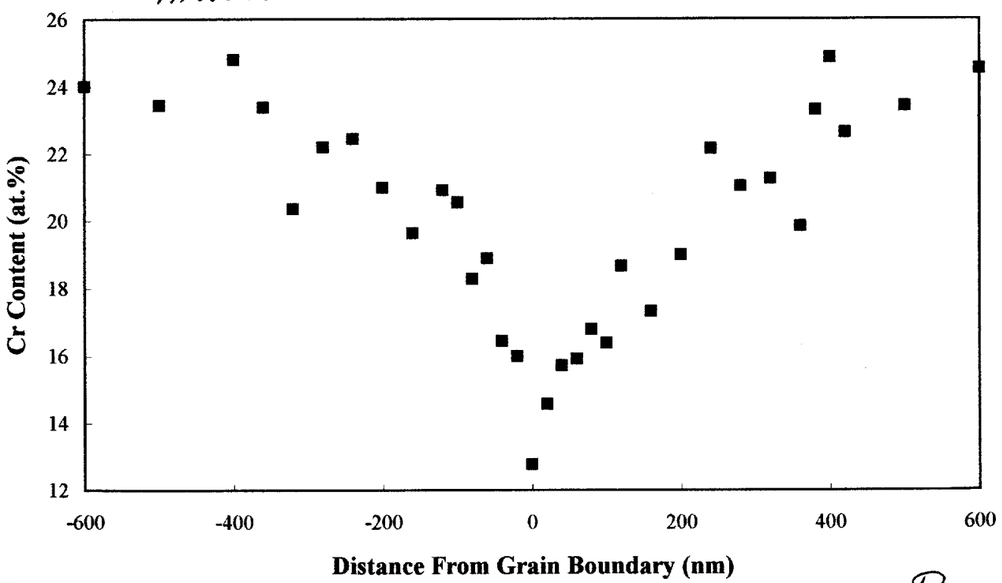

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Chemical Profile Analysis for 750°C/100hr Specimens

profile H750Fa:

H750Fa	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	97	80	84	4	23	19	12	9
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.88	0.70	1.12	0.14	0.14	0.22	0.10
GB 1-1								
I	65	45	46	4	17	7	5	5
C(rat)	1.00	0.61	0.50	0.07	0.04	0.01	0.02	0.01
C(at%)	44.40	27.03	22.12	3.05	1.66	0.65	0.74	0.35
GB 1-2								
I	50	36	31	2	8	5	7	3
C(rat)	1.00	0.63	0.44	0.04	0.02	0.01	0.03	0.01
C(at%)	45.72	28.94	19.96	2.04	1.05	0.62	1.38	0.28
GB 1-3								
I	50	47	37	4	12	5	5	4
C(rat)	1.00	0.83	0.52	0.09	0.03	0.01	0.02	0.01
C(at%)	39.77	32.87	20.72	3.56	1.37	0.54	0.86	0.32
GB 1-4								
I	66	42	41	3	16	5	6	5
C(rat)	1.00	0.56	0.44	0.05	0.03	0.01	0.02	0.01
C(at%)	47.17	26.39	20.63	2.40	1.64	0.49	0.93	0.36
PPT 1								
I	73	92	694	23	81	36	29	26
C(rat)	1.00	1.11	6.69	0.35	0.16	0.07	0.09	0.04
C(at%)	10.52	11.66	70.41	3.71	1.67	0.71	0.90	0.38
R 1								
I	52	50	39	4	14	6	7	3
C(rat)	1.00	0.85	0.53	0.09	0.04	0.02	0.03	0.01
C(at%)	39.24	33.17	20.72	3.37	1.51	0.62	1.14	0.23
R 2								
I	64	59	43	3	17	9	6	4
C(rat)	1.00	0.81	0.47	0.05	0.04	0.02	0.02	0.01
C(at%)	41.32	33.49	19.54	2.17	1.57	0.79	0.84	0.26
R 3								
I	69	56	46	4	22	11	6	8
C(rat)	1.00	0.71	0.47	0.06	0.05	0.02	0.02	0.01
C(at%)	42.63	30.42	20.01	2.76	1.95	0.93	0.80	0.50
R 4								
I	88	70	67	4	22	13	10	6
C(rat)	1.00	0.70	0.54	0.05	0.04	0.02	0.02	0.01
C(at%)	42.13	29.47	22.58	2.14	1.51	0.85	1.04	0.29
R 5								
I	84	65	59	4	21	15	11	8
C(rat)	1.00	0.68	0.49	0.05	0.04	0.02	0.03	0.01
C(at%)	42.99	29.25	21.26	2.29	1.54	1.05	1.22	0.42

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R 6

I	86	66	68	2	27	12	9	5
C(rat)	1.00	0.67	0.56	0.03	0.04	0.02	0.02	0.01
C(at%)	42.55	28.71	23.69	1.11	1.91	0.81	0.96	0.25

R 8

I	94	87	80	4	31	18	10	8
C(rat)	1.00	0.81	0.60	0.05	0.05	0.03	0.02	0.01
C(at%)	38.98	31.72	23.36	1.85	1.84	1.02	0.90	0.34

R 10

I	91	77	81	3	26	16	9	6
C(rat)	1.00	0.74	0.63	0.04	0.04	0.02	0.02	0.01
C(at%)	39.99	29.75	25.06	1.47	1.64	0.96	0.86	0.27

R 12

I	91	85	76	4	24	13	9	10
C(rat)	1.00	0.82	0.59	0.05	0.04	0.02	0.02	0.01
C(at%)	39.24	32.23	23.07	1.93	1.48	0.77	0.84	0.44

R 14

I	75	66	58	3	18	18	9	9
C(rat)	1.00	0.77	0.54	0.04	0.03	0.03	0.03	0.01
C(at%)	40.52	31.35	22.06	1.81	1.39	1.33	1.05	0.49

R 16

I	74	65	58	3	14	11	10	8
C(rat)	1.00	0.77	0.55	0.05	0.03	0.02	0.03	0.01
C(at%)	40.70	31.43	22.46	1.84	1.10	0.83	1.19	0.45

R 18

I	69	63	54	4	16	9	6	5
C(rat)	1.00	0.80	0.55	0.06	0.03	0.02	0.02	0.01
C(at%)	40.07	32.17	22.08	2.60	1.33	0.71	0.75	0.29

R 20

I	61	59	53	2	13	13	7	7
C(rat)	1.00	0.85	0.61	0.04	0.03	0.03	0.02	0.01
C(at%)	38.54	32.78	23.57	1.41	1.18	1.12	0.96	0.45

R 25

I	73	61	61	4	16	11	8	7
C(rat)	1.00	0.73	0.59	0.06	0.03	0.02	0.02	0.01
C(at%)	40.49	29.75	23.82	2.48	1.27	0.83	0.96	0.39

R 30

I	62	56	55	2	14	13	9	9
C(rat)	1.00	0.79	0.62	0.04	0.03	0.03	0.03	0.01
C(at%)	39.03	31.00	24.38	1.41	1.26	1.12	1.23	0.58

L 1

I	58	51	39	3	13	9	7	3
C(rat)	1.00	0.77	0.47	0.06	0.03	0.02	0.03	0.01
C(at%)	41.86	32.36	19.82	2.42	1.34	0.89	1.09	0.22

L 2

I	49	41	34	3	13	8	5	6
C(rat)	1.00	0.74	0.49	0.07	0.04	0.02	0.02	0.01
C(at%)	41.89	30.82	20.46	2.87	1.59	0.93	0.92	0.52

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L 3

I	43	36	31	2	15	12	9	3
C(rat)	1.00	0.74	0.51	0.05	0.05	0.04	0.05	0.01
C(at%)	41.05	30.22	20.83	2.13	2.05	1.57	1.86	0.29

L 4

I	41	37	31	2	10	7	4	3
C(rat)	1.00	0.79	0.53	0.05	0.03	0.02	0.02	0.01
C(at%)	40.53	32.02	21.48	2.20	1.41	0.94	0.85	0.30

L 5

I	45	39	33	2	11	7	6	6
C(rat)	1.00	0.76	0.52	0.05	0.04	0.02	0.03	0.01
C(at%)	41.21	31.40	21.28	2.05	1.44	0.88	1.19	0.56

L 6

I	48	42	34	4	13	9	4	3
C(rat)	1.00	0.77	0.50	0.09	0.04	0.03	0.02	0.01
C(at%)	40.82	31.40	20.36	3.80	1.58	1.05	0.74	0.26

L 8

I	37	35	28	2	10	4	6	4
C(rat)	1.00	0.83	0.53	0.06	0.04	0.01	0.04	0.01
C(at%)	39.61	32.94	21.10	2.39	1.53	0.59	1.39	0.43

L 10

I	47	36	35	1	10	5	6	6
C(rat)	1.00	0.67	0.52	0.02	0.03	0.01	0.03	0.01
C(at%)	43.34	29.19	22.72	1.03	1.32	0.63	1.20	0.56

L 12

I	36	32	31	2	10	8	5	4
C(rat)	1.00	0.78	0.61	0.06	0.04	0.03	0.03	0.01
C(at%)	39.04	30.51	23.67	2.42	1.55	1.19	1.17	0.44

L 14

I	42	33	33	2	11	8	5	4
C(rat)	1.00	0.69	0.55	0.05	0.04	0.03	0.03	0.01
C(at%)	41.73	28.83	23.08	2.22	1.56	1.09	1.07	0.40

L 16

I	41	31	35	2	10	10	6	6
C(rat)	1.00	0.66	0.60	0.05	0.03	0.03	0.03	0.01
C(at%)	41.07	27.30	24.68	2.24	1.43	1.37	1.30	0.61

L 18

I	44	42	38	3	12	6	5	4
C(rat)	1.00	0.84	0.61	0.08	0.04	0.02	0.02	0.01
C(at%)	38.24	32.09	23.25	2.91	1.49	0.71	0.94	0.35

L 20

I	46	39	39	2	12	5	6	4
C(rat)	1.00	0.75	0.60	0.05	0.04	0.01	0.03	0.01
C(at%)	40.32	30.06	24.07	1.96	1.51	0.60	1.14	0.36

L 25

I	67	62	54	3	14	11	12	5
C(rat)	1.00	0.81	0.57	0.05	0.03	0.02	0.04	0.01
C(at%)	39.53	32.16	22.43	1.98	1.18	0.89	1.53	0.30

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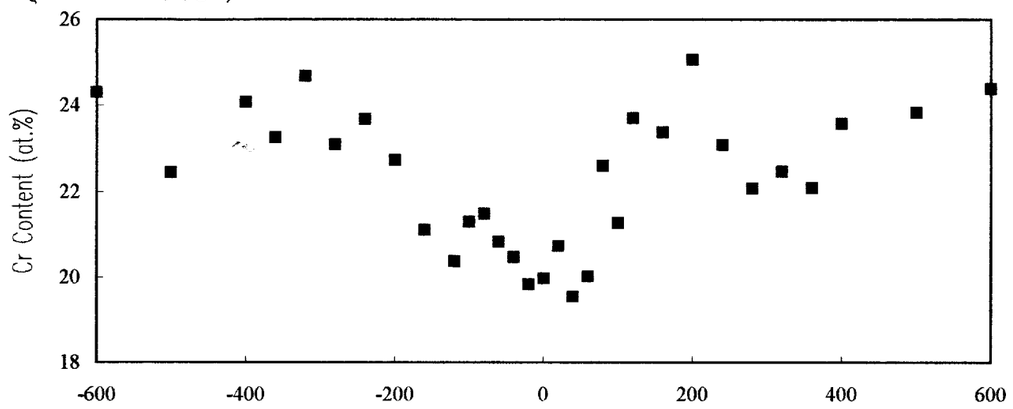
L 30

I	51	45	45	2	15	11	8	5
C(rat)	1.00	0.78	0.62	0.04	0.04	0.03	0.03	0.01
C(at%)	39.12	30.35	24.30	1.71	1.65	1.15	1.33	0.39

H750Fa



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Profile H750Fb:

H750Fb	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	884	834	777	31	93	103	63	37
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.77	0.69	1.31	0.32	0.23	0.38	0.23
GB 1-1								
I	96	78	53	5	9	16	6	3
C(rat)	1.00	0.62	0.38	0.07	0.03	0.04	0.02	0.01
C(at%)	45.98	28.72	17.61	3.15	1.39	1.76	1.08	0.32
GB 1-2								
I	88	72	53	6	9	29	17	10
C(rat)	1.00	0.63	0.42	0.09	0.03	0.08	0.07	0.03
C(at%)	42.68	26.84	17.83	3.83	1.41	3.23	3.10	1.09
GB 1-3								
I	97	78	62	5	9	17	9	5
C(rat)	1.00	0.62	0.44	0.07	0.03	0.04	0.03	0.01
C(at%)	44.53	27.52	19.74	3.02	1.33	1.79	1.55	0.52
GB 1-4								
I	132	103	73	7	11	31	10	8
C(rat)	1.00	0.60	0.38	0.07	0.03	0.05	0.03	0.01
C(at%)	45.96	27.57	17.63	3.20	1.24	2.48	1.31	0.63
PPT 1								
I	86	87	476	18	17	44	28	18
C(rat)	1.00	0.78	3.84	0.28	0.06	0.12	0.12	0.05
C(at%)	16.02	12.46	61.50	4.41	1.02	1.88	1.96	0.75
PPT 2								
I	168	159	803	31	30	83	42	24
C(rat)	1.00	0.73	3.32	0.24	0.06	0.11	0.09	0.03
C(at%)	17.91	13.03	59.38	4.34	1.03	2.03	1.68	0.58
GB 2-1								
I	122	105	84	2	10	82	25	18
C(rat)	1.00	0.66	0.48	0.02	0.03	0.15	0.08	0.03
C(at%)	40.79	26.98	19.48	0.88	1.08	6.30	3.14	1.35
GB 2-2								
I	136	125	81	6	13	100	23	20
C(rat)	1.00	0.71	0.41	0.06	0.03	0.17	0.06	0.03
C(at%)	40.42	28.56	16.70	2.34	1.25	6.83	2.57	1.34
R 1								
I	90	73	58	4	10	17	10	8
C(rat)	1.00	0.62	0.45	0.06	0.04	0.04	0.04	0.02
C(at%)	44.06	27.47	19.69	2.57	1.58	1.91	1.84	0.88
R 2								
I	87	72	61	5	11	13	8	9
C(rat)	1.00	0.64	0.49	0.08	0.04	0.03	0.03	0.02
C(at%)	42.90	27.29	20.86	3.24	1.75	1.47	1.48	1.00

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R 3								
I	83	70	60	3	9	16	8	7
C(rat)	1.00	0.65	0.50	0.05	0.03	0.04	0.04	0.02
C(at%)	42.89	27.80	21.51	2.04	1.50	1.90	1.55	0.81
R 4								
I	75	67	55	5	11	16	9	9
C(rat)	1.00	0.69	0.51	0.09	0.05	0.05	0.05	0.03
C(at%)	40.79	28.01	20.75	3.57	1.93	2.00	1.84	1.10
R 5								
I	147	122	102	6	14	25	15	8
C(rat)	1.00	0.64	0.48	0.05	0.03	0.04	0.04	0.01
C(at%)	43.61	27.82	20.99	2.34	1.34	1.70	1.67	0.53
R 6								
I	175	150	123	6	15	33	18	11
C(rat)	1.00	0.66	0.49	0.05	0.03	0.04	0.04	0.01
C(at%)	43.19	28.45	21.06	1.95	1.19	1.87	1.67	0.61
R 8								
I	239	209	185	6	28	32	19	16
C(rat)	1.00	0.67	0.54	0.03	0.04	0.03	0.03	0.02
C(at%)	42.45	28.53	22.79	1.40	1.61	1.31	1.27	0.64
R 10								
I	257	268	213	8	26	34	21	14
C(rat)	1.00	0.80	0.57	0.04	0.03	0.03	0.03	0.01
C(at%)	39.63	31.76	22.78	1.62	1.29	1.20	1.22	0.49
R 12								
I	289	290	241	11	29	46	17	19
C(rat)	1.00	0.77	0.58	0.05	0.03	0.04	0.02	0.01
C(at%)	39.91	30.78	23.08	2.00	1.29	1.46	0.88	0.59
R 14								
I	393	381	318	10	42	46	27	20
C(rat)	1.00	0.75	0.56	0.03	0.03	0.03	0.03	0.01
C(at%)	41.01	30.56	23.02	1.37	1.41	1.10	1.06	0.47
R 16								
I	487	448	402	18	69	51	33	19
C(rat)	1.00	0.71	0.57	0.05	0.05	0.02	0.03	0.01
C(at%)	41.11	29.07	23.54	2.00	1.88	0.99	1.05	0.36
R 18								
I	607	582	479	17	66	73	45	27
C(rat)	1.00	0.74	0.55	0.04	0.04	0.03	0.03	0.01
C(at%)	41.29	30.43	22.60	1.52	1.45	1.14	1.15	0.41
R 20								
I	614	580	520	21	66	83	40	22
C(rat)	1.00	0.73	0.59	0.04	0.03	0.03	0.02	0.01
C(at%)	40.70	29.55	23.91	1.83	1.41	1.26	1.00	0.33
R 25								
I	827	772	756	26	93	95	50	32
C(rat)	1.00	0.72	0.63	0.04	0.04	0.03	0.02	0.01
C(at%)	40.21	28.85	25.50	1.66	1.46	1.06	0.91	0.35

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R 30								
I	887	861	769	29	100	96	49	34
C(rat)	1.00	0.75	0.60	0.04	0.04	0.02	0.02	0.01
C(at%)	40.31	30.08	24.24	1.73	1.47	1.00	0.84	0.35
L 1								
I	87	78	57	5	12	29	11	12
C(rat)	1.00	0.69	0.45	0.08	0.04	0.08	0.05	0.03
C(at%)	41.34	28.49	18.79	3.12	1.84	3.17	1.96	1.28
L 2								
I	84	71	56	4	8	32	14	10
C(rat)	1.00	0.65	0.46	0.06	0.03	0.09	0.06	0.03
C(at%)	41.98	27.27	19.41	2.63	1.29	3.67	2.63	1.12
L 3								
I	87	75	57	3	11	30	10	12
C(rat)	1.00	0.66	0.45	0.05	0.04	0.08	0.04	0.03
C(at%)	42.43	28.11	19.28	1.92	1.73	3.36	1.83	1.32
L 4								
I	84	69	59	4	12	22	9	7
C(rat)	1.00	0.63	0.49	0.06	0.05	0.06	0.04	0.02
C(at%)	42.62	26.91	20.76	2.67	1.96	2.56	1.72	0.80
L 5								
I	96	82	70	5	10	17	6	6
C(rat)	1.00	0.66	0.51	0.07	0.03	0.04	0.02	0.01
C(at%)	42.69	28.03	21.59	2.92	1.44	1.74	1.00	0.60
L 6								
I	99	86	75	4	15	19	11	6
C(rat)	1.00	0.67	0.53	0.05	0.05	0.04	0.04	0.01
C(at%)	41.76	27.88	21.94	2.22	2.04	1.84	1.74	0.57
L 8								
I	121	107	91	4	14	22	16	12
C(rat)	1.00	0.68	0.52	0.04	0.04	0.04	0.05	0.02
C(at%)	41.74	28.37	21.77	1.81	1.56	1.74	2.07	0.93
L 10								
I	158	142	124	5	20	23	14	10
C(rat)	1.00	0.69	0.54	0.04	0.04	0.03	0.03	0.01
C(at%)	41.69	28.80	22.69	1.73	1.70	1.39	1.39	0.59
L 12								
I	173	181	138	6	22	27	15	11
C(rat)	1.00	0.80	0.55	0.05	0.04	0.04	0.03	0.01
C(at%)	39.58	31.83	21.90	1.80	1.62	1.42	1.29	0.57
L 14								
I	274	267	231	7	31	36	31	21
C(rat)	1.00	0.75	0.58	0.03	0.04	0.03	0.04	0.02
C(at%)	40.10	30.03	23.45	1.35	1.46	1.21	1.70	0.69
L 16								
I	314	283	274	11	31	42	30	21
C(rat)	1.00	0.69	0.61	0.05	0.03	0.03	0.04	0.02
C(at%)	40.69	28.19	24.63	1.87	1.30	1.25	1.46	0.61

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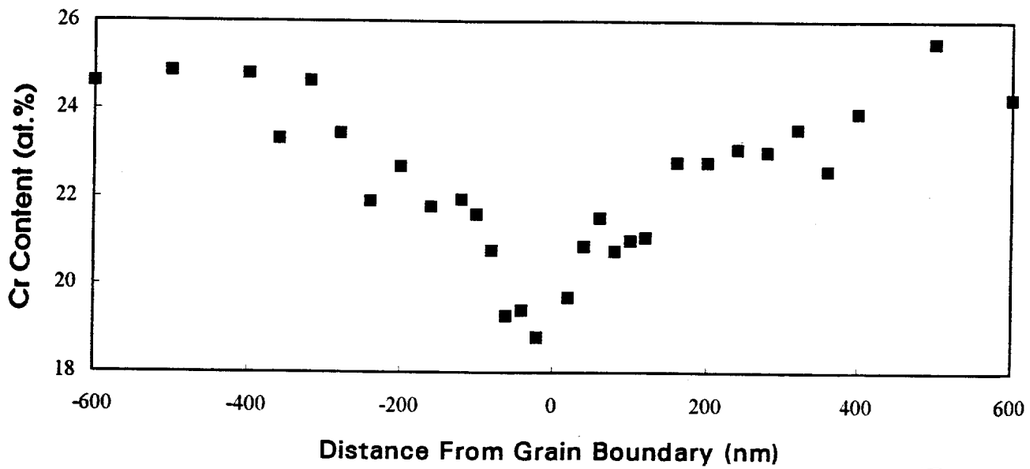
L 18								
I	395	388	328	10	36	53	35	22
C(rat)	1.00	0.76	0.58	0.03	0.03	0.03	0.03	0.01
C(at%)	40.48	30.56	23.32	1.35	1.19	1.25	1.35	0.51
L 20								
I	581	485	495	18	57	84	49	35
C(rat)	1.00	0.64	0.59	0.04	0.03	0.03	0.03	0.01
C(at%)	41.96	26.92	24.80	1.71	1.33	1.39	1.33	0.57
L 25								
I	817	688	694	22	82	105	60	36
C(rat)	1.00	0.65	0.59	0.04	0.03	0.03	0.03	0.01
C(at%)	42.17	27.30	24.85	1.49	1.37	1.24	1.16	0.42
L 30								
I	884	834	777	31	93	103	63	37
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

H 750 Fb



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Chemical Profile Analysis for 700°C/100hr Specimen

Profile 700HN (Reevaluation) polished with perchloric acid solution)

