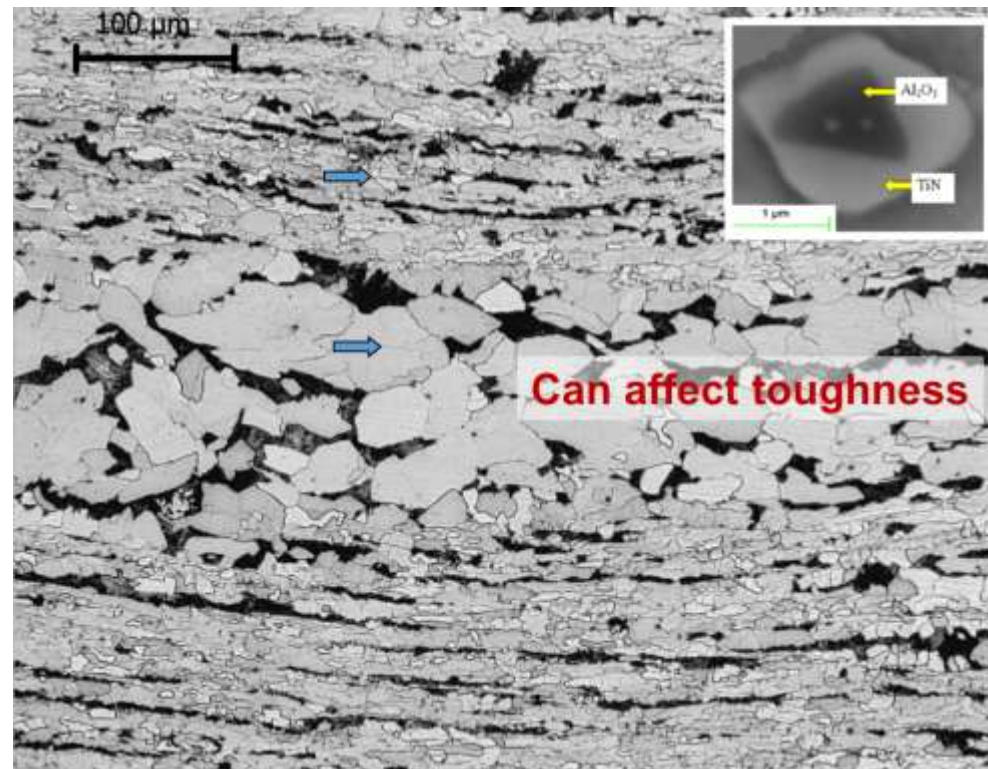




Austenite and ferrite grain size variation in microalloyed steel

1

Debalay Chakrabarti, Kumar Aniket Anand,
Sudipta Patra, Dr. David N. Crowther

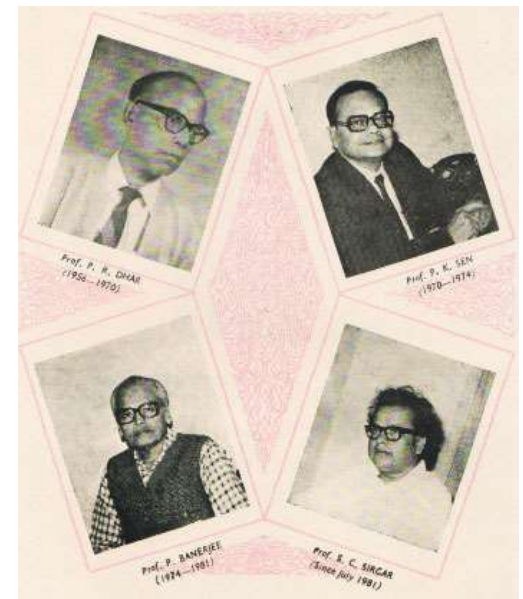




Indian Institute of Technology Kharagpur is a public technical university established by the GoI in 1951. The institute is the first of IITs to be established, is recognised as an Institute of National Importance. In 2019 it was awarded the status of Institute of Eminence. IIT Kgp has an 8.7-square-kilometre (2,100-acre) campus and has about 22,000 residents.



The Dept. of Metallurgical and Materials Engineering had its inception in 1956. Offers B.Tech (70), M.Tech (40), PhD (20).