GB700HN	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	108	106	94	3	16	18	12	7
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.74	0.70	1.66	0.23	0.16	0.24	0.15
GB Region A (50nm apart)								
PPT A1								
I	44	51	392	13	7	8	13	12
C(rat)	1.00	0.86	6.24	0.49	0.04	0.03	0.07	0.04
C(at%)	11.41	9.77	71.20	5.59	0.42	0.33	0.81	0.45
PPT A2								
I	25	34	192	8	6	12	16	9
C(rat)	1.00	1.00	5.38	0.53	0.06	0.08	0.15	0.05
C(at%)	12.12	12.18	65.20	6.44	0.67	0.93	1.87	0.63
GB A1								
I	168	93	49	6	25	49	11	8
C(rat)	1.00	0.41	0.20	0.06	0.03	0.05	0.02	0.01
C(at%)	56.30	23.03	11.50	3.34	1.92	2.64	0.89	0.39
GB A2								
I	161	96	59	6	15	35	8	8
C(rat)	1.00	0.44	0.26	0.06	0.02	0.03	0.01	0.01
C(at%)	54.51	24.01	13.99	3.37	1.16	1.90	0.65	0.39
GB A3								
I	151	87	48	4	14	36	11	5
C(rat)	1.00	0.43	0.22	0.04	0.02	0.04	0.02	0.00
C(at%)	56.36	23.99	12.55	2.48	1.20	2.16	0.99	0.27
GB A4								
I	166	87	50	3	14	36	9	10
C(rat)	1.00	0.39	0.21	0.03	0.02	0.03	0.01	0.01
C(at%)	58.68	22.72	12.38	1.76	1.13	2.04	0.77	0.51
GB A5								
I	121	72	62	5	15	32	11	7
C(rat)	1.00	0.44	0.36	0.07	0.03	0.04	0.02	0.01
C(at%)	50.80	22.33	18.23	3.48	1.44	2.16	1.11	0.43
GB A12								
I	93	55	38	3	8	34	10	11
C(rat)	1.00	0.44	0.29	0.05	0.02	0.06	0.03	0.02
C(at%)	52.68	23.02	15.08	2.82	1.04	3.09	1.36	0.91
GB Region B (25nm apart)								
PPT B1								
I	29	19	76	5	3	8	5	4
C(rat)	1.00	0.48	1.84	0.29	0.02	0.04	0.04	0.02
C(at%)	26.77	12.96	49.14	7.66	0.63	1.19	1.11	0.54

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PPT B12								
I	22	11	61	4	2	10	4	4
C(rat)	1.00	0.37	1.94	0.30	0.02	0.07	0.04	0.03
C(at%)	26.47	9.78	51.41	7.99	0.55	1.93	1.16	0.70
PPT B13								
I	15	8	63	5	2	10	6	3
C(rat)	1.00	0.39	2.94	0.55	0.03	0.11	0.10	0.03
C(at%)	19.41	7.65	57.10	10.74	0.59	2.08	1.87	0.56
PPT B2								
I	10	20	106	5	4	8	6	5
C(rat)	1.00	1.48	7.42	0.83	0.09	0.13	0.14	0.07
C(at%)	8.95	13.23	66.45	7.43	0.82	1.15	1.29	0.65
PPT B22								
I	15	16	105	9	2	9	7	11
C(rat)	1.00	0.79	4.90	1.00	0.03	0.10	0.11	0.11
C(at%)	12.45	9.81	61.05	12.40	0.38	1.20	1.40	1.33
GB B1								
I	27	14	22	3	4	7	3	3
C(rat)	1.00	0.38	0.57	0.18	0.03	0.04	0.03	0.02
C(at%)	44.31	16.98	25.29	8.17	1.50	1.84	1.19	0.72
GB B2								
I	30	11	21	1	4	16	3	5
C(rat)	1.00	0.27	0.49	0.06	0.03	0.09	0.02	0.02
C(at%)	50.48	13.68	24.75	2.79	1.54	4.32	1.22	1.22

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3rd Chemical Profile Analysis for 700°C/100hr specimen

Profile 700HNP (polished with perchloric acid solution)

E700HNP	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	108	106	94	3	16	18	12	7
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.74	0.70	1.66	0.23	0.16	0.24	0.15
GB Region A (50nm apart)								
GB A1								
I	168	93	49	6	25	49	11	8
C(rat)	1.00	0.41	0.20	0.06	0.03	0.05	0.02	0.01
C(at%)	56.30	23.03	11.50	3.34	1.92	2.64	0.89	0.39
B 1								
I	94	46	35	5	7	24	9	7
C(rat)	1.00	0.36	0.26	0.09	0.02	0.04	0.02	0.01
C(at%)	55.48	20.06	14.47	4.90	0.95	2.27	1.28	0.60
B 2								
I	93	72	43	3	10	21	10	6
C(rat)	1.00	0.57	0.32	0.05	0.02	0.04	0.03	0.01
C(at%)	48.89	27.97	15.83	2.62	1.20	1.77	1.27	0.46
B 3								
I	95	83	47	3	14	12	9	7
C(rat)	1.00	0.65	0.35	0.05	0.03	0.02	0.02	0.01
C(at%)	46.90	30.27	16.25	2.46	1.58	0.95	1.07	0.50
B 4								
I	88	97	57	3	13	11	8	6
C(rat)	1.00	0.81	0.45	0.06	0.03	0.02	0.02	0.01
C(at%)	41.49	33.79	18.82	2.35	1.40	0.83	0.91	0.41
B 5								
I	110	95	66	5	10	20	8	8
C(rat)	1.00	0.64	0.42	0.08	0.02	0.03	0.02	0.01
C(at%)	45.21	28.85	19.00	3.41	0.94	1.32	0.79	0.48
B 6								
I	112	105	71	3	16	17	7	7
C(rat)	1.00	0.69	0.44	0.04	0.03	0.02	0.02	0.01
C(at%)	44.20	30.62	19.63	1.96	1.45	1.08	0.67	0.40
B 8								
I	99	98	68	3	11	12	9	6
C(rat)	1.00	0.73	0.48	0.05	0.03	0.02	0.02	0.01
C(at%)	42.76	31.27	20.57	2.15	1.09	0.83	0.94	0.38
B 10								
I	97	87	71	3	9	14	9	7
C(rat)	1.00	0.66	0.51	0.05	0.02	0.02	0.02	0.01
C(at%)	43.40	28.76	22.25	2.23	0.92	1.01	0.97	0.46
B 12								
I	107	95	86	4	10	16	10	10
C(rat)	1.00	0.66	0.56	0.06	0.02	0.02	0.02	0.01
C(at%)	42.33	27.77	23.83	2.63	0.91	1.02	0.88	0.57

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B 14								
I	119	105	85	6	11	20	7	9
C(rat)	1.00	0.65	0.50	0.08	0.02	0.03	0.01	0.01
C(at%)	43.30	28.23	21.66	3.62	0.92	1.17	0.61	0.48

B 16								
I	130	104	97	4	11	23	10	12
C(rat)	1.00	0.59	0.52	0.05	0.02	0.03	0.02	0.01
C(at%)	44.55	26.33	23.28	2.27	0.86	1.27	0.83	0.60

B 18								
I	123	95	97	5	13	23	12	10
C(rat)	1.00	0.57	0.55	0.07	0.02	0.03	0.02	0.01
C(at%)	43.86	25.03	24.23	2.96	1.06	1.32	1.03	0.52

B 20								
I	131	98	102	5	13	19	13	7
C(rat)	1.00	0.55	0.55	0.06	0.02	0.02	0.02	0.01
C(at%)	44.66	24.68	24.36	2.83	1.02	1.04	1.07	0.35

B 25								
I	108	106	94	3	16	18	12	7
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

B 30								
I	100	92	88	6	15	18	9	9
C(rat)	1.00	0.68	0.62	0.10	0.03	0.03	0.02	0.01
C(at%)	40.10	27.26	24.72	3.99	1.38	1.16	0.87	0.52

T 1								
I	92	61	38	2	9	16	5	7
C(rat)	1.00	0.49	0.29	0.04	0.02	0.03	0.01	0.01
C(at%)	52.92	25.92	15.31	1.91	1.19	1.48	0.69	0.59

T 2								
I	94	70	43	3	9	10	9	7
C(rat)	1.00	0.55	0.32	0.05	0.02	0.02	0.02	0.01
C(at%)	50.09	27.56	16.05	2.65	1.10	0.86	1.16	0.54

T 3								
I	82	60	42	3	9	8	5	11
C(rat)	1.00	0.54	0.36	0.06	0.03	0.02	0.01	0.02
C(at%)	49.14	26.57	17.63	2.98	1.24	0.77	0.72	0.96

T 4								
I	64	60	37	3	9	8	5	11
C(rat)	1.00	0.69	0.40	0.08	0.03	0.02	0.02	0.02
C(at%)	44.02	30.49	17.83	3.42	1.42	0.88	0.83	1.10

T 5								
I	68	60	41	1	7	11	7	7
C(rat)	1.00	0.65	0.42	0.02	0.02	0.03	0.02	0.01
C(at%)	45.70	29.79	19.30	1.12	1.08	1.19	1.13	0.68

T 6								
I	64	63	38	2	11	9	5	5
C(rat)	1.00	0.73	0.42	0.05	0.04	0.02	0.02	0.01
C(at%)	43.72	31.80	18.18	2.27	1.72	0.99	0.82	0.50

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T 8								
I	59	56	35	2	6	10	8	9
C(rat)	1.00	0.70	0.42	0.06	0.02	0.03	0.03	0.02
C(at%)	43.89	30.78	18.24	2.47	1.02	1.19	1.43	0.97

T 10								
I	55	50	39	2	7	10	9	7
C(rat)	1.00	0.67	0.50	0.06	0.03	0.03	0.04	0.02
C(at%)	42.64	28.64	21.18	2.57	1.24	1.25	1.68	0.79

T 12								
I	59	50	47	2	9	13	6	4
C(rat)	1.00	0.63	0.56	0.06	0.03	0.04	0.02	0.01
C(at%)	42.64	26.70	23.79	2.40	1.49	1.51	1.04	0.42

T 14								
I	50	44	43	2	9	10	6	8
C(rat)	1.00	0.65	0.60	0.07	0.04	0.03	0.03	0.02
C(at%)	40.91	26.60	24.64	2.72	1.69	1.31	1.18	0.95

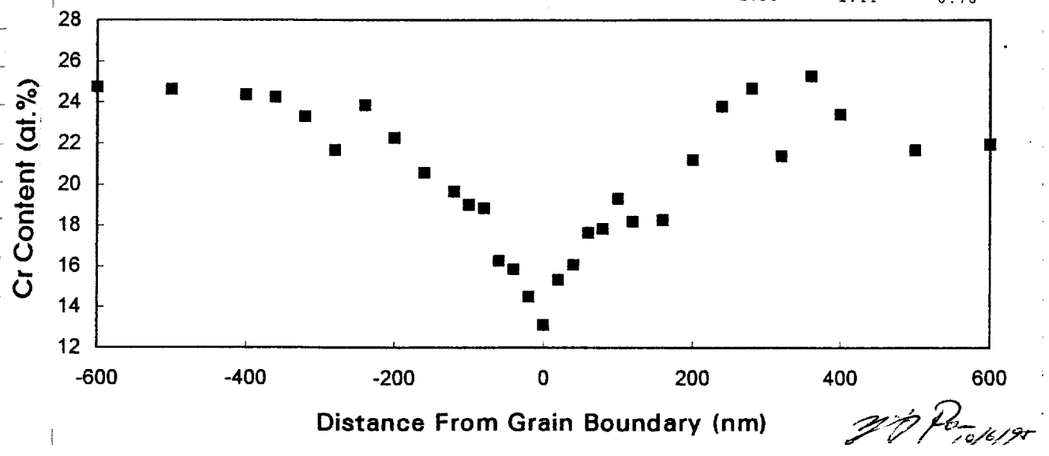
T 16								
I	52	52	39	2	8	8	9	10
C(rat)	1.00	0.74	0.53	0.06	0.04	0.02	0.04	0.03
C(at%)	40.69	30.06	21.38	2.60	1.43	1.01	1.70	1.14

T 18								
I	52	57	50	2	9	9	8	6
C(rat)	1.00	0.81	0.67	0.06	0.04	0.03	0.04	0.02
C(at%)	37.47	30.35	25.24	2.39	1.49	1.04	1.87	0.85

T 20								
I	66	60	53	3	7	10	9	6
C(rat)	1.00	0.67	0.56	0.08	0.02	0.02	0.03	0.01
C(at%)	41.59	27.93	23.39	3.14	1.01	1.01	1.37	0.55

T 25								
I	56	50	40	2	5	11	6	5
C(rat)	1.00	0.66	0.50	0.06	0.02	0.03	0.03	0.01
C(at%)	43.29	28.56	21.66	2.57	0.89	1.37	1.12	0.56

T 30								
I	57	49	42	3	7	13	8	7
C(rat)	1.00	0.64	0.52	0.09	0.03	0.04	0.03	0.02
C(at%)	42.46	26.97	21.92	3.71	1.20	1.56	1.44	0.76



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Grain Boundary Chemical Analysis for 640°C/15hr specimen

1)

A6A	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix(60sec)								
I	49	46	47	4	5	9	5	6
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.77	0.64	0.56	0.33	0.15	0.26	0.08
PPT1								
I	4	5	29	3	2	3	1	1
C(rat)	1.00	0.97	4.61	0.42	0.17	0.11	0.07	0.02
C(at%)	13.59	13.12	62.62	5.76	2.26	1.49	0.89	0.26
PPT2								
I	5	5	38	2	4	5	2	2
C(rat)	1.00	0.77	4.83	0.23	0.27	0.15	0.10	0.03
C(at%)	13.56	10.47	65.50	3.06	3.61	1.98	1.42	0.42
PPT3								
I	3	7	37	2	4	2	3	1
C(rat)	1.00	1.80	7.84	0.38	0.44	0.10	0.26	0.03
C(at%)	8.44	15.21	66.16	3.18	3.74	0.82	2.21	0.22
PPT4								
I	11	12	41	5	2	5	2	3
C(rat)	1.00	0.84	2.37	0.26	0.06	0.07	0.05	0.02
C(at%)	21.44	18.07	50.79	5.50	1.30	1.42	1.02	0.45
B 1								
I	24	29	20	2	4	3	4	3
C(rat)	1.00	0.93	0.53	0.05	0.06	0.02	0.04	0.01
C(at%)	37.92	35.39	20.09	1.78	2.10	0.69	1.66	0.36
B 2								
I	41	29	30	1	4	4	4	4
C(rat)	1.00	0.55	0.47	0.01	0.03	0.01	0.03	0.01
C(at%)	47.51	25.96	22.10	0.65	1.54	0.68	1.22	0.36
B 5								
I	40	30	25	1	4	5	4	4
C(rat)	1.00	0.58	0.40	0.01	0.03	0.02	0.03	0.01
C(at%)	48.17	27.91	19.14	0.68	1.60	0.88	1.26	0.37
B 10								
I	28	29	24	5	6	7	3	2
C(rat)	1.00	0.80	0.54	0.10	0.07	0.04	0.03	0.01
C(at%)	38.65	30.92	21.06	3.90	2.76	1.41	1.09	0.21
B 20								
I	31	31	28	1	5	5	7	3
C(rat)	1.00	0.77	0.57	0.02	0.05	0.02	0.06	0.01
C(at%)	39.86	30.79	22.88	0.73	2.14	0.94	2.36	0.30
B 30								
I	31	29	28	1	5	9	4	3
C(rat)	1.00	0.72	0.57	0.02	0.05	0.04	0.03	0.01
C(at%)	40.78	29.47	23.41	0.74	2.19	1.73	1.38	0.30

YD Rao 10/19/95

2)

A63								
PPT1								
I	14	17	100	4	3	6	5	5
C(rat)	1.00	0.93	5.46	0.43	0.09	0.07	0.06	0.04
C(at%)	12.40	11.47	67.72	5.30	1.08	0.85	0.75	0.45
PPT2								
I	58	61	86	4	7	11	8	9
C(rat)	1.00	0.80	1.13	0.10	0.05	0.03	0.02	0.02
C(at%)	31.68	25.39	35.92	3.27	1.55	0.96	0.74	0.50
PPT3								
I	542	567	651	36	118	93	48	26
C(rat)	1.00	0.80	0.92	0.10	0.09	0.03	0.01	0.00
C(at%)	33.89	27.02	31.12	3.36	2.99	0.93	0.51	0.17

3)

A6AGB	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	54	52	45	2	5	11	8	5
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.75	0.73	1.24	0.37	0.13	0.18	0.10
PPT 1-1								
I	6	5	20	2	2	2	4	2
C(rat)	1.00	0.63	2.44	0.41	0.12	0.04	0.12	0.03
C(at%)	20.83	13.07	50.80	8.64	2.55	0.91	2.51	0.71
PPT 1-2								
I	5	7	17	1	1	1	2	1
C(rat)	1.00	1.05	2.49	0.25	0.07	0.03	0.07	0.02
C(at%)	20.07	21.16	49.92	5.00	1.47	0.53	1.45	0.41
PPT 2-1								
I	21	20	23	1	2	5	1	1
C(rat)	1.00	0.72	0.80	0.06	0.03	0.03	0.01	0.00
C(at%)	37.63	26.99	30.15	2.23	1.31	1.18	0.32	0.18
PPT 4-1								
I	39	41	36	2	5	9	6	5
C(rat)	1.00	0.79	0.68	0.06	0.05	0.03	0.03	0.01
C(at%)	37.75	29.89	25.49	2.41	1.77	1.14	1.05	0.49
PPT 5-1								
I	58	55	61	4	7	10	8	7
C(rat)	1.00	0.71	0.77	0.09	0.04	0.02	0.02	0.01
C(at%)	37.40	26.71	28.78	3.21	1.66	0.85	0.93	0.46
PPT 6-1								
I	51	49	59	3	5	11	5	4
C(rat)	1.00	0.72	0.85	0.07	0.04	0.03	0.02	0.01
C(at%)	36.59	26.47	30.97	2.68	1.32	1.04	0.65	0.29

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GB 2-1								
I	20	19	17	1	2	2	3	2
C(rat)	1.00	0.72	0.62	0.06	0.04	0.01	0.03	0.01
C(at%)	40.22	28.77	25.01	2.50	1.47	0.53	1.09	0.41
GB 3-1								
I	28	22	25	3	3	7	5	2
C(rat)	1.00	0.59	0.65	0.13	0.04	0.03	0.03	0.01
C(at%)	40.16	23.76	26.23	5.36	1.58	1.32	1.30	0.29
GB 4-1								
I	39	35	38	2	9	6	5	2
C(rat)	1.00	0.68	0.71	0.06	0.08	0.02	0.02	0.01
C(at%)	38.67	26.13	27.57	2.47	3.27	0.78	0.90	0.20
GB 5-1								
I	66	57	49	2	8	11	5	5
C(rat)	1.00	0.65	0.54	0.04	0.04	0.02	0.01	0.01
C(at%)	43.12	28.04	23.42	1.63	1.92	0.94	0.59	0.33
GB 6-1								
I	66	52	46	2	8	8	7	6
C(rat)	1.00	0.59	0.51	0.04	0.04	0.02	0.02	0.01
C(at%)	44.85	26.61	22.87	1.69	1.99	0.71	0.86	0.41

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Chemical Profile Analysis for 800°C/100hr Specimen

Profile 800H51

E800H51	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	98	89	75	5	10	15	9	10
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.80	0.80	0.90	0.33	0.17	0.29	0.09
GB 1-1								
I	52	50	36	3	9	5	6	3
C(rat)	1.00	0.77	0.55	0.05	0.06	0.02	0.03	0.01
C(at%)	40.25	30.90	22.20	2.10	2.32	0.68	1.35	0.21
GB 1-2								
I	58	56	43	3	5	7	6	5
C(rat)	1.00	0.77	0.59	0.05	0.03	0.02	0.03	0.01
C(at%)	40.06	30.88	23.66	1.87	1.15	0.85	1.21	0.32
GB 1-3								
I	57	47	43	3	7	7	6	4
C(rat)	1.00	0.66	0.60	0.05	0.04	0.02	0.03	0.01
C(at%)	41.56	27.36	24.98	1.98	1.70	0.89	1.28	0.27
PPT 1								
I	12	29	260	8	5	12	10	8
C(rat)	1.00	1.93	17.26	0.60	0.14	0.17	0.24	0.06
C(at%)	4.67	9.01	80.61	2.81	0.65	0.82	1.13	0.29
PPT 2								
I	9	12	144	5	2	7	6	5
C(rat)	1.00	1.06	12.75	0.50	0.07	0.14	0.19	0.05
C(at%)	6.34	6.75	80.81	3.18	0.47	0.86	1.23	0.33
R 1								
I	46	45	33	3	5	12	7	4
C(rat)	1.00	0.78	0.57	0.06	0.04	0.05	0.04	0.01
C(at%)	39.28	30.68	22.45	2.31	1.42	1.79	1.74	0.32
R 2								
I	52	41	34	3	6	8	6	6
C(rat)	1.00	0.63	0.52	0.05	0.04	0.03	0.03	0.01
C(at%)	43.25	27.23	22.53	2.25	1.66	1.16	1.45	0.46
R 3								
I	52	45	35	2	4	5	3	6
C(rat)	1.00	0.69	0.54	0.03	0.03	0.02	0.02	0.01
C(at%)	42.89	29.64	23.00	1.49	1.10	0.72	0.72	0.46
R 4								
I	48	46	35	2	5	8	5	5
C(rat)	1.00	0.77	0.58	0.04	0.03	0.03	0.03	0.01
C(at%)	40.20	30.76	23.35	1.51	1.39	1.17	1.22	0.39

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R 5

I	44	40	32	2	5	10	5	5
C(rat)	1.00	0.73	0.58	0.04	0.04	0.04	0.03	0.01
C(at%)	40.53	29.42	23.48	1.66	1.53	1.61	1.34	0.43

R 6

I	47	49	37	4	5	8	6	4
C(rat)	1.00	0.83	0.63	0.08	0.04	0.03	0.04	0.01
C(at%)	37.78	31.45	23.69	2.91	1.34	1.12	1.41	0.30

R 8

I	49	30	30	2	4	7	7	5
C(rat)	1.00	0.49	0.49	0.04	0.03	0.02	0.04	0.01
C(at%)	47.24	23.09	23.04	1.74	1.28	1.18	1.97	0.44

R 10

I	55	42	37	2	5	7	6	5
C(rat)	1.00	0.61	0.54	0.03	0.03	0.02	0.03	0.01
C(at%)	44.03	26.85	23.60	1.45	1.33	0.98	1.40	0.37

R 12

I	51	48	37	2	4	7	4	3
C(rat)	1.00	0.75	0.58	0.04	0.03	0.02	0.02	0.01
C(at%)	40.93	30.76	23.66	1.45	1.07	0.98	0.94	0.22

R 14

I	54	48	39	2	4	7	5	3
C(rat)	1.00	0.71	0.58	0.03	0.02	0.02	0.03	0.01
C(at%)	41.70	29.60	23.99	1.40	1.03	0.95	1.13	0.21

R 16

I	65	57	49	2	6	10	5	3
C(rat)	1.00	0.70	0.60	0.03	0.03	0.03	0.02	0.00
C(at%)	41.44	29.02	24.89	1.15	1.27	1.11	0.93	0.18

R 18

I	65	60	51	2	10	9	6	4
C(rat)	1.00	0.74	0.63	0.03	0.05	0.02	0.03	0.01
C(at%)	40.03	29.50	25.02	1.11	2.05	0.97	1.08	0.23

R 20

I	74	62	57	4	7	13	7	7
C(rat)	1.00	0.67	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	41.15	27.53	25.25	2.01	1.30	1.26	1.13	0.36

R 25

I	82	80	66	4	12	14	7	7
C(rat)	1.00	0.78	0.64	0.04	0.05	0.03	0.02	0.01
C(at%)	38.83	30.25	24.90	1.71	1.89	1.16	0.97	0.31

R 30

I	92	75	70	4	10	12	9	6
C(rat)	1.00	0.65	0.61	0.04	0.04	0.02	0.03	0.01
C(at%)	41.84	27.24	25.36	1.64	1.51	0.95	1.19	0.25

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L 1

I	54	55	37	2	5	8	5	5
C(rat)	1.00	0.81	0.55	0.03	0.03	0.03	0.03	0.01
C(at%)	40.24	32.73	21.96	1.35	1.24	1.04	1.09	0.34

L 2

I	53	48	37	5	6	7	6	4
C(rat)	1.00	0.72	0.56	0.09	0.04	0.02	0.03	0.01
C(at%)	40.56	29.33	22.56	3.46	1.53	0.94	1.34	0.28

L 3

I	55	42	36	3	7	8	4	4
C(rat)	1.00	0.61	0.52	0.05	0.04	0.03	0.02	0.01
C(at%)	43.93	26.79	22.91	2.16	1.86	1.12	0.93	0.29

L 4

I	59	58	42	3	4	6	5	6
C(rat)	1.00	0.78	0.57	0.05	0.02	0.02	0.02	0.01
C(at%)	40.45	31.75	22.94	1.86	0.91	0.72	1.00	0.38

L 5

I	63	50	42	2	6	9	6	4
C(rat)	1.00	0.63	0.53	0.03	0.03	0.02	0.03	0.01
C(at%)	43.79	27.75	23.26	1.26	1.39	1.09	1.22	0.26

L 6

I	65	55	47	4	6	13	8	5
C(rat)	1.00	0.68	0.58	0.06	0.03	0.03	0.04	0.01
C(at%)	41.39	27.96	23.84	2.30	1.27	1.45	1.48	0.29

L 8

I	69	56	51	5	11	14	9	7
C(rat)	1.00	0.65	0.59	0.07	0.05	0.04	0.04	0.01
C(at%)	41.01	26.58	24.15	2.68	2.18	1.46	1.56	0.38

L 10

I	79	73	60	5	9	11	11	4
C(rat)	1.00	0.74	0.61	0.06	0.04	0.02	0.04	0.00
C(at%)	39.88	29.43	24.13	2.28	1.51	0.97	1.62	0.19

L 12

I	78	75	57	3	9	17	11	8
C(rat)	1.00	0.77	0.58	0.03	0.04	0.04	0.04	0.01
C(at%)	39.81	30.57	23.18	1.38	1.53	1.52	1.64	0.38

L 14

I	86	70	63	3	12	12	8	7
C(rat)	1.00	0.65	0.58	0.03	0.05	0.02	0.03	0.01
C(at%)	42.19	27.42	24.62	1.33	1.96	1.03	1.14	0.32

L 16

I	82	79	65	4	11	12	9	7
C(rat)	1.00	0.77	0.63	0.04	0.04	0.03	0.03	0.01
C(at%)	39.14	30.11	24.72	1.73	1.75	1.00	1.25	0.31

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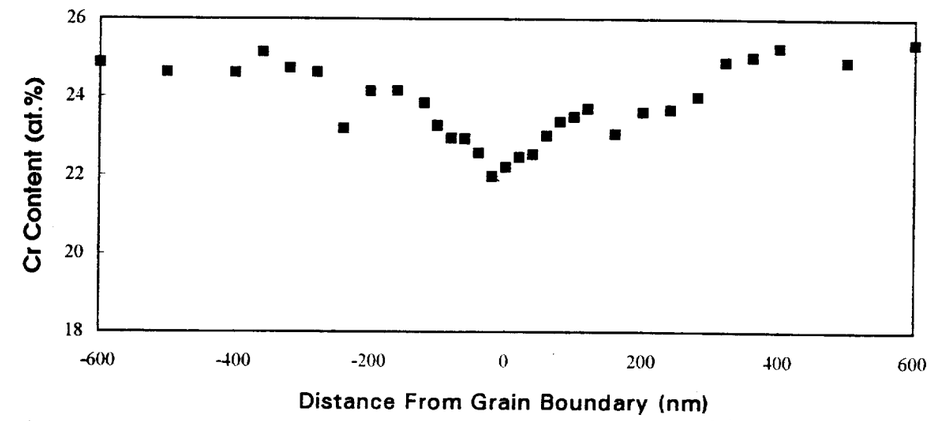
L 18								
I	90	80	71	4	11	14	14	8
C(rat)	1.00	0.71	0.63	0.04	0.04	0.03	0.05	0.01
C(at%)	40.00	28.39	25.14	1.61	1.63	1.09	1.81	0.33
L 20								
I	87	81	67	3	13	12	7	7
C(rat)	1.00	0.74	0.61	0.03	0.05	0.02	0.02	0.01
C(at%)	40.12	29.83	24.61	1.25	1.99	0.97	0.94	0.30
L 25								
I	88	84	69	6	8	15	6	8
C(rat)	1.00	0.76	0.62	0.06	0.03	0.03	0.02	0.01
C(at%)	39.42	30.05	24.62	2.43	1.19	1.18	0.78	0.33
L 30								
I	84	79	66	5	8	11	7	7
C(rat)	1.00	0.75	0.63	0.05	0.03	0.02	0.02	0.01
C(at%)	39.73	29.84	24.87	2.14	1.26	0.91	0.96	0.31



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Profile 800H52:

E800H52	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	72	62	57	3	8	12	6	5
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.84	0.77	1.11	0.31	0.16	0.32	0.14
GB 1-1								
I	38	42	30	4	5	12	5	5
C(rat)	1.00	0.93	0.61	0.12	0.04	0.05	0.04	0.02
C(at%)	35.64	33.17	21.67	4.15	1.43	1.81	1.51	0.64
GB 1-2								
I	44	44	34	4	5	10	4	2
C(rat)	1.00	0.84	0.60	0.10	0.03	0.04	0.03	0.01
C(at%)	37.82	31.85	22.51	3.80	1.31	1.38	1.10	0.23
PPT 1								
I	33	36	56	4	6	16	4	6
C(rat)	1.00	0.92	1.31	0.13	0.06	0.08	0.04	0.02
C(at%)	28.12	25.83	36.75	3.77	1.56	2.19	1.09	0.69
PPT 2								
I	57	55	95	5	5	5	6	4
C(rat)	1.00	0.81	1.28	0.10	0.03	0.01	0.03	0.01
C(at%)	30.51	24.79	39.16	2.96	0.82	0.43	1.03	0.29
PPT 3								
I	8	13	113	5	5	6	8	5
C(rat)	1.00	1.37	10.88	0.69	0.19	0.12	0.32	0.08
C(at%)	6.82	9.33	74.19	4.72	1.30	0.82	2.19	0.58
R 1								
I	37	38	29	2	6	8	4	3
C(rat)	1.00	0.86	0.60	0.06	0.05	0.03	0.03	0.01
C(at%)	37.62	32.54	22.71	2.25	1.86	1.31	1.31	0.41
R 2								
I	60	46	41	3	7	4	4	3
C(rat)	1.00	0.65	0.53	0.06	0.04	0.01	0.02	0.01
C(at%)	43.45	28.05	22.87	2.40	1.55	0.47	0.93	0.29
R 3								
I	63	47	45	3	6	7	7	5
C(rat)	1.00	0.63	0.55	0.05	0.03	0.02	0.04	0.01
C(at%)	43.02	27.03	23.66	2.27	1.25	0.77	1.54	0.46
R 4								
I	61	51	44	2	6	11	7	5
C(rat)	1.00	0.70	0.56	0.04	0.03	0.03	0.04	0.01
C(at%)	41.62	29.30	23.12	1.51	1.25	1.21	1.53	0.46

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R 5

I	57	53	43	3	6	9	7	6
C(rat)	1.00	0.78	0.58	0.06	0.03	0.03	0.04	0.01
C(at%)	39.47	30.91	22.93	2.30	1.27	1.00	1.56	0.56

R 6

I	59	52	45	2	6	12	4	5
C(rat)	1.00	0.74	0.59	0.04	0.03	0.03	0.02	0.01
C(at%)	40.58	30.12	23.84	1.52	1.26	1.33	0.88	0.47

R 8

I	60	52	47	4	7	12	5	6
C(rat)	1.00	0.73	0.60	0.07	0.04	0.03	0.03	0.01
C(at%)	39.76	29.02	23.99	2.93	1.42	1.28	1.06	0.54

R 10

I	64	56	49	3	8	8	6	6
C(rat)	1.00	0.74	0.59	0.05	0.04	0.02	0.03	0.01
C(at%)	40.33	29.72	23.78	2.09	1.54	0.81	1.21	0.51

R 12

I	74	63	54	4	7	8	7	5
C(rat)	1.00	0.72	0.56	0.06	0.03	0.02	0.03	0.01
C(at%)	41.25	29.57	23.18	2.47	1.19	0.72	1.25	0.38

R 14

I	77	63	56	3	9	9	8	5
C(rat)	1.00	0.69	0.56	0.04	0.04	0.02	0.03	0.01
C(at%)	41.86	28.84	23.44	1.80	1.50	0.79	1.40	0.37

R 16

I	72	57	54	3	8	13	10	10
C(rat)	1.00	0.67	0.58	0.05	0.03	0.03	0.04	0.02
C(at%)	41.38	27.59	23.90	1.91	1.40	1.20	1.85	0.78

R 18

I	75	79	66	4	10	11	7	6
C(rat)	1.00	0.89	0.68	0.06	0.04	0.02	0.03	0.01
C(at%)	36.65	32.51	24.84	2.16	1.49	0.86	1.10	0.40

R 20

I	81	65	67	3	11	11	8	5
C(rat)	1.00	0.68	0.64	0.04	0.04	0.02	0.03	0.01
C(at%)	40.70	27.50	25.93	1.67	1.69	0.89	1.29	0.34

R 25

I	75	67	60	3	12	14	7	8
C(rat)	1.00	0.75	0.62	0.04	0.05	0.03	0.03	0.01
C(at%)	39.43	29.66	24.29	1.74	1.93	1.18	1.18	0.57

R 30

I	72	70	60	4	10	11	6	5
C(rat)	1.00	0.82	0.64	0.06	0.04	0.02	0.03	0.01
C(at%)	38.09	31.19	24.44	2.34	1.62	0.93	1.02	0.36

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L 1

I	36	33	25	2	4	4	3	3
C(rat)	1.00	0.77	0.53	0.06	0.03	0.02	0.03	0.01
C(at%)	40.68	31.40	21.76	2.50	1.38	0.73	1.09	0.46

L 2

I	37	40	30	2	6	5	5	6
C(rat)	1.00	0.91	0.62	0.06	0.05	0.02	0.04	0.02
C(at%)	36.61	33.33	22.86	2.19	1.81	0.79	1.59	0.81

L 3

I	32	29	24	2	6	5	6	6
C(rat)	1.00	0.76	0.58	0.07	0.06	0.03	0.06	0.03
C(at%)	38.79	29.60	22.40	2.68	2.22	0.97	2.34	0.99

L 4

I	30	27	23	2	3	8	3	3
C(rat)	1.00	0.76	0.59	0.07	0.03	0.04	0.03	0.01
C(at%)	39.35	29.82	23.23	2.90	1.20	1.69	1.26	0.53

L 5

I	32	29	25	1	3	4	4	7
C(rat)	1.00	0.76	0.60	0.03	0.03	0.02	0.04	0.03
C(at%)	39.72	30.31	23.90	1.37	1.14	0.80	1.59	1.18

L 6

I	32	29	25	1	3	6	6	4
C(rat)	1.00	0.76	0.60	0.03	0.03	0.03	0.06	0.02
C(at%)	39.44	30.10	23.73	1.36	1.13	1.19	2.38	0.67

L 8

I	35	31	26	2	4	4	4	4
C(rat)	1.00	0.75	0.57	0.06	0.03	0.02	0.04	0.02
C(at%)	40.21	29.99	23.00	2.54	1.40	0.74	1.48	0.62

L 10

I	34	26	25	1	3	4	7	5
C(rat)	1.00	0.64	0.57	0.03	0.03	0.02	0.07	0.02
C(at%)	42.11	27.12	23.84	1.37	1.14	0.80	2.78	0.84

L 12

I	33	23	24	3	5	5	4	4
C(rat)	1.00	0.59	0.56	0.10	0.05	0.02	0.04	0.02
C(at%)	42.13	24.73	23.60	4.24	1.95	1.03	1.64	0.69

L 14

I	31	27	26	4	5	6	4	4
C(rat)	1.00	0.73	0.65	0.14	0.05	0.03	0.04	0.02
C(at%)	37.57	27.56	24.27	5.36	1.85	1.17	1.56	0.66

L 16

I	25	23	20	2	5	4	3	4
C(rat)	1.00	0.77	0.62	0.09	0.06	0.03	0.04	0.02
C(at%)	38.08	29.50	23.46	3.37	2.33	0.98	1.47	0.83

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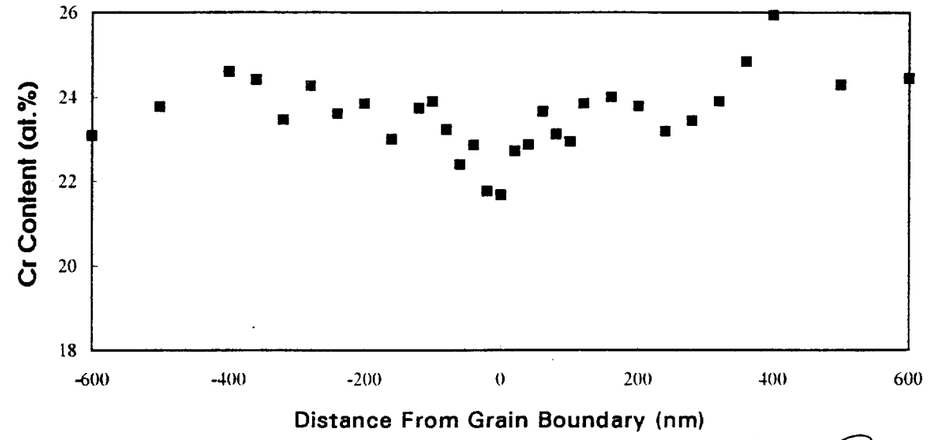
L 18								
I	26	24	21	1	3	3	3	3
C(rat)	1.00	0.78	0.62	0.04	0.04	0.02	0.04	0.02
C(at%)	39.24	30.50	24.41	1.67	1.38	0.73	1.45	0.61
L 20								
I	30	29	26	2	4	6	5	7
C(rat)	1.00	0.81	0.67	0.07	0.04	0.03	0.05	0.03
C(at%)	36.86	30.01	24.60	2.72	1.50	1.18	1.97	1.17
L 25								
I	25	22	20	2	3	5	4	5
C(rat)	1.00	0.74	0.62	0.09	0.04	0.03	0.05	0.03
C(at%)	38.57	28.58	23.76	3.41	1.41	1.24	1.98	1.05
L 30								
I	26	24	21	3	4	6	5	4
C(rat)	1.00	0.78	0.62	0.13	0.05	0.04	0.06	0.02
C(at%)	37.12	28.85	23.09	4.74	1.75	1.38	2.29	0.77



12/7/95

Profile 640H51:

E640H51	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	58	49	51	3	14	14	6	7
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.86	0.69	0.89	0.14	0.11	0.26	0.08
PPT 1								
I	27	31	78	3	10	10	5	4
C(rat)	1.00	0.99	2.00	0.10	0.05	0.04	0.05	0.01
C(at%)	23.58	23.24	47.23	2.33	1.23	0.97	1.13	0.27
PPT 2								
I	15	14	34	2	4	7	3	3
C(rat)	1.00	0.80	1.57	0.12	0.04	0.05	0.05	0.02
C(at%)	27.41	21.96	43.08	3.26	1.03	1.42	1.42	0.43
GB								
I	42	45	32	3	8	6	3	5
C(rat)	1.00	0.92	0.53	0.06	0.03	0.02	0.02	0.01
C(at%)	38.73	35.62	20.46	2.47	1.04	0.61	0.72	0.36
R 1								
I	46	42	34	2	8	8	8	6
C(rat)	1.00	0.78	0.51	0.04	0.02	0.02	0.04	0.01
C(at%)	41.09	32.20	21.06	1.59	1.01	0.79	1.85	0.42
R 2								
I	45	46	35	3	9	11	6	7
C(rat)	1.00	0.88	0.54	0.06	0.03	0.03	0.03	0.01
C(at%)	38.79	34.04	20.92	2.30	1.09	1.05	1.34	0.47
R 3								
I	46	41	35	2	8	9	4	6
C(rat)	1.00	0.77	0.53	0.04	0.02	0.02	0.02	0.01
C(at%)	41.49	31.74	21.89	1.61	1.01	0.90	0.93	0.42
R 4								
I	47	41	37	2	12	6	5	3
C(rat)	1.00	0.75	0.55	0.04	0.04	0.01	0.03	0.00
C(at%)	41.41	31.01	22.60	1.57	1.49	0.59	1.14	0.21
R 5								
I	47	35	37	2	10	9	4	5
C(rat)	1.00	0.64	0.55	0.04	0.03	0.02	0.02	0.01
C(at%)	43.39	27.73	23.68	1.65	1.30	0.92	0.96	0.36
R 6								
I	40	37	37	2	10	7	4	5
C(rat)	1.00	0.79	0.64	0.04	0.04	0.02	0.03	0.01
C(at%)	38.91	30.89	24.95	1.73	1.37	0.76	1.01	0.38

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R 8								
I	50	44	43	2	13	7	4	6
C(rat)	1.00	0.76	0.60	0.04	0.04	0.02	0.02	0.01
C(at%)	40.50	30.59	24.15	1.44	1.48	0.63	0.84	0.38

R 10								
I	48	40	42	2	12	8	5	9
C(rat)	1.00	0.72	0.61	0.04	0.04	0.02	0.03	0.01
C(at%)	40.74	29.14	24.72	1.51	1.43	0.75	1.10	0.60

R 12								
I	56	45	48	3	14	10	9	5
C(rat)	1.00	0.69	0.59	0.05	0.04	0.02	0.04	0.01
C(at%)	41.06	28.32	24.40	1.96	1.44	0.81	1.71	0.29

R 14								
I	60	53	51	3	13	8	6	5
C(rat)	1.00	0.76	0.59	0.04	0.03	0.01	0.03	0.01
C(at%)	40.49	30.70	23.86	1.80	1.23	0.60	1.05	0.26

R 16								
I	55	48	50	3	12	10	9	8
C(rat)	1.00	0.75	0.63	0.05	0.03	0.02	0.04	0.01
C(at%)	39.49	29.58	24.89	1.92	1.21	0.80	1.67	0.45

R 18								
I	56	46	49	2	14	12	6	6
C(rat)	1.00	0.71	0.61	0.03	0.04	0.02	0.03	0.01
C(at%)	41.01	28.91	24.88	1.31	1.44	0.97	1.14	0.34

R 20								
I	58	49	51	3	14	14	6	7
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

R 25								
I	61	51	53	3	12	14	6	8
C(rat)	1.00	0.72	0.60	0.04	0.03	0.03	0.03	0.01
C(at%)	40.77	29.26	24.56	1.79	1.13	1.04	1.04	0.42

R 30								
I	64	56	57	2	13	13	7	6
C(rat)	1.00	0.75	0.62	0.03	0.03	0.02	0.03	0.01
C(at%)	40.27	30.24	24.87	1.12	1.15	0.91	1.14	0.29

L 1								
I	47	40	34	3	10	9	8	7
C(rat)	1.00	0.73	0.50	0.06	0.03	0.02	0.04	0.01
C(at%)	41.74	30.49	20.94	2.37	1.25	0.89	1.84	0.49

L 2								
I	49	38	35	3	9	7	8	5
C(rat)	1.00	0.67	0.50	0.05	0.03	0.02	0.04	0.01
C(at%)	43.34	28.85	21.46	2.36	1.12	0.69	1.83	0.35

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L 3								
I	49	46	37	3	10	8	7	8
C(rat)	1.00	0.81	0.52	0.05	0.03	0.02	0.04	0.01
C(at%)	40.32	32.49	21.11	2.20	1.16	0.73	1.49	0.51

L 4								
I	42	45	39	3	8	10	5	8
C(rat)	1.00	0.92	0.64	0.06	0.03	0.03	0.03	0.01
C(at%)	36.68	33.73	23.62	2.33	0.98	0.97	1.13	0.55

L 5								
I	40	43	36	2	9	9	5	5
C(rat)	1.00	0.92	0.62	0.04	0.03	0.02	0.03	0.01
C(at%)	37.17	34.30	23.19	1.66	1.18	0.93	1.20	0.36

L 6								
I	42	38	35	2	10	7	7	5
C(rat)	1.00	0.78	0.58	0.04	0.03	0.02	0.04	0.01
C(at%)	39.98	31.05	23.10	1.70	1.34	0.74	1.72	0.37

L 8								
I	37	36	30	2	8	9	5	4
C(rat)	1.00	0.84	0.56	0.05	0.03	0.03	0.03	0.01
C(at%)	39.27	32.80	22.08	1.89	1.19	1.06	1.37	0.33

L 10								
I	40	37	34	2	7	6	5	3
C(rat)	1.00	0.79	0.59	0.04	0.02	0.02	0.03	0.01
C(at%)	39.88	31.66	23.50	1.78	0.98	0.66	1.29	0.23

L 12								
I	36	38	31	3	8	5	5	4
C(rat)	1.00	0.91	0.60	0.07	0.03	0.02	0.04	0.01
C(at%)	37.47	33.95	22.37	2.78	1.17	0.58	1.35	0.32

L 14								
I	33	40	32	3	6	4	4	3
C(rat)	1.00	1.04	0.67	0.08	0.03	0.01	0.03	0.01
C(at%)	34.83	36.24	23.42	2.82	0.89	0.47	1.09	0.25

L 16								
I	24	24	21	2	6	5	4	3
C(rat)	1.00	0.86	0.61	0.07	0.04	0.02	0.04	0.01
C(at%)	37.73	32.39	22.89	2.80	1.33	0.87	1.63	0.37

L 18								
I	17	16	15	2	5	4	4	5
C(rat)	1.00	0.81	0.61	0.10	0.04	0.03	0.06	0.02
C(at%)	37.37	30.19	22.86	3.92	1.55	0.98	2.28	0.86

L 20								
I	23	20	21	2	6	3	5	8
C(rat)	1.00	0.75	0.63	0.08	0.04	0.01	0.06	0.03
C(at%)	38.59	28.80	24.43	2.99	1.42	0.56	2.17	1.05