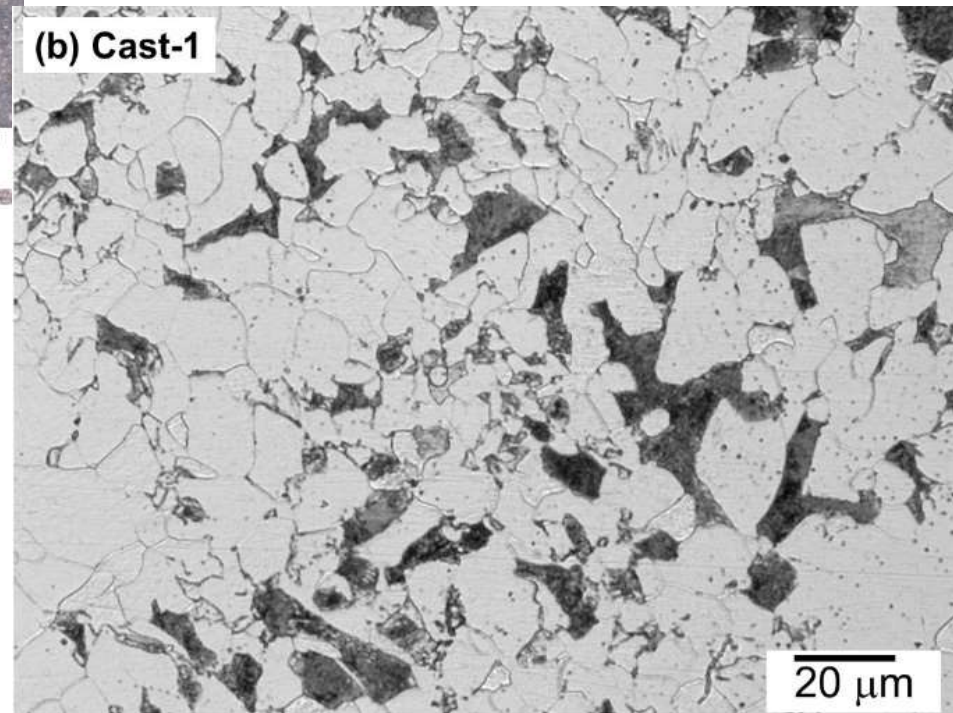
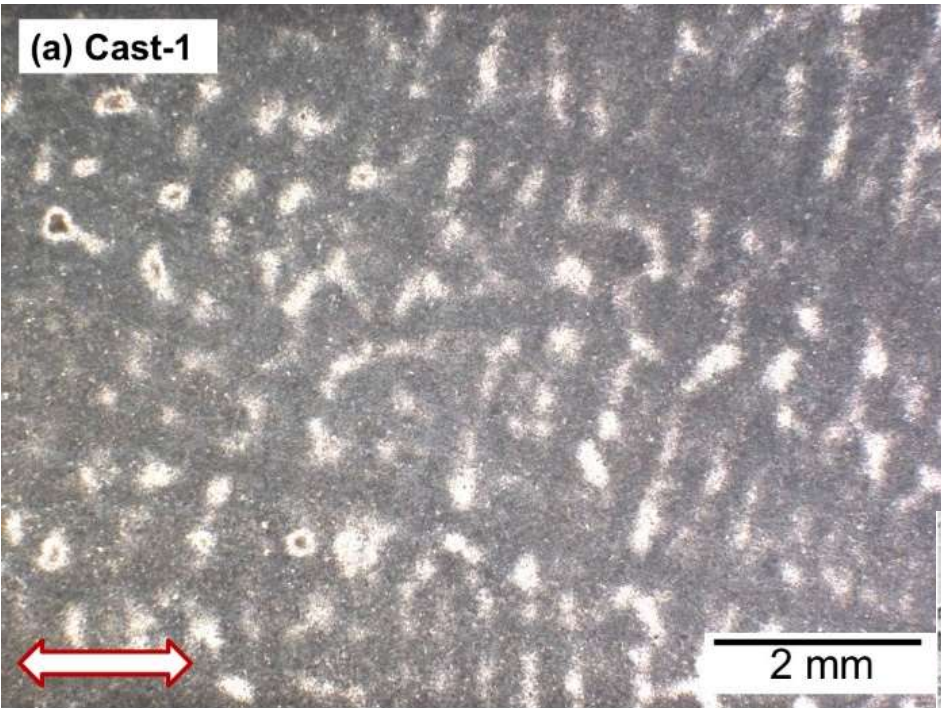