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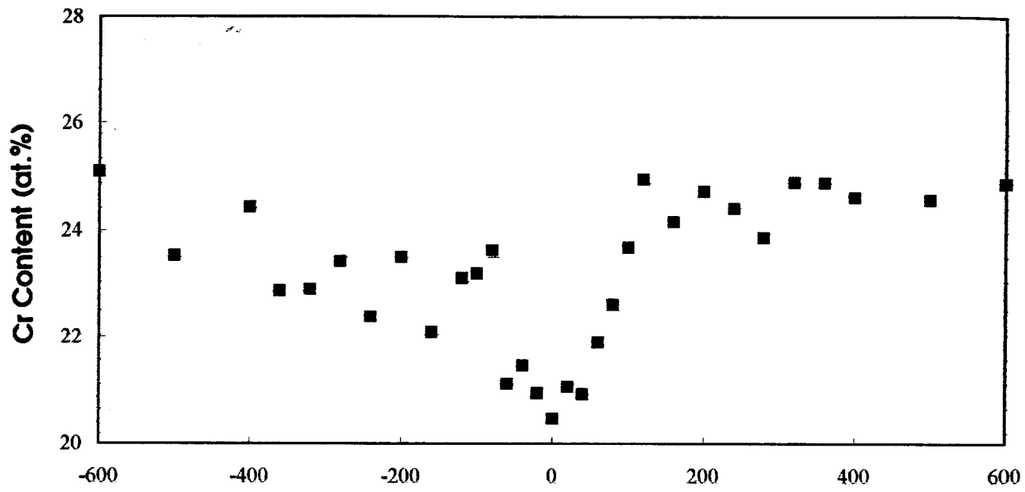
L 25								
I	19	18	17	2	4	4	3	4
C(rat)	1.00	0.81	0.62	0.09	0.03	0.02	0.04	0.02
C(at%)	37.91	30.83	23.52	3.56	1.12	0.88	1.55	0.62
L 30								
I	21	19	20	2	5	3	4	3
C(rat)	1.00	0.78	0.66	0.08	0.03	0.02	0.05	0.01
C(at%)	38.00	29.51	25.09	3.23	1.27	0.60	1.87	0.42



12/28/95

2nd Chemical Profile Analysis for 640°C/100hr Specimen

Profile 640H31:

E640H31	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	70	65	55	4	8	15	13	12
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.78	0.78	0.81	0.30	0.12	0.14	0.05
GB								
I	91	95	66	4	9	13	12	8
C(rat)	1.00	0.82	0.56	0.04	0.03	0.02	0.02	0.00
C(at%)	40.25	32.81	22.65	1.43	1.18	0.72	0.76	0.19
R 1								
I	72	60	48	3	9	15	12	8
C(rat)	1.00	0.65	0.52	0.03	0.04	0.03	0.02	0.01
C(at%)	43.57	28.35	22.54	1.46	1.62	1.13	1.05	0.27
R 2								
I	87	75	60	4	10	11	17	13
C(rat)	1.00	0.67	0.54	0.04	0.03	0.02	0.03	0.01
C(at%)	42.89	28.87	22.95	1.59	1.46	0.68	1.21	0.35
R 3								
I	77	72	57	2	8	14	13	12
C(rat)	1.00	0.73	0.57	0.02	0.03	0.02	0.02	0.01
C(at%)	41.46	30.28	23.81	0.87	1.28	0.94	1.01	0.35
R 4								
I	80	67	60	3	12	10	14	12
C(rat)	1.00	0.65	0.58	0.03	0.04	0.02	0.03	0.01
C(at%)	42.38	27.72	24.66	1.28	1.89	0.66	1.07	0.35
R 5								
I	80	69	61	2	9	14	12	8
C(rat)	1.00	0.67	0.59	0.02	0.03	0.02	0.02	0.01
C(at%)	42.23	28.44	24.99	0.85	1.41	0.92	0.91	0.23
R 6								
I	78	77	63	3	8	14	14	14
C(rat)	1.00	0.77	0.63	0.03	0.03	0.02	0.03	0.01
C(at%)	39.73	30.63	24.90	1.23	1.21	0.89	1.03	0.39
R 8								
I	75	77	61	2	12	19	13	7
C(rat)	1.00	0.80	0.63	0.02	0.05	0.03	0.02	0.01
C(at%)	39.01	31.28	24.62	0.84	1.85	1.23	0.97	0.20
R 10								
I	76	70	55	4	9	13	15	11
C(rat)	1.00	0.72	0.56	0.04	0.04	0.02	0.03	0.01
C(at%)	41.39	29.77	23.24	1.76	1.46	0.88	1.18	0.33

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R 12								
I	78	63	56	2	9	15	13	8
C(rat)	1.00	0.63	0.56	0.02	0.03	0.02	0.02	0.01
C(at%)	43.54	27.46	24.26	0.90	1.49	1.05	1.05	0.25

R 14								
I	82	67	58	3	10	15	11	11
C(rat)	1.00	0.64	0.55	0.03	0.04	0.02	0.02	0.01
C(at%)	43.44	27.72	23.84	1.28	1.57	0.99	0.84	0.32

R 16								
I	78	69	60	3	8	17	15	9
C(rat)	1.00	0.69	0.60	0.03	0.03	0.03	0.03	0.01
C(at%)	41.49	28.66	24.76	1.29	1.26	1.13	1.15	0.26

R 18								
I	83	68	61	3	9	13	15	13
C(rat)	1.00	0.64	0.57	0.03	0.03	0.02	0.03	0.01
C(at%)	43.00	27.51	24.52	1.25	1.39	0.84	1.12	0.37

R 20								
I	68	57	50	3	10	13	14	9
C(rat)	1.00	0.65	0.57	0.04	0.04	0.02	0.03	0.01
C(at%)	42.28	27.68	24.12	1.50	1.85	1.01	1.25	0.31

R 25								
I	70	65	55	4	8	15	13	12
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

R 30								
I	75	69	60	3	10	12	9	12
C(rat)	1.00	0.72	0.62	0.03	0.04	0.02	0.02	0.01
C(at%)	40.70	29.24	25.26	1.31	1.61	0.81	0.70	0.36

L 1								
I	103	91	74	3	12	12	16	11
C(rat)	1.00	0.69	0.56	0.02	0.03	0.01	0.02	0.01
C(at%)	42.58	29.38	23.74	1.00	1.47	0.62	0.95	0.25

L 2								
I	99	94	71	4	9	15	14	12
C(rat)	1.00	0.74	0.56	0.03	0.03	0.02	0.02	0.01
C(at%)	41.61	30.85	23.16	1.36	1.12	0.79	0.85	0.28

L 3								
I	96	89	72	2	12	19	16	11
C(rat)	1.00	0.72	0.58	0.02	0.04	0.02	0.02	0.01
C(at%)	41.41	29.98	24.10	0.70	1.54	1.02	0.99	0.26

L 4								
I	88	77	67	3	10	18	18	13
C(rat)	1.00	0.68	0.59	0.03	0.03	0.03	0.03	0.01
C(at%)	41.69	28.49	24.63	1.15	1.41	1.07	1.23	0.34

L 5								
I	90	71	65	3	12	19	13	11
C(rat)	1.00	0.62	0.56	0.03	0.04	0.03	0.02	0.01
C(at%)	43.54	26.82	24.40	1.17	1.72	1.15	0.91	0.29

L 6								
I	89	79	63	2	10	17	13	10
C(rat)	1.00	0.69	0.55	0.02	0.03	0.02	0.02	0.01
C(at%)	42.64	29.56	23.42	0.77	1.42	1.02	0.90	0.26

L 8								
I	80	69	59	2	8	11	11	7
C(rat)	1.00	0.67	0.57	0.02	0.03	0.02	0.02	0.00
C(at%)	42.78	28.81	24.48	0.86	1.27	0.73	0.85	0.21

L 10								
I	78	67	60	4	12	12	11	12
C(rat)	1.00	0.67	0.60	0.04	0.05	0.02	0.02	0.01
C(at%)	41.62	27.92	24.84	1.72	1.90	0.80	0.85	0.35

L 12								
I	70	62	57	2	11	9	10	9
C(rat)	1.00	0.69	0.63	0.02	0.05	0.02	0.02	0.01
C(at%)	41.03	28.38	25.92	0.95	1.92	0.66	0.84	0.29

L 14								
I	66	55	52	3	10	14	12	9
C(rat)	1.00	0.65	0.61	0.04	0.05	0.03	0.03	0.01
C(at%)	41.60	27.07	25.43	1.53	1.87	1.10	1.09	0.31

L 16								
I	60	51	45	3	12	8	11	10
C(rat)	1.00	0.66	0.58	0.04	0.06	0.02	0.03	0.01
C(at%)	41.71	27.69	24.27	1.68	2.48	0.69	1.10	0.38

L 18								
I	58	52	43	4	8	9	6	8
C(rat)	1.00	0.70	0.58	0.06	0.04	0.02	0.01	0.01
C(at%)	41.43	29.01	23.83	2.30	1.70	0.80	0.62	0.31

L 20								
I	56	44	42	3	6	8	9	6
C(rat)	1.00	0.61	0.58	0.04	0.03	0.02	0.02	0.01
C(at%)	43.15	26.48	25.11	1.86	1.37	0.77	1.00	0.25

L 25								
I	45	37	34	2	5	9	7	6
C(rat)	1.00	0.64	0.59	0.04	0.03	0.02	0.02	0.01
C(at%)	42.52	27.30	24.93	1.52	1.40	1.06	0.95	0.31

L 30								
I	42	33	30	2	7	6	7	4
C(rat)	1.00	0.61	0.55	0.04	0.05	0.02	0.02	0.01
C(at%)	43.42	26.64	24.07	1.67	2.15	0.77	1.04	0.23

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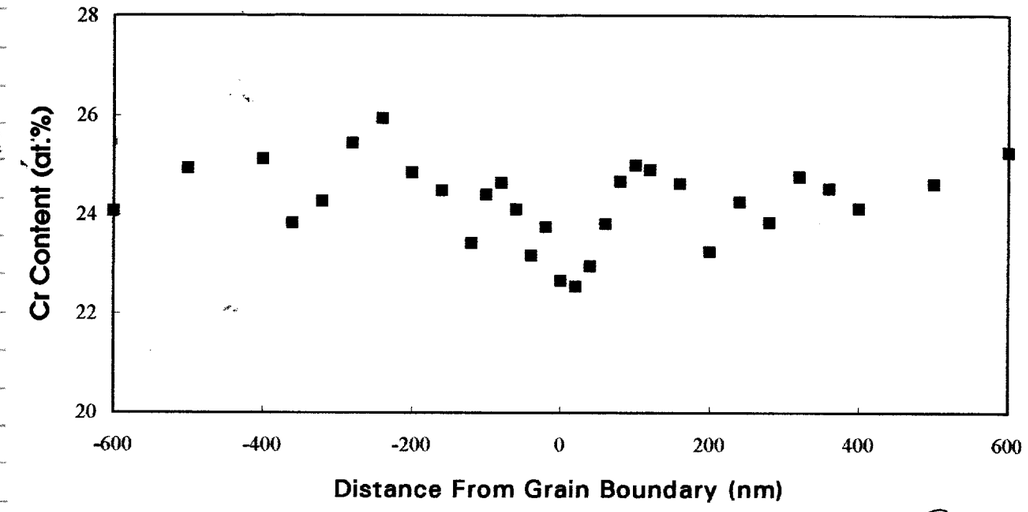

M. Pan 1/10/96

As a result of budget changes decided by the Nuclear Regulatory Commissiom for the remaining of FY 96, the Engineered Barrier System Experimental Research (EBSER) Project has been closed. Starting from January 20, 1996, the experimental research activities have been reoriented according to the prioritization of technical needs described in the Key Technical Issue of Container Life and Source Term.

The task that replaces EBSER, titled Container Life and Source Applied Technical Investigations, includes the continuation of long-term experimental studies on corrosion and stress corrosion cracking of candidate waste package materials, the long-term thermal stability, and the effect of microbial activity on the long-term performance of these materials. The scientific notebooks for activities under EBSER will continue to be used for similar activities that are contained in the new task.

N. Sridhar 12/19/96

Chemical Profile Analysis for 640°C/100hr Specimen

1) Preliminary analysis

E640T2	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	199	182	170	7	27	31	18	16
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.79	0.71	1.31	0.25	0.17	0.30	0.12
GB 1								
I	147	118	82	6	12	18	12	9
C(rat)	1.00	0.64	0.40	0.05	0.02	0.02	0.02	0.01
C(at%)	46.28	28.53	17.85	2.40	0.92	0.94	1.08	0.32
GB 12								
I	101	75	58	4	12	19	9	6
C(rat)	1.00	0.59	0.41	0.05	0.03	0.03	0.03	0.01
C(at%)	46.60	26.58	18.50	2.34	1.34	1.46	1.19	0.31
GB 2								
I	102	86	71	3	13	23	11	7
C(rat)	1.00	0.67	0.50	0.04	0.03	0.04	0.03	0.01
C(at%)	43.21	27.93	20.75	1.61	1.33	1.62	1.33	0.34
GB 22								
I	101	82	69	4	12	19	12	8
C(rat)	1.00	0.64	0.49	0.05	0.03	0.03	0.04	0.01
C(at%)	43.67	27.19	20.59	2.19	1.26	1.37	1.49	0.39
GB 23								
I	118	103	72	3	15	15	12	9
C(rat)	1.00	0.69	0.44	0.03	0.03	0.02	0.03	0.01
C(at%)	44.37	29.71	18.69	1.43	1.37	0.94	1.29	0.38
GB 3								
I	49	40	34	2	7	7	6	7
C(rat)	1.00	0.65	0.50	0.05	0.04	0.02	0.04	0.02
C(at%)	43.30	27.10	20.73	2.24	1.50	1.03	1.52	0.70
GB 32								
I	47	37	30	3	8	7	7	6
C(rat)	1.00	0.62	0.46	0.08	0.04	0.03	0.04	0.01
C(at%)	43.66	26.35	19.23	3.53	1.80	1.08	1.86	0.63
GB 33								
I	44	36	28	2	7	7	6	5
C(rat)	1.00	0.65	0.45	0.06	0.04	0.03	0.04	0.01
C(at%)	43.80	27.48	19.24	2.52	1.69	1.16	1.71	0.56
PPT 1								
I	107	100	453	15	17	17	21	14
C(rat)	1.00	0.74	3.02	0.18	0.04	0.03	0.06	0.02
C(at%)	19.66	13.89	56.65	3.44	0.75	0.51	1.09	0.29
PPT 2								
I	41	41	115	5	5	3	7	8
C(rat)	1.00	0.79	2.00	0.16	0.03	0.01	0.05	0.02
C(at%)	24.56	18.63	47.04	3.76	0.72	0.30	1.19	0.54

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2) Profile 640T21:

E640T21	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	199	182	170	7	27	31	18	16
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.79	0.71	1.31	0.25	0.17	0.30	0.12
GB								
I	147	118	82	6	12	18	12	9
C(rat)	1.00	0.64	0.40	0.05	0.02	0.02	0.02	0.01
C(at%)	46.28	28.53	17.85	2.40	0.92	0.94	1.08	0.32
R 1								
I	134	131	86	6	16	15	16	9
C(rat)	1.00	0.78	0.46	0.06	0.03	0.02	0.04	0.01
C(at%)	41.94	32.51	19.21	2.46	1.25	0.81	1.48	0.33
R 2								
I	135	128	97	5	15	18	18	10
C(rat)	1.00	0.75	0.51	0.05	0.03	0.02	0.04	0.01
C(at%)	41.46	31.17	21.26	2.01	1.15	0.95	1.64	0.36
R 3								
I	146	118	94	7	15	18	19	13
C(rat)	1.00	0.64	0.46	0.06	0.03	0.02	0.04	0.01
C(at%)	44.27	28.37	20.34	2.78	1.14	0.94	1.70	0.46
R 4								
I	194	160	136	6	28	23	18	13
C(rat)	1.00	0.65	0.50	0.04	0.04	0.02	0.03	0.01
C(at%)	43.73	28.60	21.88	1.77	1.58	0.89	1.20	0.34
R 5								
I	198	185	164	7	24	27	30	16
C(rat)	1.00	0.74	0.59	0.05	0.03	0.02	0.04	0.01
C(at%)	40.22	29.80	23.77	1.86	1.22	0.94	1.80	0.38
R 6								
I	218	187	171	6	24	33	17	21
C(rat)	1.00	0.68	0.56	0.04	0.03	0.03	0.02	0.01
C(at%)	42.30	28.77	23.68	1.53	1.17	1.10	0.98	0.48
R 8								
I	212	197	174	8	26	27	21	18
C(rat)	1.00	0.74	0.59	0.05	0.03	0.02	0.03	0.01
C(at%)	40.59	29.91	23.78	2.01	1.25	0.89	1.19	0.40
R 10								
I	223	184	177	8	24	37	19	17
C(rat)	1.00	0.65	0.57	0.05	0.03	0.03	0.03	0.01
C(at%)	42.42	27.75	24.03	1.99	1.14	1.21	1.07	0.38
R 12								
I	220	176	166	7	20	26	24	12
C(rat)	1.00	0.63	0.54	0.04	0.02	0.02	0.03	0.01
C(at%)	43.55	27.62	23.45	1.82	0.99	0.88	1.41	0.28

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R 14								
I	188	168	148	7	19	24	16	12
C(rat)	1.00	0.71	0.56	0.05	0.03	0.02	0.03	0.01
C(at%)	41.68	29.53	23.42	2.03	1.05	0.91	1.05	0.31
R 16								
I	182	156	144	7	21	26	15	15
C(rat)	1.00	0.68	0.56	0.05	0.03	0.02	0.02	0.01
C(at%)	41.98	28.53	23.70	2.12	1.21	1.03	1.02	0.41
R 18								
I	174	154	146	8	23	28	22	8
C(rat)	1.00	0.70	0.60	0.06	0.03	0.03	0.04	0.01
C(at%)	40.58	28.48	24.30	2.44	1.34	1.12	1.52	0.22
R 20								
I	168	142	134	10	21	30	17	11
C(rat)	1.00	0.67	0.57	0.08	0.03	0.03	0.03	0.01
C(at%)	41.37	27.73	23.55	3.23	1.29	1.27	1.24	0.32
R 25								
I	166	147	139	8	20	26	13	13
C(rat)	1.00	0.70	0.60	0.06	0.03	0.03	0.02	0.01
C(at%)	40.78	28.63	24.37	2.58	1.23	1.10	0.95	0.37
R 30								
I	184	173	151	6	26	29	18	14
C(rat)	1.00	0.75	0.59	0.04	0.04	0.03	0.03	0.01
C(at%)	40.42	30.13	23.67	1.73	1.43	1.09	1.17	0.36
L 1								
I	79	64	47	3	11	15	10	9
C(rat)	1.00	0.64	0.42	0.05	0.03	0.03	0.04	0.01
C(at%)	44.74	28.74	19.00	2.23	1.56	1.46	1.68	0.60
L 2								
I	83	78	59	4	6	11	11	12
C(rat)	1.00	0.75	0.51	0.06	0.02	0.02	0.04	0.02
C(at%)	41.45	30.89	21.03	2.62	0.75	0.94	1.63	0.70
L 3								
I	85	59	51	3	7	11	11	7
C(rat)	1.00	0.55	0.43	0.05	0.02	0.02	0.04	0.01
C(at%)	47.27	26.02	20.24	2.19	0.97	1.05	1.81	0.46
L 4								
I	64	65	52	3	8	14	7	5
C(rat)	1.00	0.81	0.58	0.06	0.03	0.04	0.03	0.01
C(at%)	39.11	31.49	22.68	2.40	1.22	1.47	1.27	0.36
L 5								
I	67	53	49	5	10	11	9	7
C(rat)	1.00	0.63	0.52	0.10	0.04	0.03	0.04	0.01
C(at%)	42.29	26.52	22.07	4.14	1.58	1.19	1.68	0.52
L 6								
I	71	61	55	3	10	12	14	8
C(rat)	1.00	0.68	0.55	0.06	0.04	0.03	0.06	0.01
C(at%)	41.23	28.09	22.79	2.28	1.45	1.20	2.41	0.54

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L 8								
I	67	65	46	3	6	13	8	8
C(rat)	1.00	0.77	0.49	0.06	0.02	0.03	0.04	0.01
C(at%)	41.27	31.75	20.22	2.42	0.92	1.38	1.46	0.58
L 10								
I	58	59	49	3	11	15	10	9
C(rat)	1.00	0.81	0.60	0.07	0.05	0.04	0.05	0.02
C(at%)	37.90	30.57	22.85	2.57	1.80	1.68	1.93	0.69
L 12								
I	67	54	52	4	8	13	6	5
C(rat)	1.00	0.64	0.55	0.08	0.03	0.03	0.03	0.01
C(at%)	42.20	26.97	23.37	3.30	1.26	1.41	1.12	0.37
L 14								
I	76	59	63	3	8	9	8	8
C(rat)	1.00	0.62	0.59	0.05	0.03	0.02	0.03	0.01
C(at%)	42.57	26.20	25.18	2.20	1.12	0.87	1.33	0.52
L 16								
I	71	54	56	4	8	13	7	8
C(rat)	1.00	0.60	0.56	0.07	0.03	0.03	0.03	0.01
C(at%)	42.70	25.75	24.04	3.15	1.20	1.34	1.25	0.56
L 18								
I	66	57	51	2	6	12	7	8
C(rat)	1.00	0.68	0.55	0.04	0.02	0.03	0.03	0.01
C(at%)	42.10	28.83	23.22	1.67	0.96	1.32	1.32	0.60
L 20								
I	59	51	47	3	7	11	6	7
C(rat)	1.00	0.69	0.57	0.07	0.03	0.03	0.03	0.01
C(at%)	41.22	28.25	23.43	2.75	1.22	1.32	1.24	0.57
L 25								
I	56	49	49	4	7	12	7	5
C(rat)	1.00	0.69	0.62	0.09	0.03	0.04	0.04	0.01
C(at%)	39.57	27.45	24.71	3.70	1.24	1.46	1.46	0.41
L 30								
I	52	50	45	3	10	11	6	6
C(rat)	1.00	0.76	0.62	0.08	0.05	0.04	0.03	0.01
C(at%)	38.64	29.46	23.86	2.92	1.86	1.40	1.32	0.52

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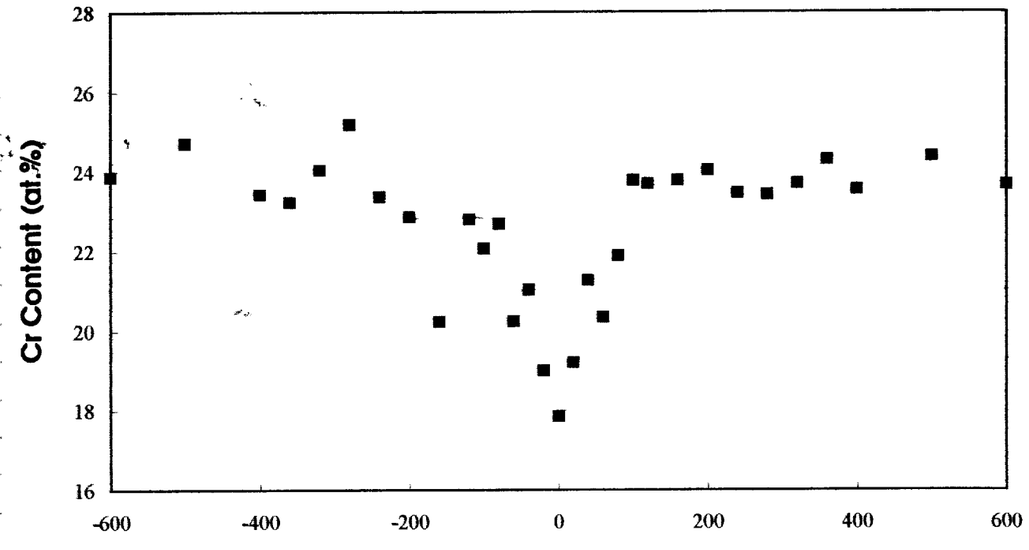

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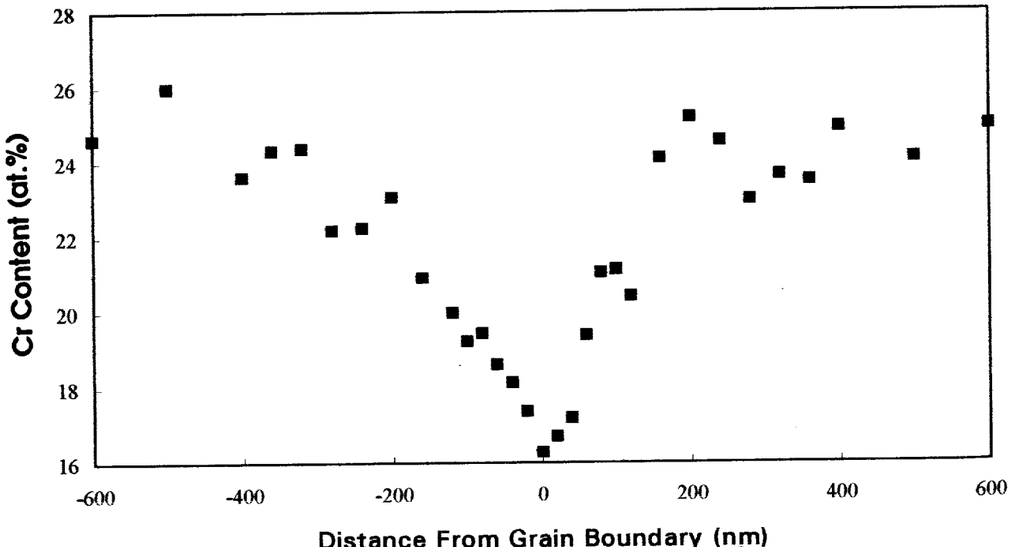
3) Profile 640T31:



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E640T31	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	302	249	231	11	34	44	19	22
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.88	0.80	1.27	0.30	0.18	0.43	0.13
GB 1								
I	98	72	44	3	11	8	6	6
C(rat)	1.00	0.65	0.36	0.04	0.03	0.01	0.03	0.01
C(at%)	47.05	30.40	16.84	1.82	1.59	0.71	1.23	0.37
GB 12								
I	84	69	39	4	12	16	7	5
C(rat)	1.00	0.72	0.37	0.06	0.04	0.03	0.04	0.01
C(at%)	43.98	31.77	16.28	2.65	1.89	1.54	1.56	0.34
GB 13								
I	100	70	47	4	11	12	7	5
C(rat)	1.00	0.62	0.37	0.05	0.03	0.02	0.03	0.01
C(at%)	46.90	28.87	17.57	2.37	1.56	1.03	1.40	0.30
R 1								
I	88	75	42	3	11	16	5	6
C(rat)	1.00	0.75	0.38	0.04	0.04	0.03	0.02	0.01
C(at%)	43.91	32.91	16.70	1.89	1.66	1.47	1.06	0.39
R 2								
I	96	81	48	4	19	13	7	7
C(rat)	1.00	0.74	0.40	0.05	0.06	0.02	0.03	0.01
C(at%)	43.13	32.01	17.19	2.27	2.57	1.07	1.34	0.41
R 3								
I	114	102	67	4	20	11	10	7
C(rat)	1.00	0.79	0.47	0.04	0.05	0.02	0.04	0.01
C(at%)	41.40	32.58	19.39	1.84	2.19	0.73	1.55	0.33
R 4								
I	136	103	82	4	14	16	12	8
C(rat)	1.00	0.67	0.48	0.04	0.03	0.02	0.04	0.01
C(at%)	43.83	29.19	21.06	1.63	1.36	0.95	1.65	0.33
R 5								
I	130	113	85	5	19	22	14	11
C(rat)	1.00	0.76	0.52	0.05	0.04	0.03	0.05	0.01
C(at%)	40.55	31.00	21.13	1.97	1.79	1.26	1.86	0.44
R 6								
I	150	149	99	6	26	18	16	7
C(rat)	1.00	0.87	0.53	0.05	0.05	0.02	0.05	0.01
C(at%)	38.82	33.91	20.42	1.97	2.03	0.86	1.76	0.23
R 8								
I	183	142	133	5	19	21	20	13
C(rat)	1.00	0.68	0.58	0.03	0.03	0.02	0.05	0.01
C(at%)	41.59	28.38	24.09	1.44	1.30	0.88	1.93	0.38

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R 10								
I	195	168	156	7	20	23	14	13
C(rat)	1.00	0.76	0.64	0.05	0.03	0.02	0.03	0.01
C(at%)	39.49	29.92	25.18	1.79	1.22	0.86	1.21	0.34

R 12								
I	248	217	195	7	36	37	23	20
C(rat)	1.00	0.77	0.63	0.04	0.04	0.03	0.04	0.01
C(at%)	39.17	30.14	24.55	1.40	1.71	1.07	1.55	0.41

R 14								
I	287	244	206	13	33	37	30	18
C(rat)	1.00	0.75	0.57	0.06	0.03	0.02	0.04	0.01
C(at%)	40.19	30.05	22.99	2.30	1.39	0.95	1.79	0.33

R 16								
I	298	273	226	10	35	44	22	21
C(rat)	1.00	0.81	0.60	0.04	0.04	0.03	0.03	0.01
C(at%)	39.13	31.53	23.65	1.66	1.39	1.06	1.23	0.36

R 18								
I	303	258	223	13	45	41	21	17
C(rat)	1.00	0.75	0.59	0.05	0.04	0.02	0.03	0.01
C(at%)	40.06	30.00	23.50	2.18	1.79	1.00	1.18	0.29

R 20								
I	316	270	249	11	38	44	21	21
C(rat)	1.00	0.75	0.63	0.04	0.04	0.03	0.03	0.01
C(at%)	39.65	29.80	24.90	1.75	1.44	1.01	1.12	0.34

R 25								
I	330	273	247	11	46	45	26	22
C(rat)	1.00	0.73	0.60	0.04	0.04	0.03	0.03	0.01
C(at%)	40.39	29.39	24.10	1.70	1.70	1.01	1.35	0.35

R 30								
I	337	291	267	10	41	40	29	20
C(rat)	1.00	0.76	0.63	0.04	0.04	0.02	0.04	0.01
C(at%)	39.51	30.01	24.95	1.48	1.45	0.86	1.45	0.30

L 1								
I	72	61	36	2	11	9	7	4
C(rat)	1.00	0.75	0.40	0.04	0.05	0.02	0.04	0.01
C(at%)	43.55	32.45	17.36	1.53	2.01	1.00	1.80	0.31

L 2								
I	78	57	39	2	12	16	6	4
C(rat)	1.00	0.64	0.40	0.03	0.05	0.04	0.03	0.01
C(at%)	45.51	29.25	18.14	1.48	2.11	1.72	1.49	0.30

L 3								
I	70	55	38	4	14	9	6	5
C(rat)	1.00	0.69	0.43	0.07	0.06	0.02	0.04	0.01
C(at%)	43.00	29.71	18.61	3.11	2.59	1.02	1.57	0.40

L 4								
I	66	64	40	2	10	9	5	4
C(rat)	1.00	0.85	0.48	0.04	0.05	0.03	0.03	0.01
C(at%)	40.24	34.32	19.44	1.54	1.84	1.01	1.30	0.32

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L 5								
I	74	75	46	3	13	12	8	5
C(rat)	1.00	0.89	0.50	0.05	0.05	0.03	0.05	0.01
C(at%)	38.82	34.60	19.23	1.99	2.06	1.16	1.79	0.34

L 6								
I	111	96	66	3	16	12	8	7
C(rat)	1.00	0.76	0.47	0.03	0.04	0.02	0.03	0.01
C(at%)	42.18	32.08	19.99	1.44	1.83	0.84	1.29	0.34

L 8								
I	142	131	92	5	16	17	10	9
C(rat)	1.00	0.81	0.52	0.04	0.03	0.02	0.03	0.01
C(at%)	40.54	32.89	20.93	1.81	1.38	0.89	1.21	0.33

L 10								
I	179	160	131	6	30	23	14	13
C(rat)	1.00	0.79	0.58	0.04	0.05	0.02	0.03	0.01
C(at%)	39.55	31.09	23.07	1.68	2.00	0.93	1.32	0.37

L 12								
I	166	168	124	8	28	28	16	9
C(rat)	1.00	0.89	0.60	0.06	0.05	0.03	0.04	0.01
C(at%)	37.36	33.25	22.24	2.28	1.90	1.16	1.53	0.26

L 14								
I	228	211	160	7	30	32	19	14
C(rat)	1.00	0.81	0.56	0.04	0.04	0.03	0.04	0.01
C(at%)	39.67	32.29	22.19	1.54	1.57	1.02	1.41	0.31

L 16								
I	247	216	191	8	30	31	21	15
C(rat)	1.00	0.77	0.62	0.04	0.04	0.02	0.04	0.01
C(at%)	39.52	30.40	24.36	1.62	1.45	0.91	1.43	0.31

L 18								
I	259	228	202	11	34	34	22	16
C(rat)	1.00	0.77	0.62	0.05	0.04	0.02	0.04	0.01
C(at%)	39.10	30.27	24.31	2.10	1.55	0.94	1.41	0.31

L 20								
I	268	239	203	10	36	39	30	14
C(rat)	1.00	0.78	0.60	0.05	0.04	0.03	0.05	0.01
C(at%)	39.11	30.68	23.61	1.85	1.58	1.05	1.86	0.26

L 25								
I	295	256	247	9	34	42	23	15
C(rat)	1.00	0.76	0.67	0.04	0.03	0.03	0.03	0.01
C(at%)	38.91	29.70	25.97	1.50	1.35	1.02	1.29	0.26

L 30								
I	302	249	231	11	34	44	19	22
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38

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Chemical Profile Analysis for 600°C/1000hr Specimen

Profile 600T5I :

	Ni	Fe	Cr	Mo	Cu	Ti	Si	Al
Bulk(at%)	40.35	29.26	24.60	1.86	1.37	1.08	1.08	0.38
Matrix								
I	88	75	71	5	9	16	11	11
C(rat)	1.00	0.73	0.61	0.05	0.03	0.03	0.03	0.01
C(at%)	40.36	29.27	24.61	1.86	1.37	1.08	1.08	0.38
k	1.00	0.85	0.76	0.81	0.33	0.15	0.21	0.08
PPT 1								
I	31	47	360	15	8	7	13	9
C(rat)	1.00	1.29	8.78	0.39	0.09	0.03	0.09	0.02
C(at%)	8.56	11.04	75.12	3.36	0.73	0.28	0.77	0.19
PPT 2								
I	112	105	346	18	16	12	14	8
C(rat)	1.00	0.80	2.33	0.13	0.05	0.02	0.03	0.01
C(at%)	22.95	18.31	53.57	2.99	1.09	0.36	0.61	0.12
GB 11								
I	146	114	68	5	14	11	8	8
C(rat)	1.00	0.66	0.35	0.03	0.03	0.01	0.01	0.00
C(at%)	47.55	31.59	16.73	1.32	1.51	0.53	0.56	0.20
GB 12								
I	140	97	81	5	16	11	11	7
C(rat)	1.00	0.59	0.44	0.03	0.04	0.01	0.02	0.00
C(at%)	47.04	27.73	20.57	1.36	1.78	0.54	0.79	0.18
GB 21								
I	127	106	72	4	15	14	8	8
C(rat)	1.00	0.71	0.43	0.03	0.04	0.02	0.01	0.00
C(at%)	44.69	31.74	19.14	1.14	1.75	0.73	0.60	0.21
GB 22								
I	134	104	87	3	10	17	10	9
C(rat)	1.00	0.66	0.49	0.02	0.02	0.02	0.02	0.01
C(at%)	44.77	29.56	21.96	0.81	1.11	0.84	0.72	0.23
GB 31								
I	153	130	94	4	18	19	17	15
C(rat)	1.00	0.72	0.46	0.02	0.04	0.02	0.02	0.01
C(at%)	43.54	31.48	20.21	0.92	1.70	0.80	1.04	0.32
GB 32								
I	160	133	75	3	18	17	10	10
C(rat)	1.00	0.71	0.35	0.02	0.04	0.02	0.01	0.00
C(at%)	46.56	32.93	16.49	0.71	1.74	0.73	0.62	0.22
GB 41								
I	85	69	52	3	10	13	7	5
C(rat)	1.00	0.69	0.46	0.03	0.04	0.02	0.02	0.00
C(at%)	44.15	30.49	20.41	1.26	1.72	0.99	0.78	0.20
GB 42								
I	80	64	58	4	10	11	7	6
C(rat)	1.00	0.68	0.55	0.04	0.04	0.02	0.02	0.01
C(at%)	42.46	28.90	23.26	1.72	1.76	0.86	0.80	0.24

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GB 51								
I	112	86	60	8	13	17	11	6
C(rat)	1.00	0.65	0.40	0.06	0.04	0.02	0.02	0.00
C(at%)	45.41	29.67	18.38	2.63	1.75	1.01	0.95	0.18
GB 52								
I	111	86	53	4	11	19	13	6
C(rat)	1.00	0.66	0.36	0.03	0.03	0.03	0.03	0.00
C(at%)	46.81	30.86	16.89	1.37	1.54	1.18	1.17	0.19
R 1								
I	124	89	67	4	13	22	11	7
C(rat)	1.00	0.61	0.41	0.03	0.03	0.03	0.02	0.00
C(at%)	46.96	28.68	19.17	1.23	1.63	1.23	0.89	0.20
R 2								
I	116	88	74	3	12	18	18	11
C(rat)	1.00	0.65	0.48	0.02	0.03	0.02	0.03	0.01
C(at%)	44.52	28.74	21.46	0.93	1.53	1.02	1.48	0.32
R 3								
I	112	95	70	5	13	19	12	9
C(rat)	1.00	0.72	0.47	0.04	0.04	0.02	0.02	0.01
C(at%)	43.05	31.07	20.33	1.56	1.66	1.08	0.99	0.26
R 4								
I	106	90	75	4	14	16	11	11
C(rat)	1.00	0.72	0.53	0.03	0.04	0.02	0.02	0.01
C(at%)	41.95	30.31	22.43	1.28	1.84	0.93	0.93	0.33
R 5								
I	100	97	79	3	12	18	14	9
C(rat)	1.00	0.83	0.60	0.02	0.04	0.03	0.03	0.01
C(at%)	39.22	32.37	23.41	0.95	1.56	1.04	1.18	0.27
R 6								
I	104	87	73	6	14	17	10	9
C(rat)	1.00	0.71	0.53	0.05	0.04	0.02	0.02	0.01
C(at%)	41.93	29.84	22.24	1.96	1.87	1.01	0.86	0.27
R 8								
I	103	86	77	4	13	19	12	9
C(rat)	1.00	0.71	0.56	0.03	0.04	0.03	0.02	0.01
C(at%)	41.54	29.51	23.47	1.31	1.74	1.13	1.04	0.27
R 10								
I	101	108	94	6	8	20	18	10
C(rat)	1.00	0.91	0.70	0.05	0.03	0.03	0.04	0.01
C(at%)	36.20	32.94	25.46	1.74	0.95	1.06	1.38	0.27
R 12								
I	113	105	93	5	11	20	12	10
C(rat)	1.00	0.79	0.62	0.04	0.03	0.03	0.02	0.01
C(at%)	39.43	31.17	24.52	1.42	1.27	1.03	0.90	0.26
R 14								
I	107	102	94	5	10	18	8	7
C(rat)	1.00	0.81	0.66	0.04	0.03	0.02	0.02	0.00
C(at%)	38.62	31.32	25.64	1.46	1.20	0.96	0.62	0.19

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R 16								
I	105	110	85	4	15	21	14	12
C(rat)	1.00	0.89	0.61	0.03	0.05	0.03	0.03	0.01
C(at%)	37.76	33.66	23.10	1.17	1.79	1.11	1.08	0.33
R 18								
I	96	103	90	7	8	16	12	8
C(rat)	1.00	0.91	0.71	0.06	0.03	0.02	0.03	0.01
C(at%)	36.16	33.01	25.62	2.14	1.00	0.89	0.97	0.23
R 20								
I	95	87	81	4	8	21	13	11
C(rat)	1.00	0.78	0.64	0.03	0.03	0.03	0.03	0.01
C(at%)	39.12	30.48	25.20	1.34	1.09	1.27	1.15	0.34
R 25								
I	94	89	79	3	9	16	9	11
C(rat)	1.00	0.81	0.64	0.03	0.03	0.03	0.02	0.01
C(at%)	39.17	31.55	24.88	1.01	1.25	0.98	0.80	0.35
R 30								
I	95	73	75	5	11	11	14	11
C(rat)	1.00	0.65	0.60	0.04	0.04	0.02	0.03	0.01
C(at%)	41.86	27.37	24.97	1.79	1.61	0.71	1.32	0.37
L 1								
I	82	65	44	3	9	10	10	6
C(rat)	1.00	0.67	0.41	0.03	0.04	0.02	0.03	0.01
C(at%)	45.55	30.72	18.47	1.35	1.66	0.82	1.19	0.25
L 2								
I	66	65	38	2	6	11	8	7
C(rat)	1.00	0.84	0.44	0.02	0.03	0.02	0.03	0.01
C(at%)	41.91	35.12	18.23	1.03	1.26	1.03	1.09	0.33
L 3								
I	80	53	46	3	8	16	9	11
C(rat)	1.00	0.56	0.43	0.03	0.03	0.03	0.02	0.01
C(at%)	47.04	26.52	20.44	1.43	1.56	1.38	1.13	0.49
L 4								
I	68	51	45	3	9	11	10	11
C(rat)	1.00	0.64	0.50	0.04	0.04	0.02	0.03	0.01
C(at%)	43.76	27.92	21.88	1.57	1.92	1.04	1.38	0.53
L 5								
I	59	61	41	2	9	10	11	9
C(rat)	1.00	0.88	0.53	0.03	0.05	0.02	0.04	0.01
C(at%)	39.07	34.37	20.52	1.07	1.98	0.97	1.56	0.45
L 6								
I	55	56	44	3	8	14	8	6
C(rat)	1.00	0.87	0.60	0.04	0.05	0.04	0.03	0.01
C(at%)	37.88	32.82	22.90	1.68	1.83	1.42	1.18	0.31
L 8								
I	61	57	49	2	6	12	8	6
C(rat)	1.00	0.80	0.61	0.03	0.03	0.03	0.03	0.01
C(at%)	39.59	31.48	24.03	1.05	1.29	1.15	1.11	0.29

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L 10								
I	44	39	38	2	4	10	8	5
C(rat)	1.00	0.75	0.65	0.04	0.03	0.03	0.04	0.01
C(at%)	39.14	29.52	25.54	1.44	1.18	1.31	1.52	0.34
L 12								
I	41	30	32	3	6	10	6	4
C(rat)	1.00	0.62	0.59	0.06	0.05	0.04	0.03	0.01
C(at%)	41.76	26.00	24.63	2.48	2.03	1.50	1.31	0.31
L 14								
I	49	42	43	2	7	10	12	8
C(rat)	1.00	0.73	0.66	0.03	0.05	0.03	0.05	0.01
C(at%)	38.94	28.40	25.82	1.29	1.85	1.17	2.04	0.48
L 16								
I	46	47	42	2	7	6	7	5
C(rat)	1.00	0.87	0.69	0.04	0.05	0.02	0.03	0.01
C(at%)	36.97	32.14	25.51	1.30	1.87	0.71	1.20	0.30
L 18								
I	56	44	46	4	5	9	11	7
C(rat)	1.00	0.67	0.62	0.06	0.03	0.02	0.04	0.01
C(at%)	40.78	27.26	25.31	2.36	1.21	0.96	1.72	0.38
L 20								
I	48	42	41	3	8	10	11	7
C(rat)	1.00	0.74	0.65	0.05	0.06	0.03	0.05	0.01
C(at%)	38.66	28.78	24.95	1.96	2.14	1.19	1.90	0.42
L 25								
I	63	58	52	3	9	16	12	9
C(rat)	1.00	0.78	0.62	0.04	0.05	0.04	0.04	0.01
C(at%)	38.73	30.34	24.16	1.50	1.84	1.45	1.58	0.42
L 30								
I	78	72	69	4	10	18	14	11
C(rat)	1.00	0.79	0.67	0.04	0.04	0.03	0.04	0.01
C(at%)	38.15	29.96	25.50	1.59	1.62	1.30	1.47	0.41

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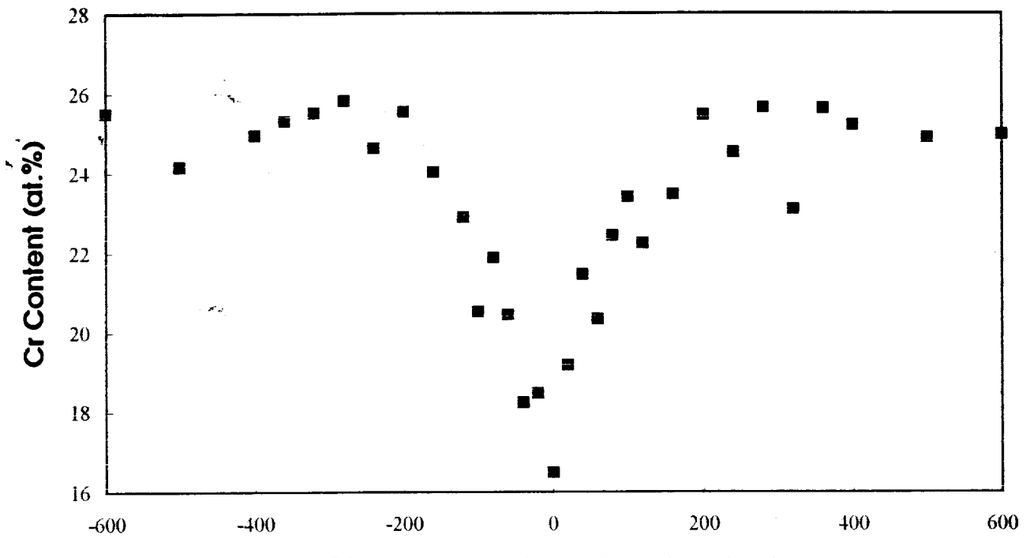