Ongoing events at Dept. of MME: ICAMMP Conference, International Conference on Advances in Materials and Materials Processing organized in 2002, 2006, 2011, and 2016. **Congress of Metallurgical Professionals involving Students, Industry and Teachers (COMPOSIT)** is a National students meet conducted annually since 1994.

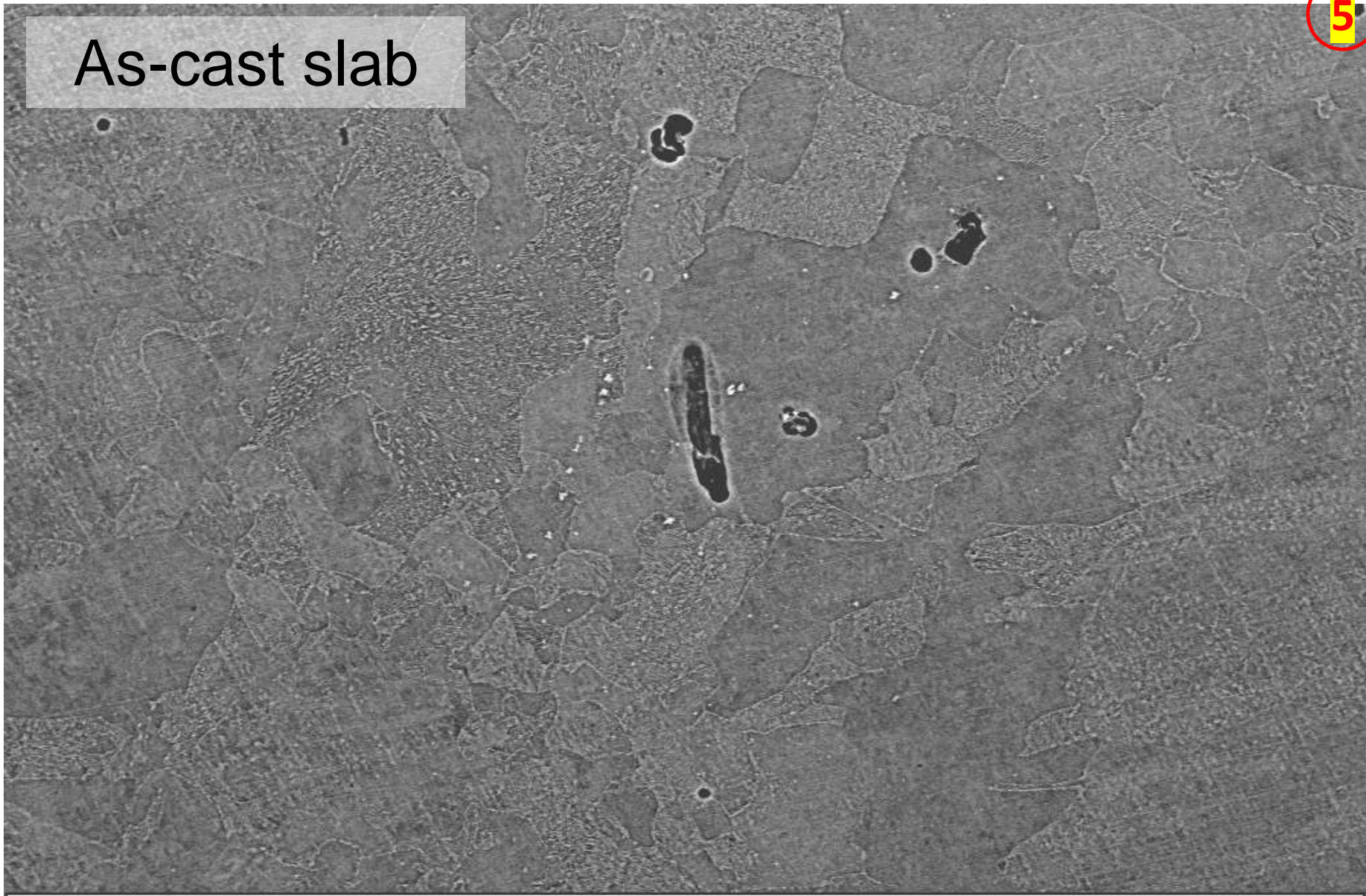
Compositions of the investigated steels (wt.%)