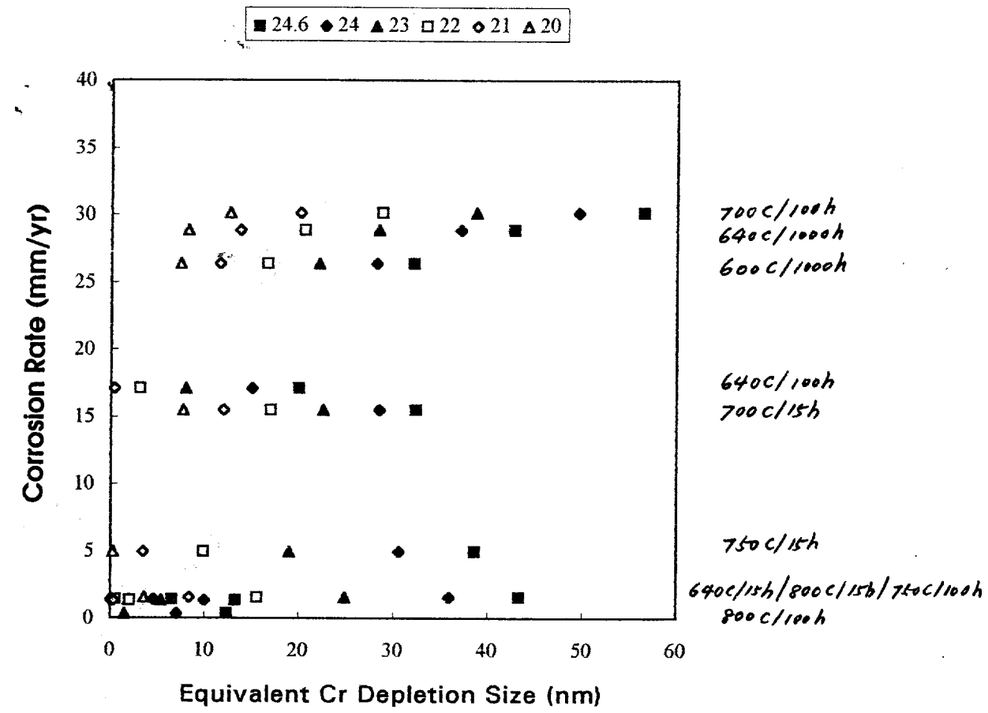
Chromium Depletion Parameter Analysis

Summary Table:

Specimen	Corr Rate	Inv CRx10	Depl Vol (nm)						
	mm/yr		24.60%	24%	23%	22%	21%	20%	19%
SA	0.116	86.207							
640C/15h	1.397	7.158	6.6	4.6	2	0.51	0.06		
700C/15h	15.459	0.647	32.4	28.5	22.6	17	12	7.7	4.2
700C/100h	30.095	0.332	56.5	49.6	38.7	28.8	20.1	12.6	6.6
750C/15h	4.937	2.026	38.6	30.6	19	9.9	3.5	0.27	
800C/15h	1.315	7.605	13.3	10	5.4	2.1	0.36		
638C/1000h	38.688	0.258	78.1	72.2	62.7	53.5	44.7	36.5	28.7
750C/100h	19.49	0.513	43.3	35.9	24.9	15.6	8.4	3.6	1.3
638C/1000h(S)									
638C/1000h			78.1	72.2	62.7	53.5	44.7	36.5	28.7
640C/100h	17.1		20	15	8	3.1	0.4		
800C/100h	0.34		12.4	7.1	1.5				
600C/1000h	26.33		32.1	28.2	22.1	16.6	11.6	7.4	4
640C/1000h	28.83		42.8	37.1	28.4	20.6	13.7	8.2	4

		Temp(C)	Erp(mV)	min Cr(%)	
18%	17%				
		640	155	21.1	
1.72		700	142	16.5	
2.37	0.21		79	16.6	
		750	163	19.6	
		800	171	20.4	
21.5	15.1	640		12.5	
		750		19.96	17.6
				20.8	
21.5	15.1	638		12.5	
		640	147	20.46	22.65
		800	119	21.67	22.2
1.5	0.2	600	108	16.49	
1.4		640	93	17.85	16.28

Cr Depletion Size Vs. Corrosion Rate Plot:



M Pa
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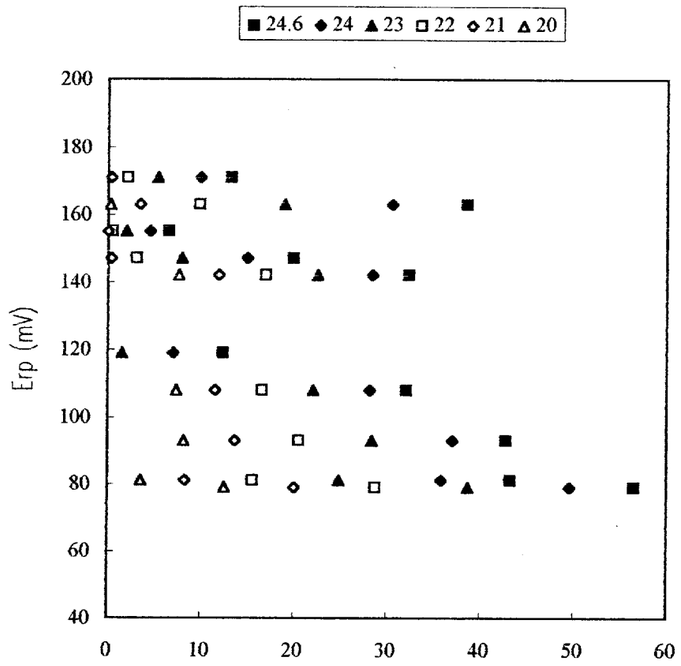
Cr Depletion size vs. Erp plot:



M Pa
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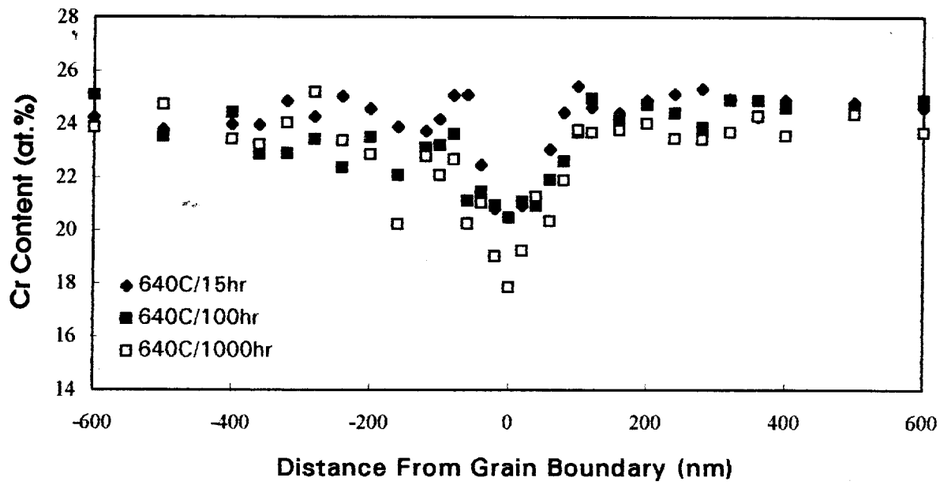
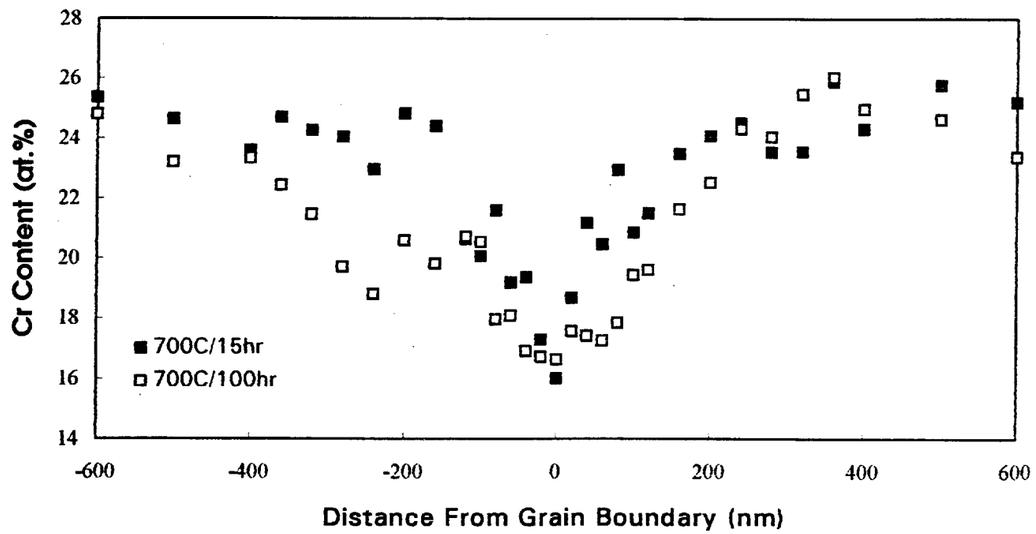
Chromium Depletion Profiles Summary

1) Chromium depletion profiles were plotted in relation to aging time for various heat treatment temperatures.

a. 640°C



b. 700°C



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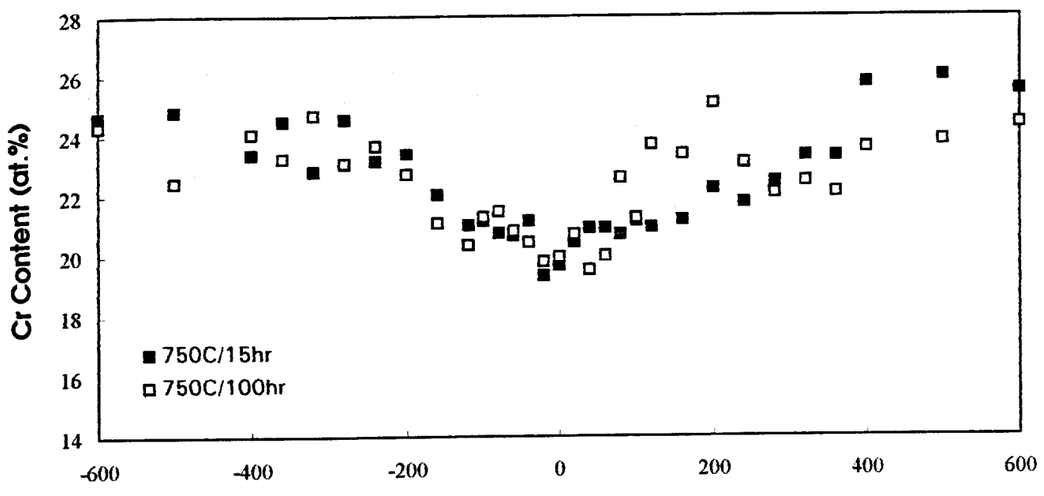
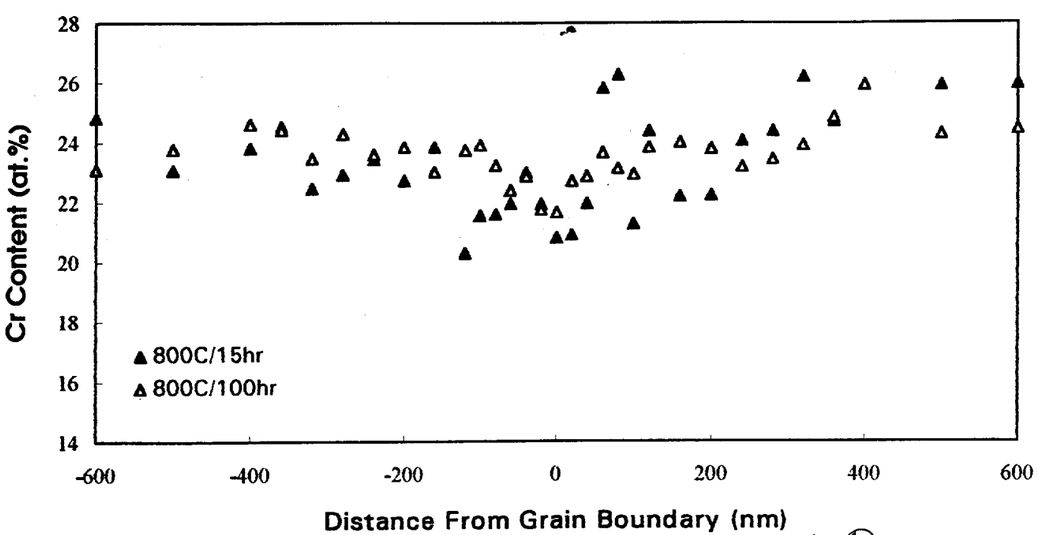
c. 750°C



d. 800C



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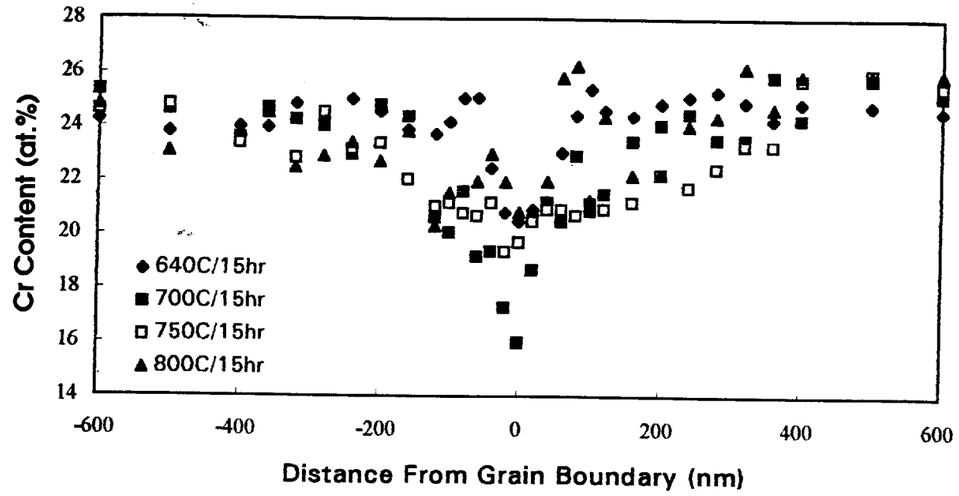
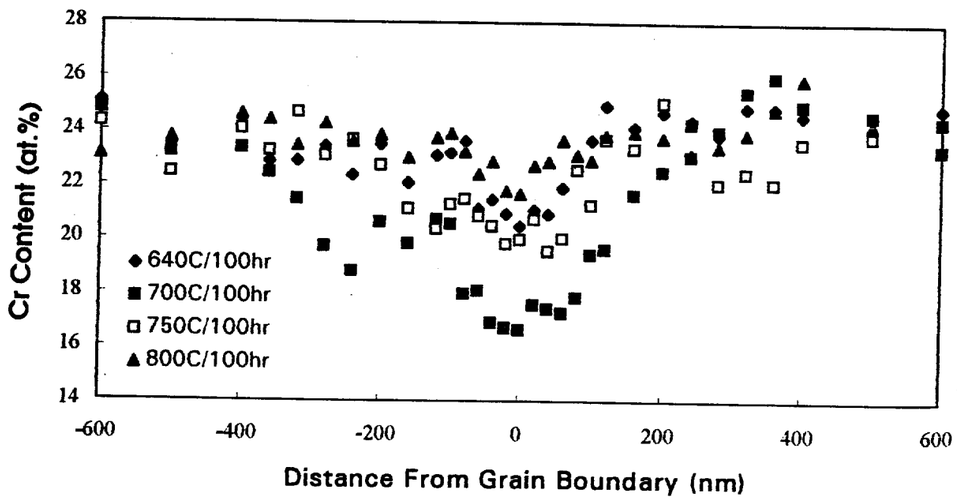
2) Effect of heat treatment temperature

a. 15 hr



b. 100 hr



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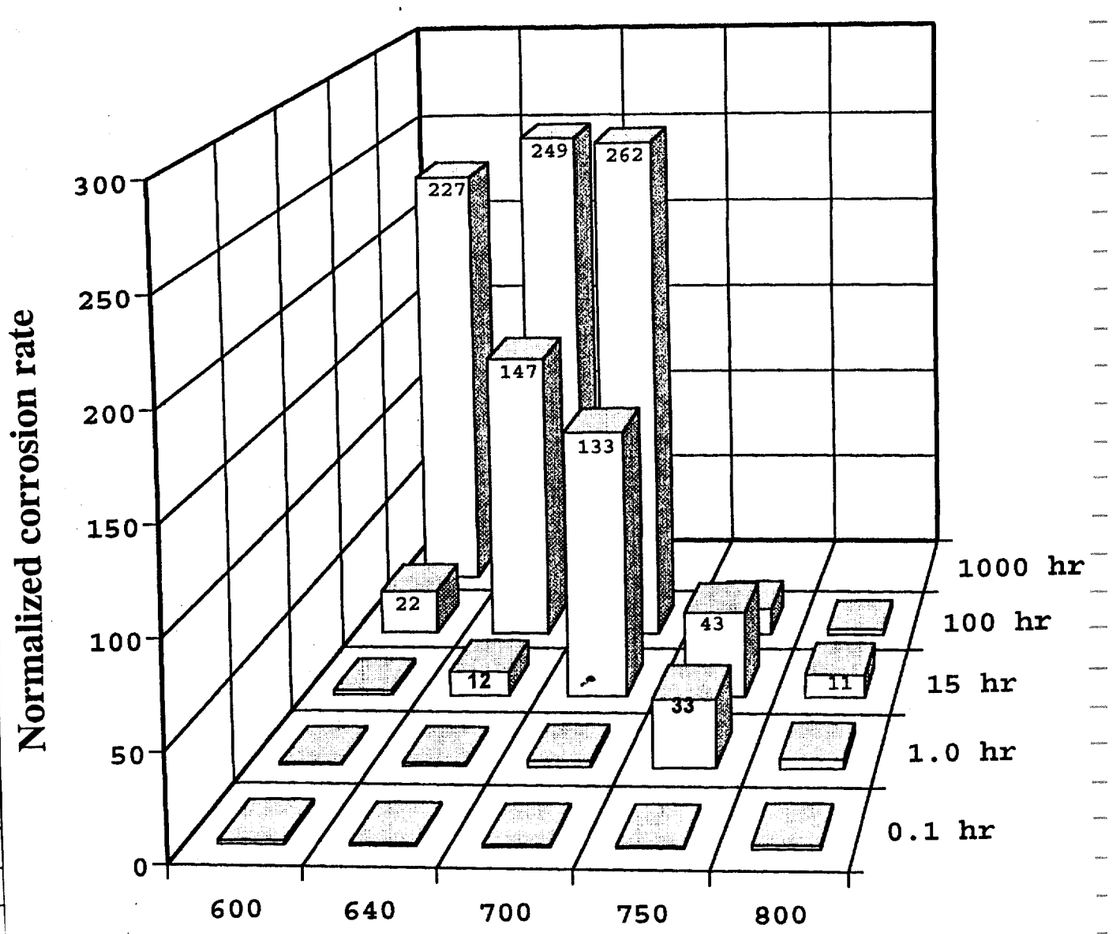
Correlation of Chromium Depletion to Corrosion Data

1) Effect of heat treatment temperature and time on corrosion rate



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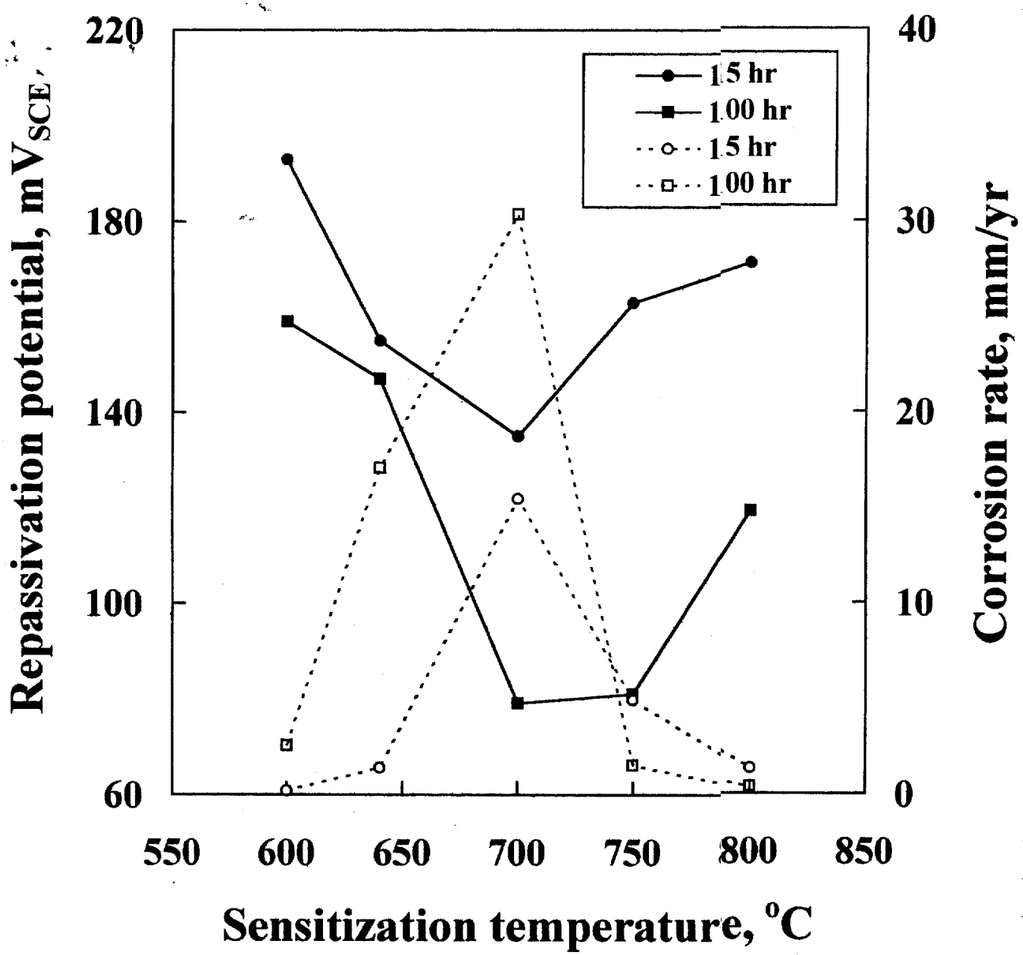
2) Correlation of depletion sensitization to repassivation potential, E_{rp}, and corrosion rate.



W D Pa
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Modelling of Chromium Depletion in 304 stainless steels 316

1) Cr concentration profile based on diffusion controlled growth of carbides. [HALLBRI 84]

$$\frac{\partial C(\bar{r},t)}{\partial t} = D\frac{\partial^2 C(\bar{r},t)}{\partial r^2} + \left(\frac{2D}{r}\right)\frac{\partial C(\bar{r},t)}{\partial r}$$

Boundary conditions:

$C(\bar{r},0) = C_M$ (bulk concentration)

$C(\bar{r}_e,t) = C_e$ (interfacial concentration),

Solution:

$$C(\bar{r},t) = C_M + (C_e - C_M)\cdot\left\{\frac{\frac{e^{-r^2/4Dt}}{r/\sqrt{Dt}} - \frac{\sqrt{\pi}}{2}\left[1-erf(r/2\sqrt{Dt})\right]}{\frac{e^{-r_e^2/4Dt}}{r_e/\sqrt{Dt}} - \frac{\sqrt{\pi}}{2}\left[1-erf(r_e/2\sqrt{Dt})\right]}\right\}$$

D – diffusion coefficient

$D = 1.39\times10^{-16}\ cm^2/s$ @ 650°C

$8.62\times10^{-16}\ cm^2/s$ @ 700°C

$r_e = 0.1\ \mu m$

2) Cr depletion width [BRO 90]

$$W_{Cr} = 2\sqrt{D_{Cr}\cdot t}\cdot\left(\frac{X'_{Cr}-X_{Cr}}{C_r - X_{Cr}}\right)$$

X'_{Cr} – critical Cr content for GB attack

X_{Cr} – Cr content at carbide interface

C_r – bulk Cr level

$D_{Cr} = 0.08\exp[-58500\ (cal/mol)/RT]$ for 304 SS.

$D_{Cr} = 0.33\exp[-63900\ (cal/mol)/RT]$ for 316 SS.

W D Pa
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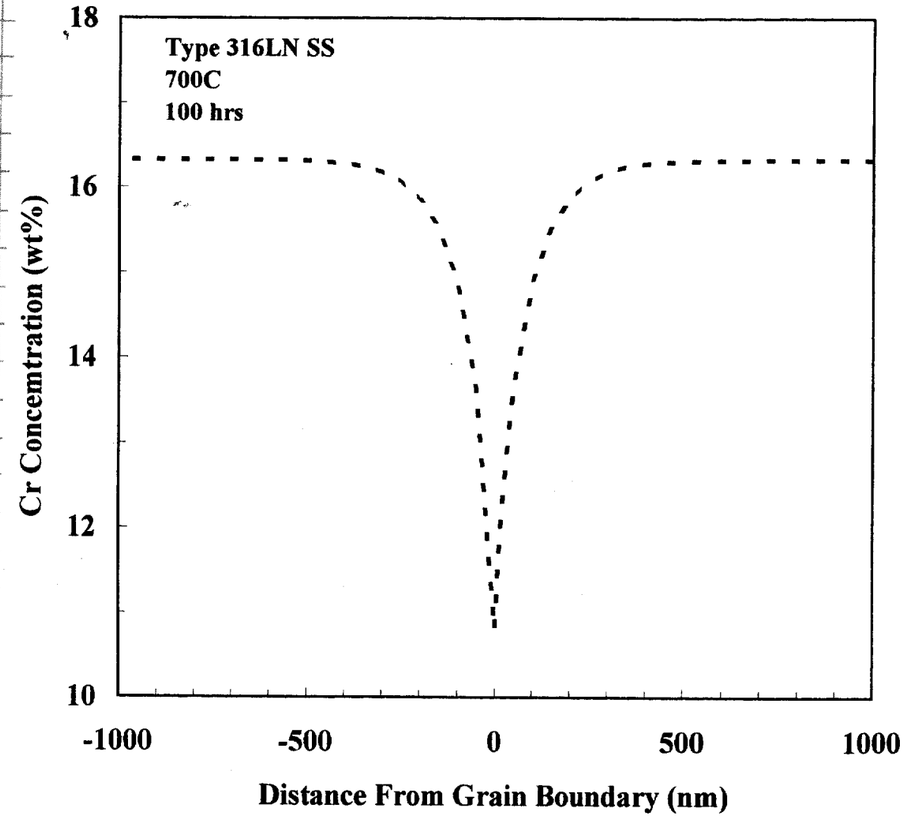
3) Results

a. Cr conc. profile for 316 S.S.



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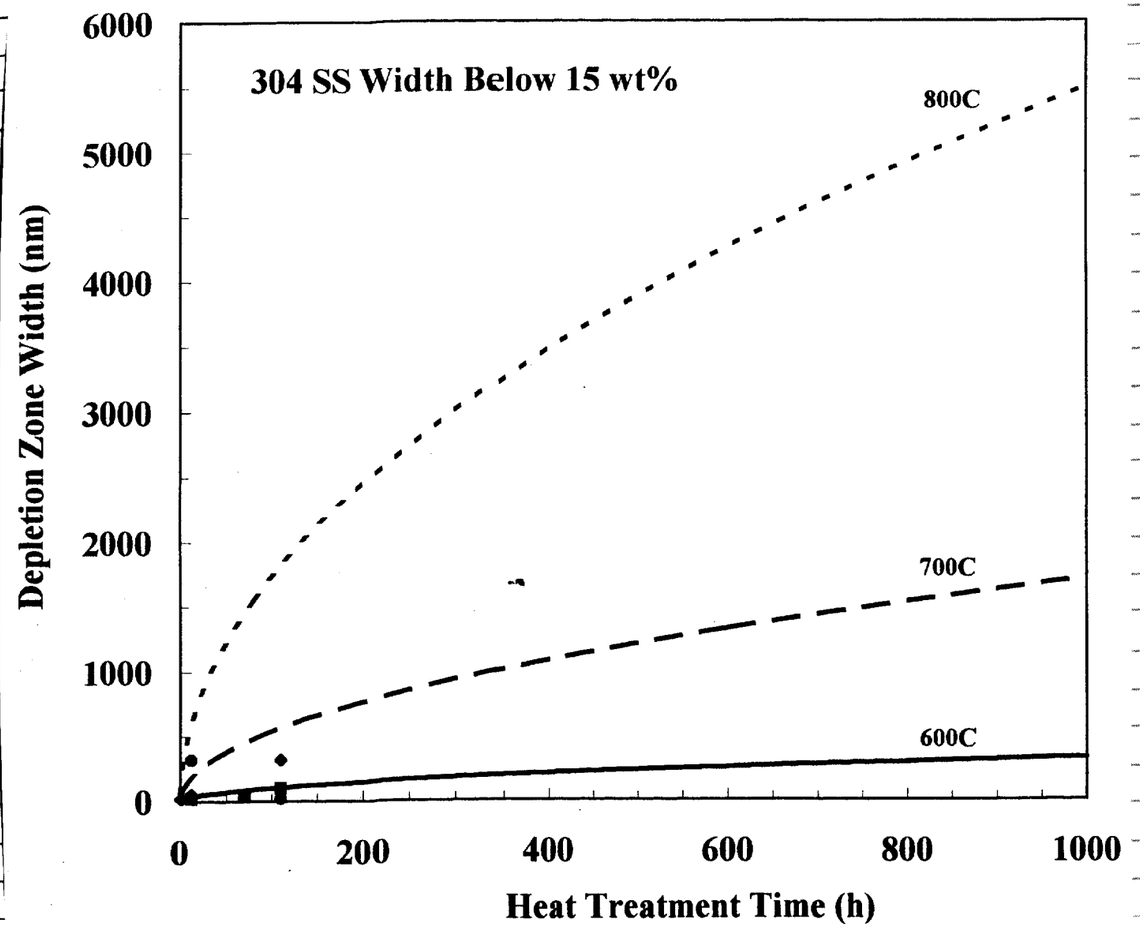
b. Cr depletion width vs. aging time plots



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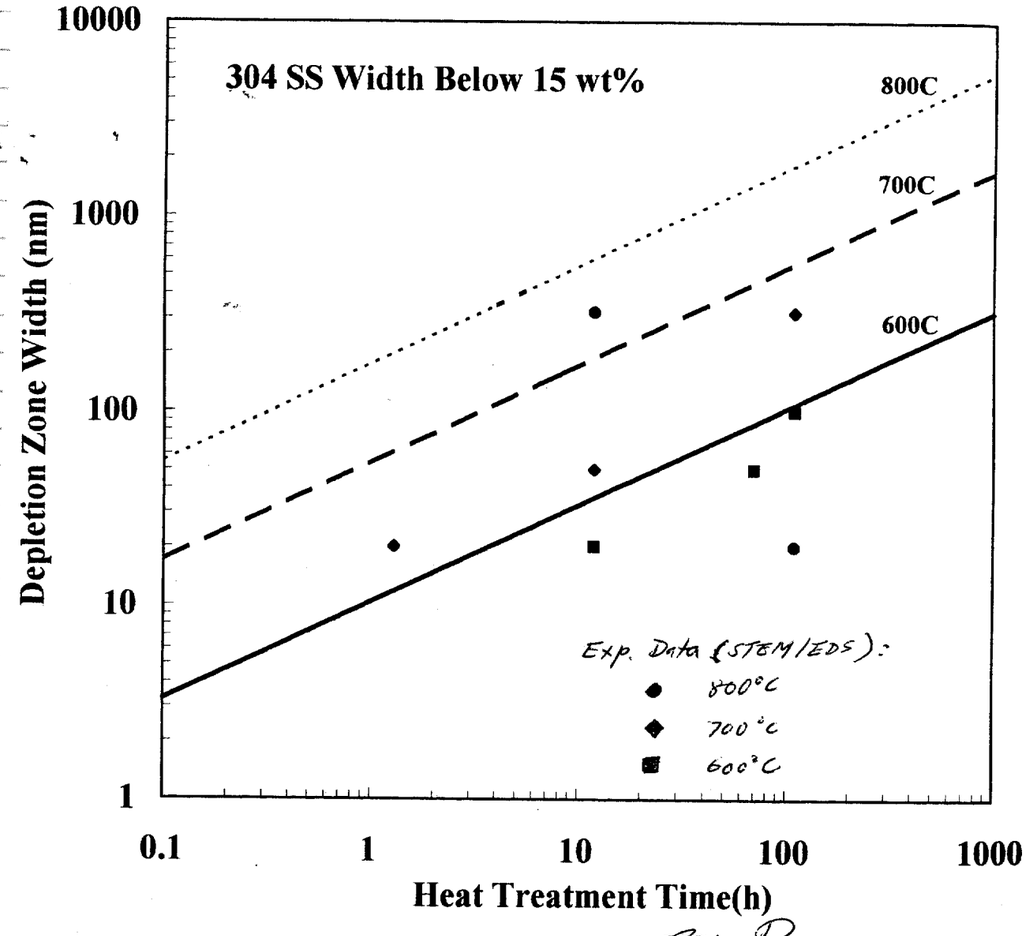


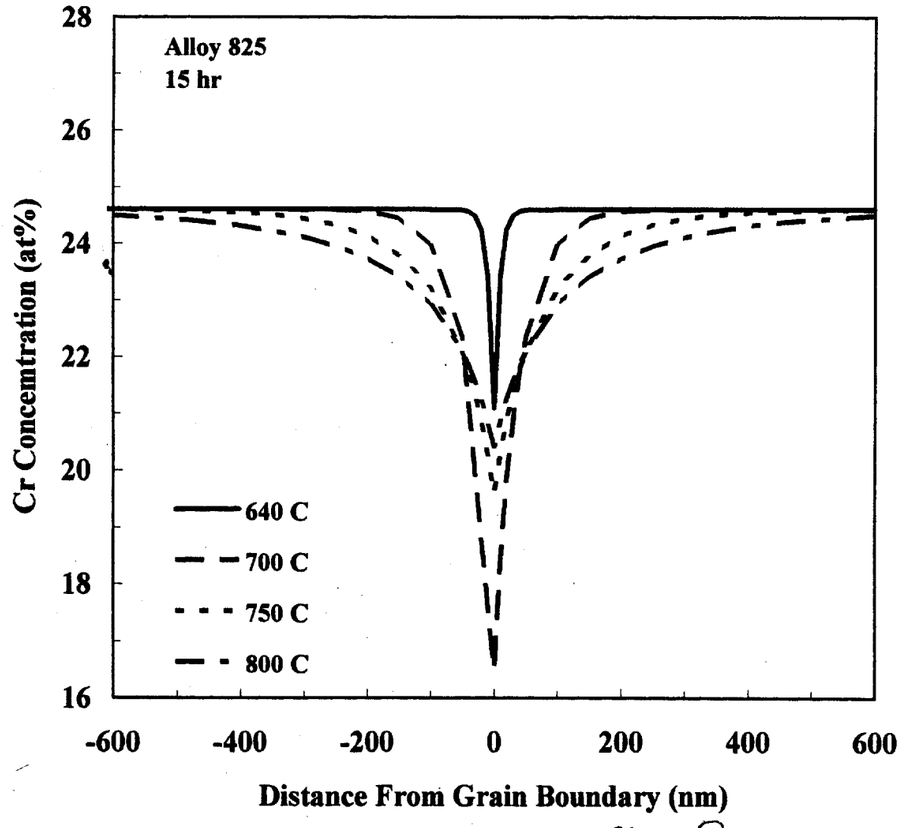
5/24/96

1) Cr depletion profile was calculated for 825 alloy based on the equations in page 248. Diffusion coefficients were calculated using the relation from [PAU/KAI 94].

$$D_{Cr} = 3.24 \exp\left[-287.4\ (kJ/mol)/RT\right]$$

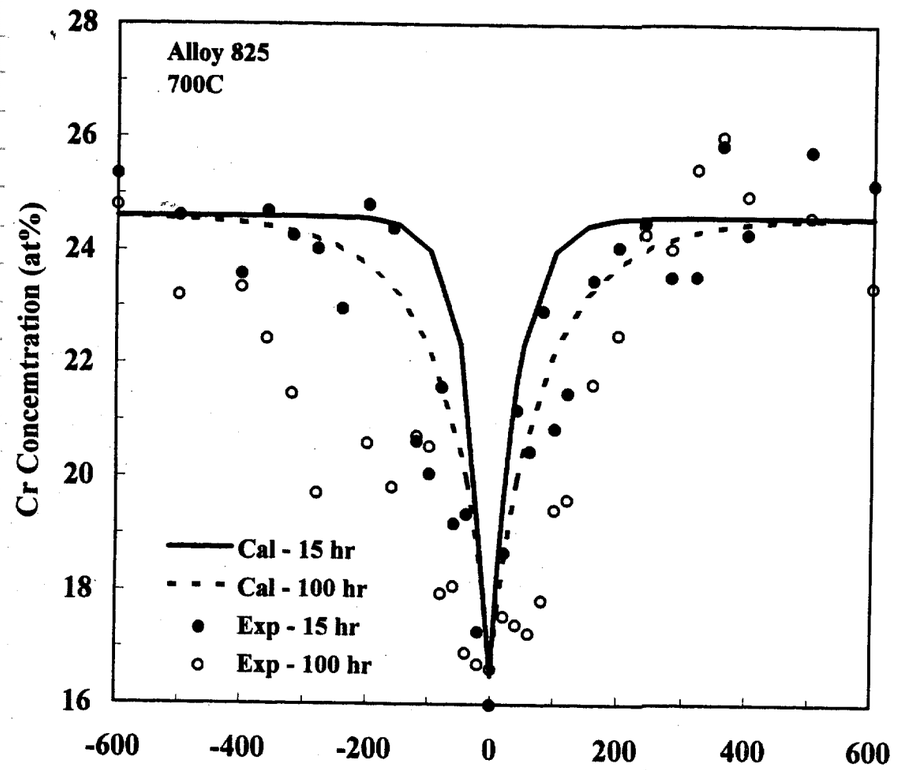
Results:

a. Profiles for 15 hr at various temperatures



6/1/96

b. Profiles for 700°C superimposed on the experimental data.



6/7/96

2) Cr concentration at carbide-matrix interface [BRU90]

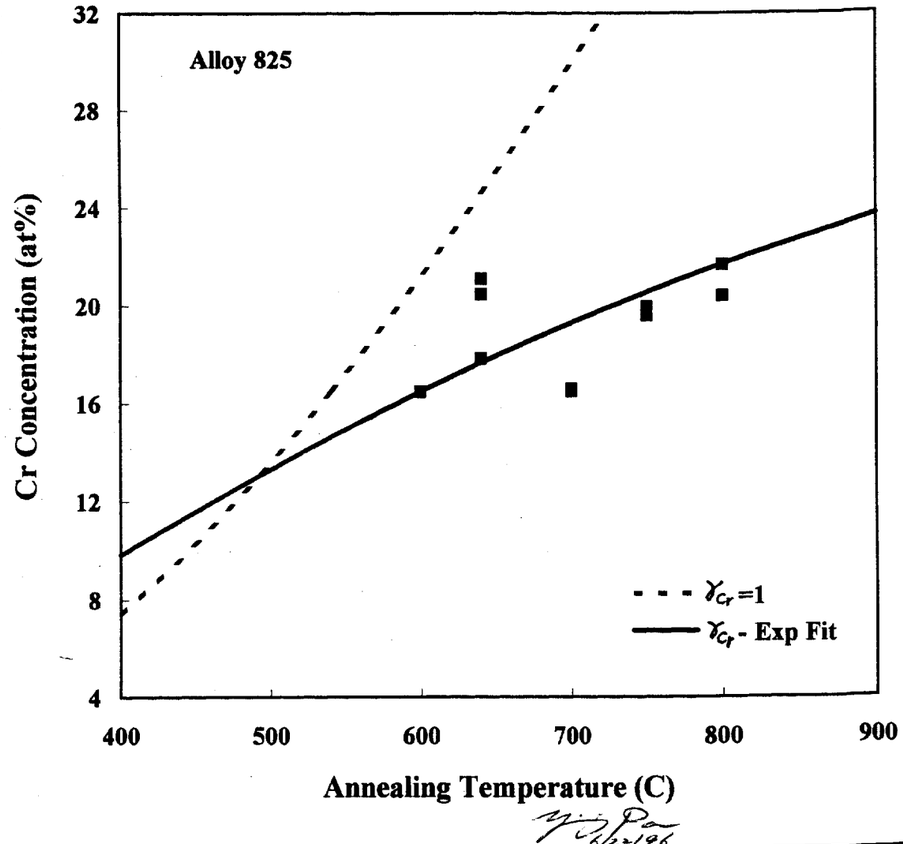
$$M_{23}C_6 \rightleftharpoons 23M + 6C$$

$$K = \exp\left(-\frac{\Delta G}{RT}\right) = \frac{a_{M_{23}C_6}}{(a_M)^{23}(a_C)^6}$$

$a_{Cr}^* = \gamma_{Cr}^* X_{Cr}^*$, C_r^* = equivalent Cr conc.

$a_C = \gamma_C X_C$

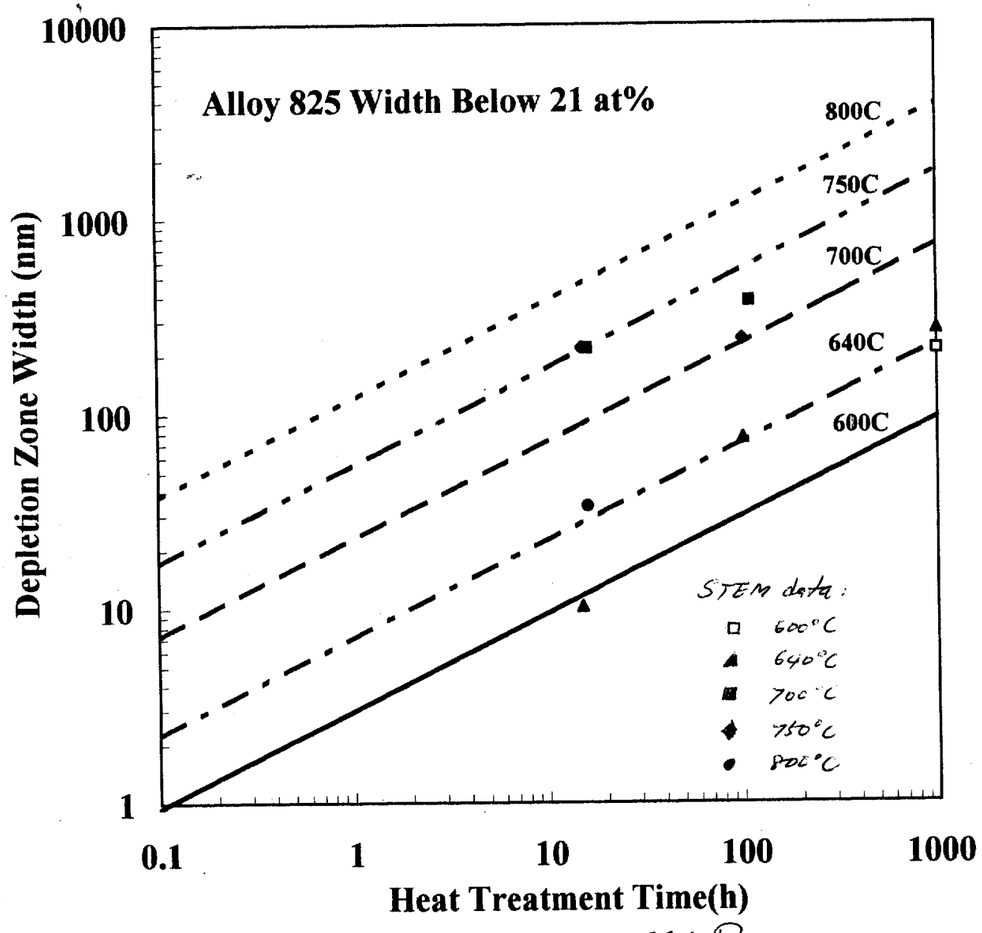
Results: Interfacial Cr conc. vs temperature plot for two different activity coefficients superimposed on experimental data.