Sample	C	Si	Mn	P	S	Al	Ni	Cr	Nb	Ti	V	N
Cast-1: Nb-Ti-V	0.09	0.33	1.42	0.01	0.003	0.035	-	-	0.05	0.019	0.05	0.007
Cast-2: Nb-V	0.09	0.27	1.22	0.01	0.01	0.020	-	-	0.05	-	0.06	0.008
Cast-3: Nb-Ti	0.09	0.28	1.26	0.01	0.01	0.030	-	-	0.05	0.015	-	0.008
Cast-4: Nb-Ti-V with Ni and Cr	0.08	0.28	1.19	0.01	0.01	0.010	3.0	0.3	0.04	0.020	0.02	0.008
Cast-5: C-Mn	0.10	0.30	1.60	0.01	0.01	0.050	-	-	-	-	-	0.010
Cast-6: LVLN_Al	0.16	0.55	1.58	0.01	0.01	0.200					0.06	0.008
Cast-7: HVHN_Al	0.17	0.60	1.60	0.01	0.01	0.180					0.12	0.013
Cast-8: LVLN	0.14	0.29	1.02	0.01	0.01	0.03					0.04	0.007
Cast-9: LVHN	0.15	0.24	1.17	0.01	0.01	0.002					0.04	0.017
Cast-10: HVHN	0.15	0.20	1.22	0.02	0.01	0.001					0.08	0.019