6/22/96

3) Cr depletion width was estimated with a critical Cr level of 21 at. % using activation energy (287.4 kJ/mol) and preexponential (3.24 cm²/s) for Cr diffusion in alloy 825. [PAU/KAI 94]

INITIAL ENTRY : N 1/10/97



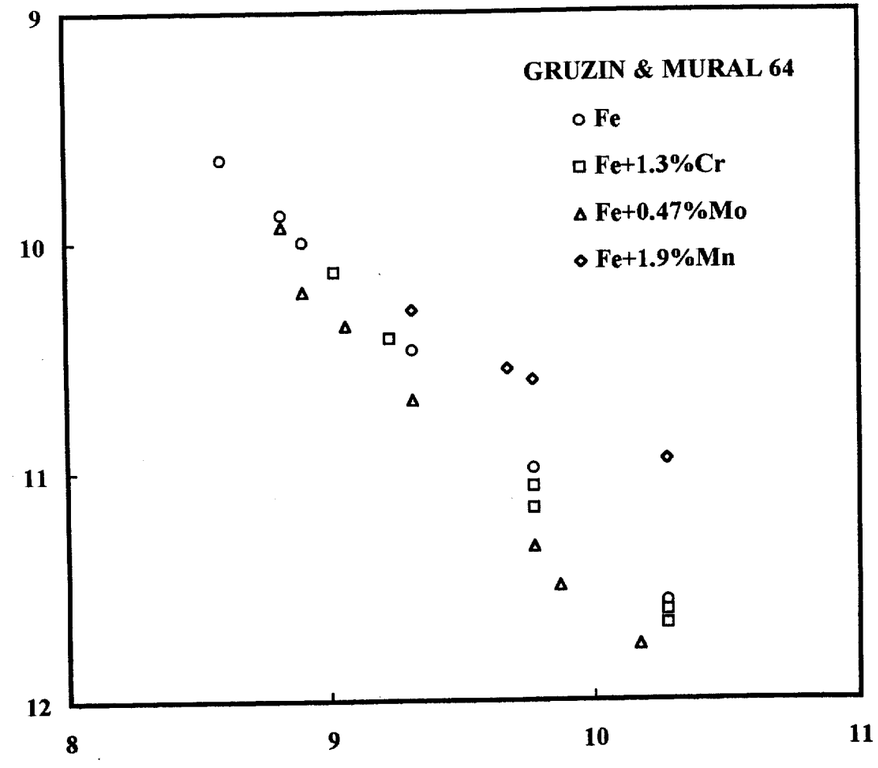
YP 7/14/96

Embrittlement in steels is essentially controlled by P segregation at grain boundaries. Segregation of P is governed by diffusion of P. Thus, diffusion coefficients of P in steels should be compiled and evaluated to assess the validity of the parameters for thermal embrittlement prediction. ~~9/10/97~~ plots

The following figures are ~~calculations~~ based on literature data and models. Experimental work was not performed at CNWRA

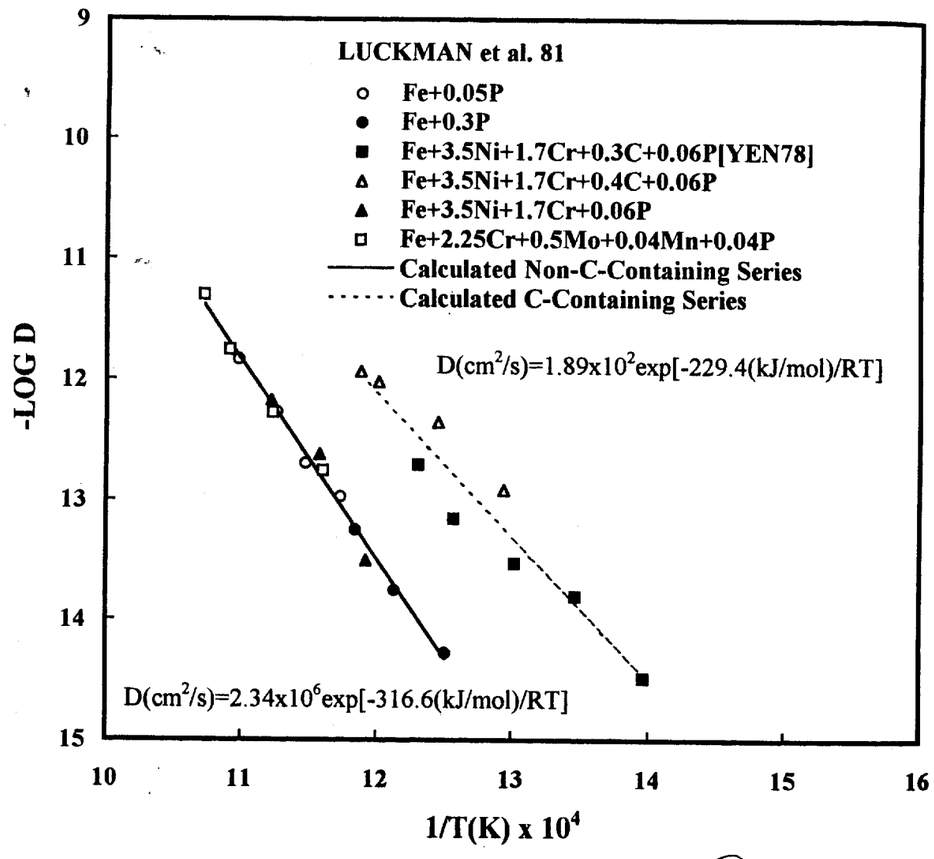
Results:

1) [GRU/MUR 64] N 1/10/97



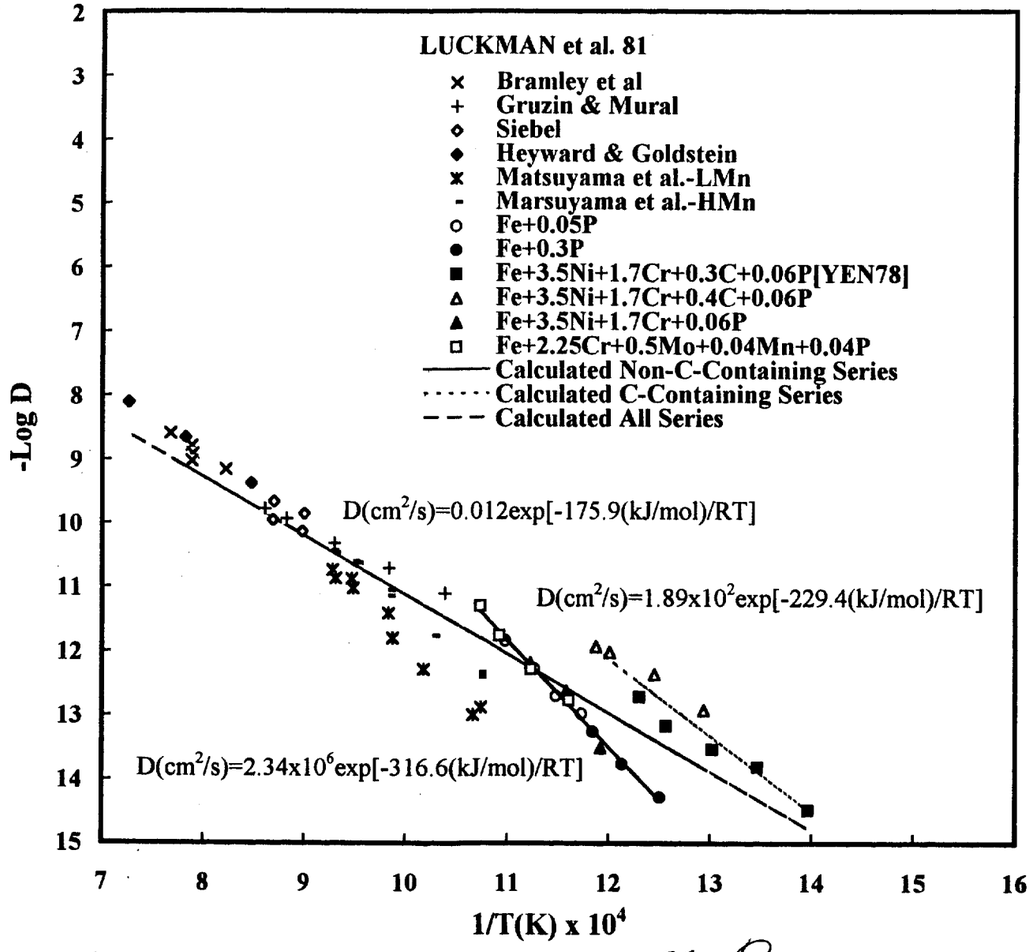
YP 7/21/96

2) [LUC/DID 81]



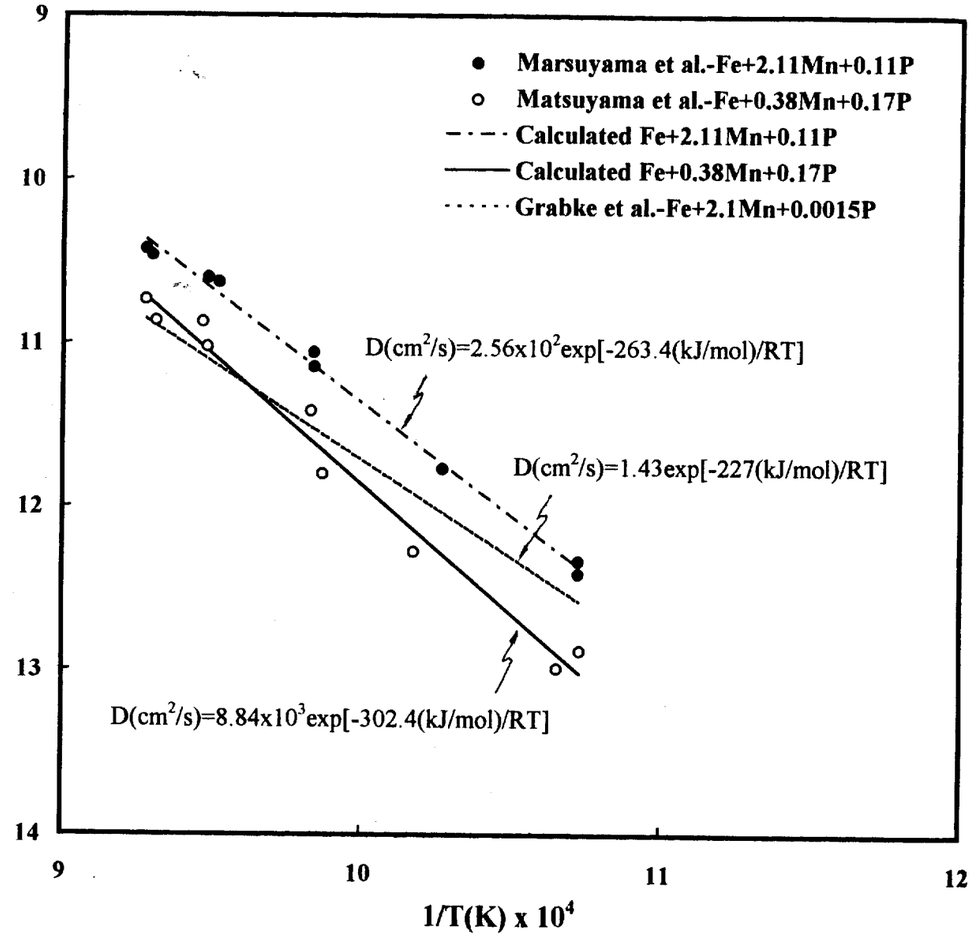
YJP
8/1/96

3) All data series



YJP
8/10/96

4) Effect of Mn



Yijie Pa
8/16/96

Prediction of Phosphorus segregation

From [VAT/HIP 91]:

$$X_p^{\phi} = \frac{X_p^B \exp(-\Delta G_p/RT)}{1 + X_p^B \exp(-\Delta G_p/RT)} \qquad \text{(eq. 1)}$$

X_p^{ϕ} : equilibrium level of P at grain boundary

X_p^B : bulk P conc. in matrix

ΔG_p : Gibbs free energy of segregation

$$[X_p^{\phi}]_t^{T_2} = [X_p^{\phi}]_{\infty}^{T_2} - X_p^B(\alpha_2 - \alpha_1)\exp\left(\frac{4Dt}{\alpha_2^2 d^2}\right)\operatorname{erfc}\left[\frac{2\sqrt{Dt}}{\alpha_2 d}\right] \qquad \text{(eq. 2)}$$

$\alpha_1 = [X_p^{\phi}]_{\infty}^{T_1} / X_p^B$

$\alpha_2 = [X_p^{\phi}]_{\infty}^{T_2} / X_p^B$

D : diffusion coefficient at T_2

d : grain boundary thickness.

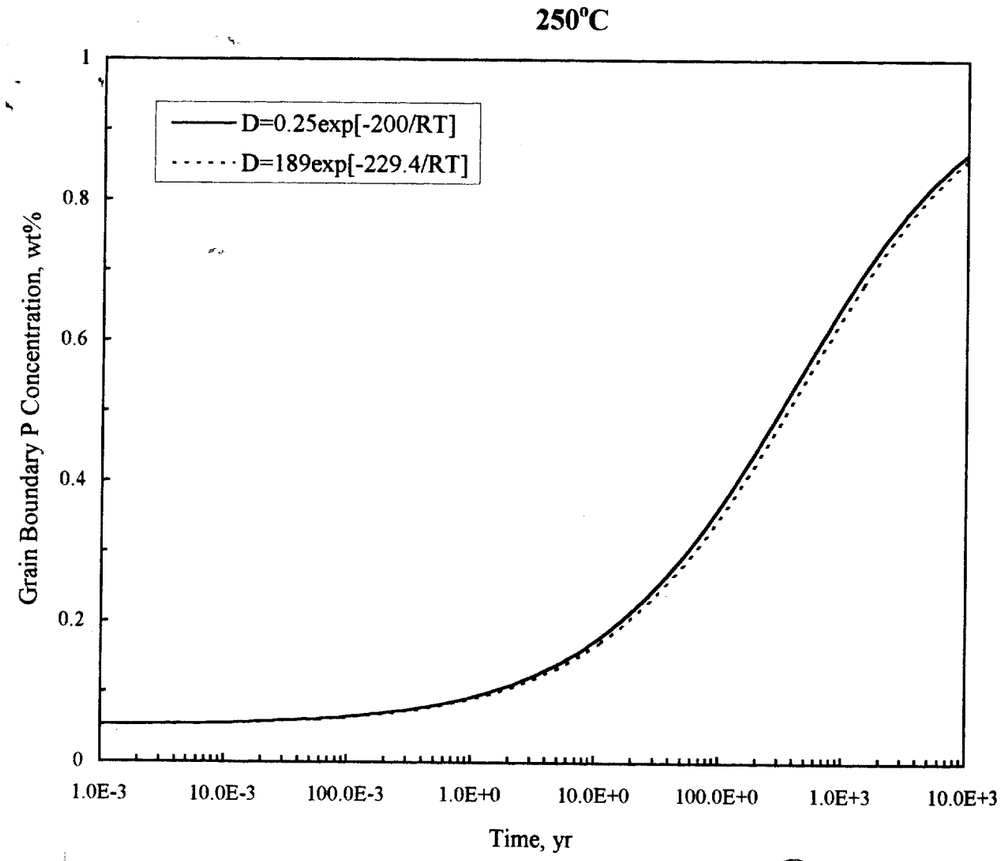
ΔG_b can be expressed by the following equation [DRU/GAG 86].

ΔG_b (J/mol) $= -63{,}000 + 21.0\,T$ (°K)

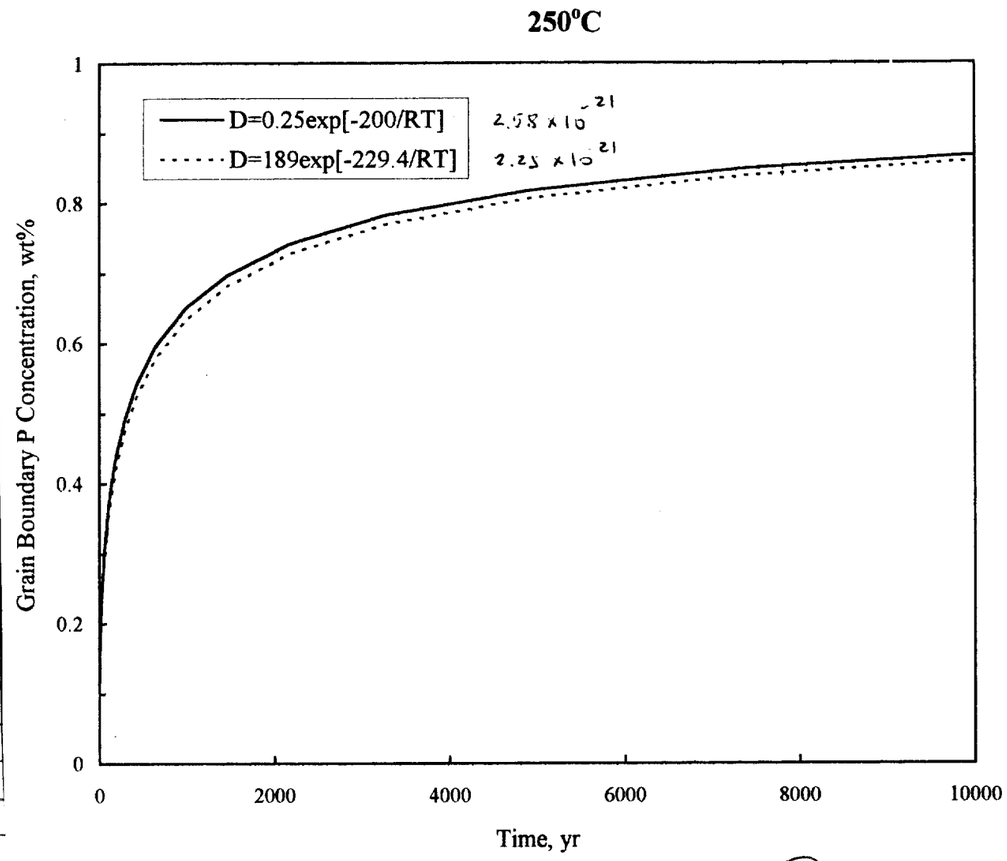
Yijie Pa
8/23/96

1) P segregation @ 250°C.

a: GB P conc. vs time plot (semi-log scale)



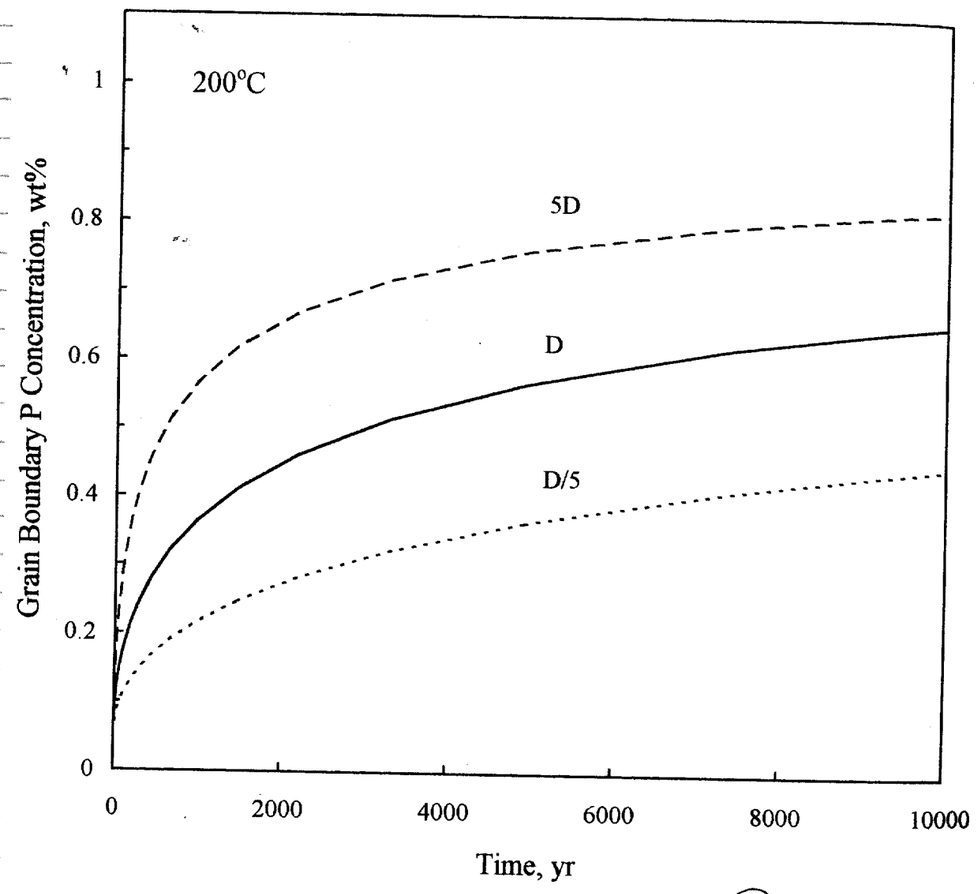
b. GB P conc. vs time plot (regular scale)



8/30/96

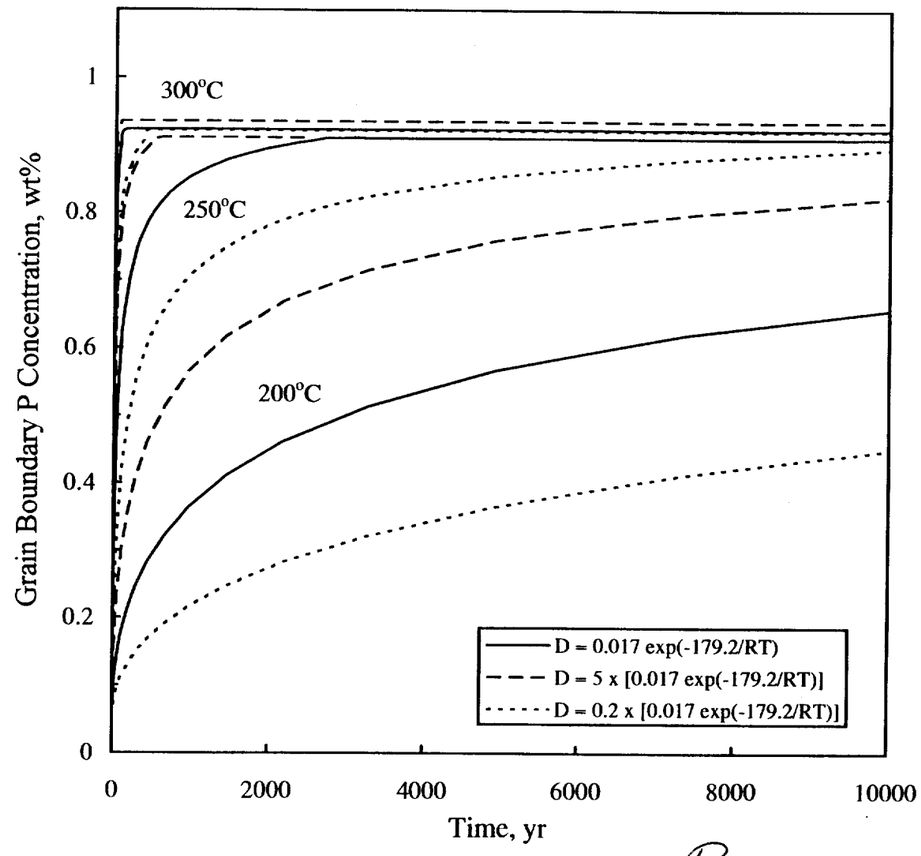
8/30/96

2) Sensitivity study using three different diffusion coefficients.
$D = 0.017 \exp(-179.2/RT)$



Y. J. Pa
9/7/96

3) Sensitivity study for three temperatures.



Y. J. Pa
9/14/96

I have reviewed this scientific notebook and find it in compliance with QAP-001. There is sufficient information regarding procedures used for conducting tests, acquiring and analyzing data so that another qualifiied individual could repeat the activity.

N. Kicker

EM, EBS

1/10/97

1/10/97