Microstructures of the as-cast slab



As-cast slab



10 μ m
|-----|

EHT = 20.00 kV
WD = 8.5 mm

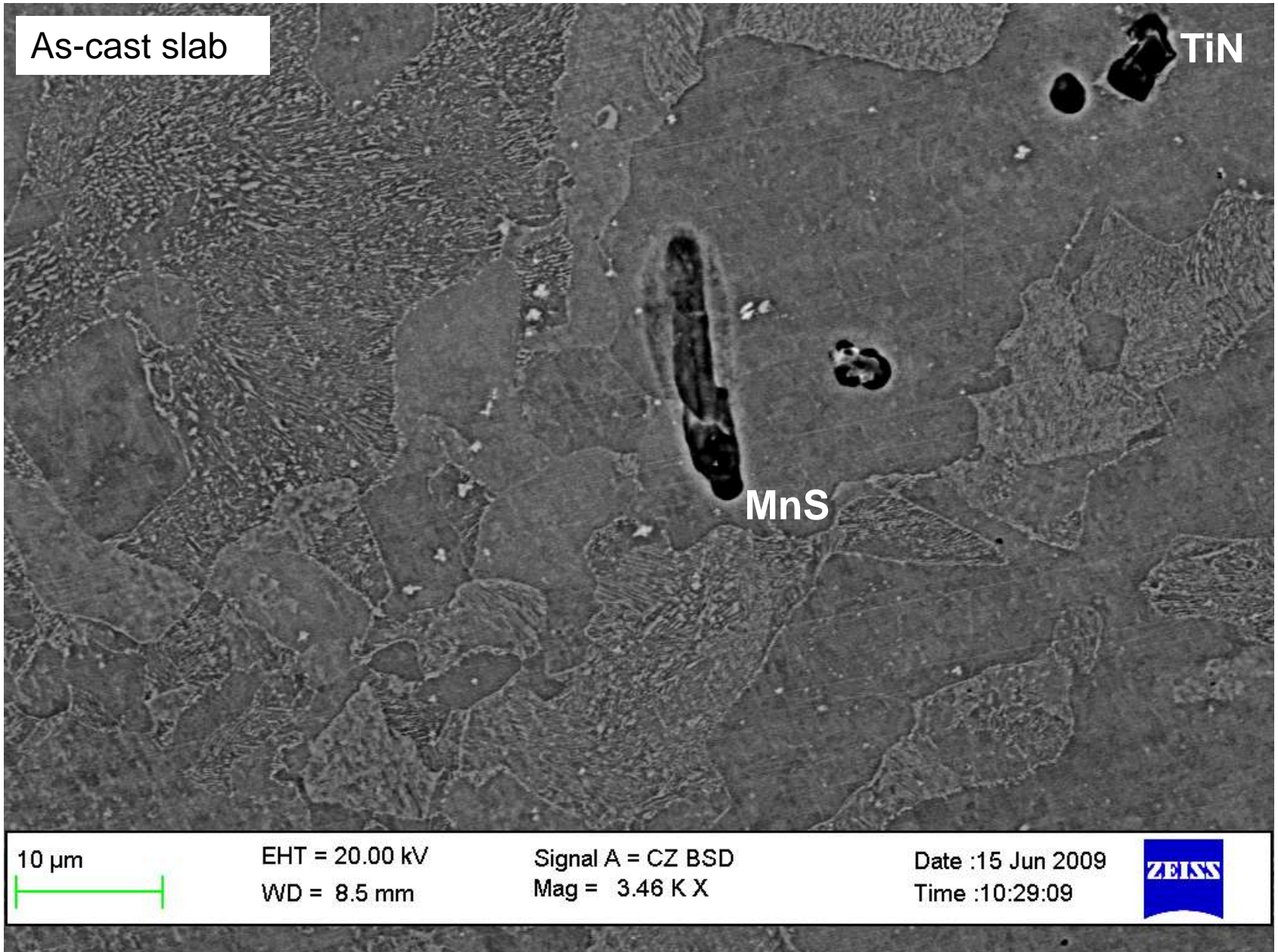
Signal A = CZ BSD
Mag = 1.92 K X

Date :15 Jun 2009
Time :10:40:08

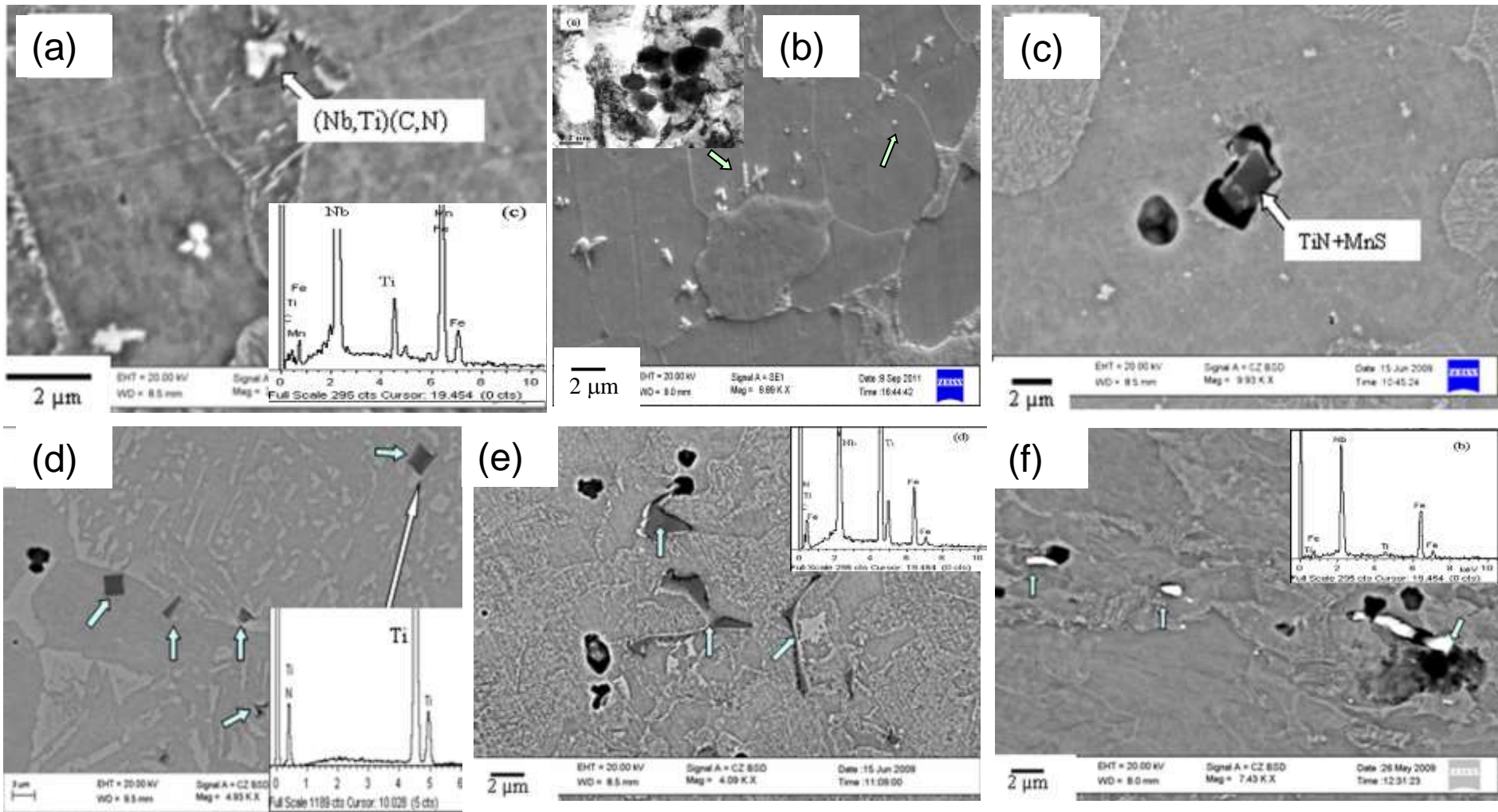


Inhomogeneous distribution of microalloy precipitates

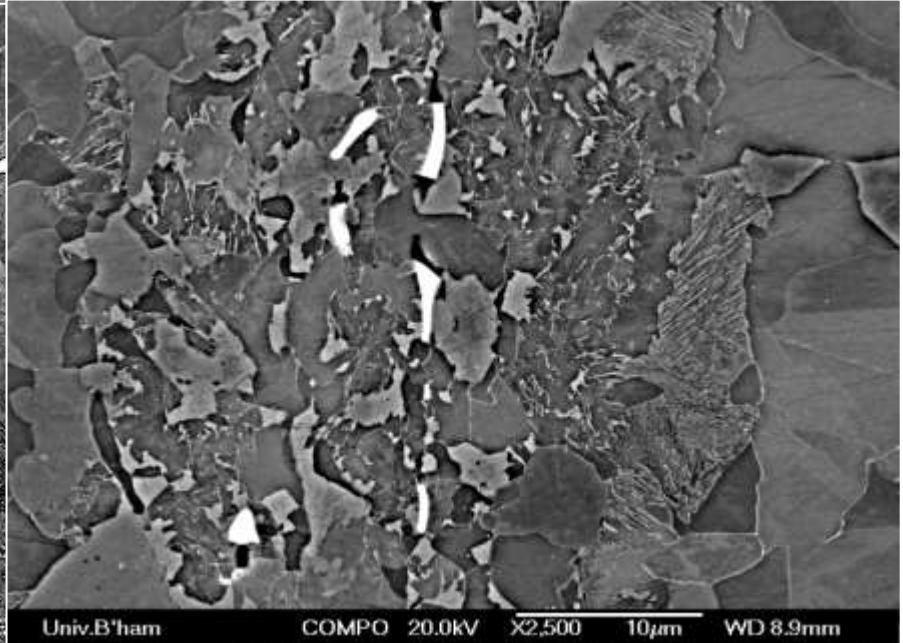
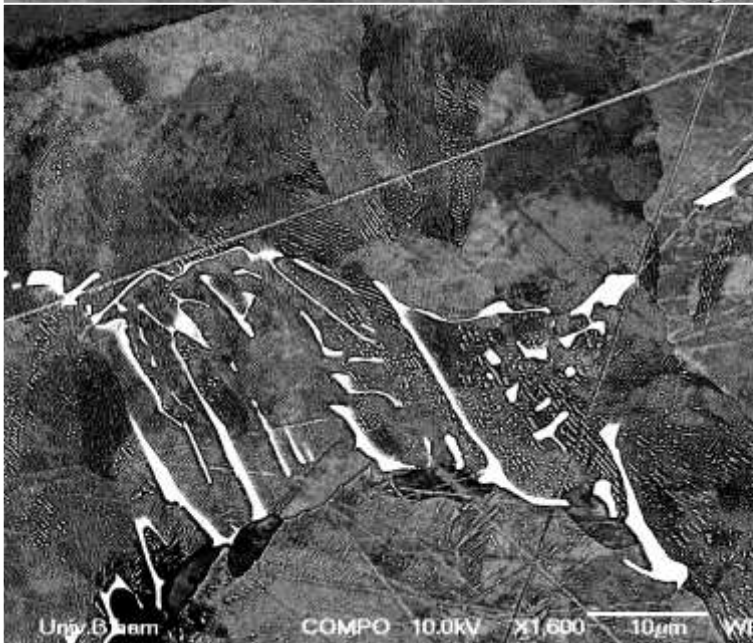
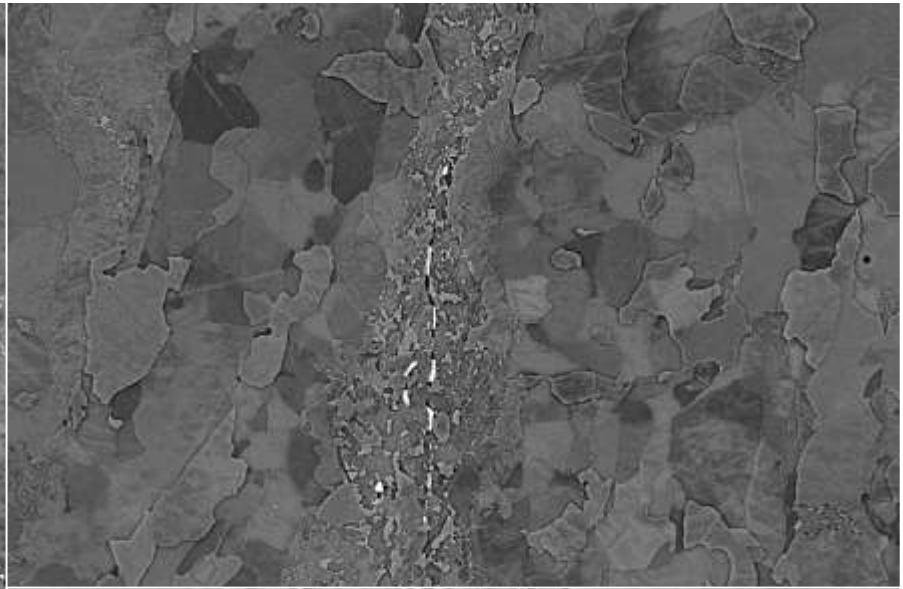
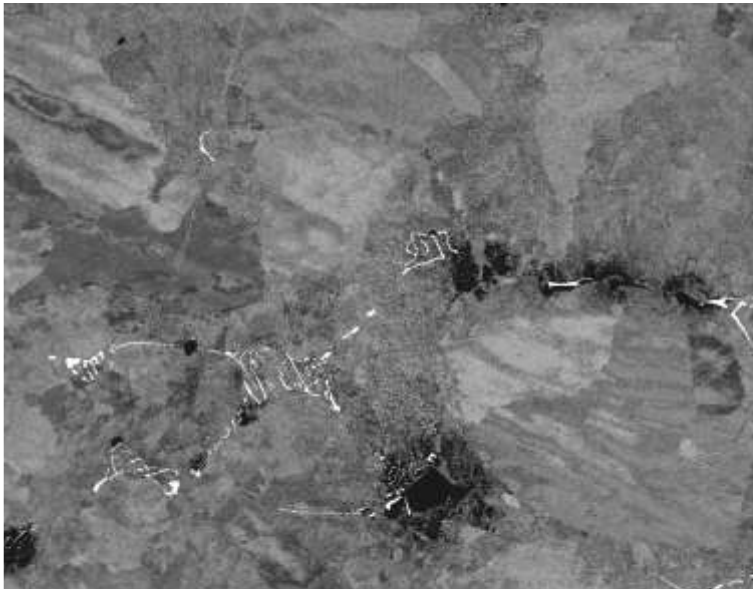
6



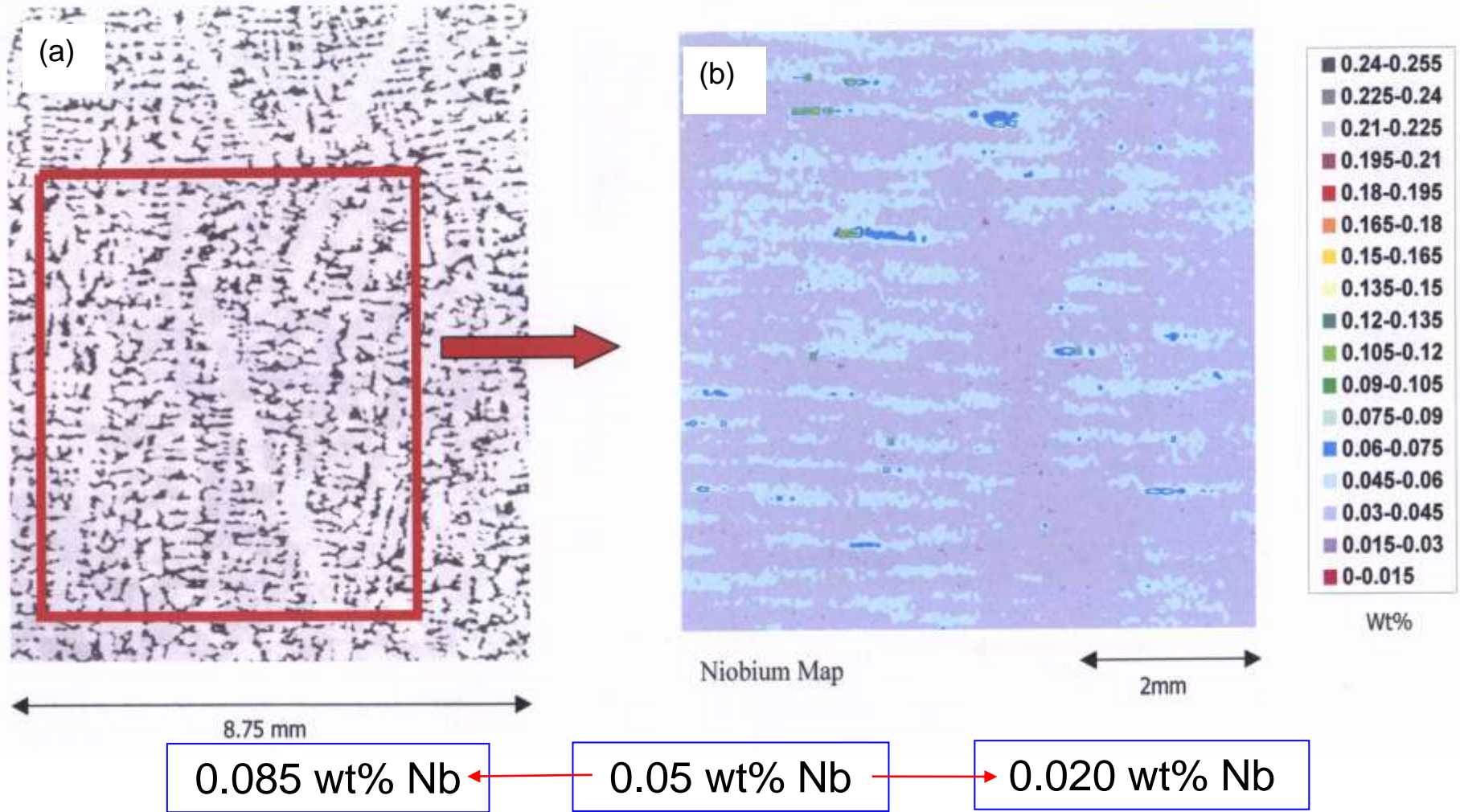
Precipitates in as-cast Nb-Ti microalloyed steel



Large scale segregation of Nb as Nb(C,N) eutectic

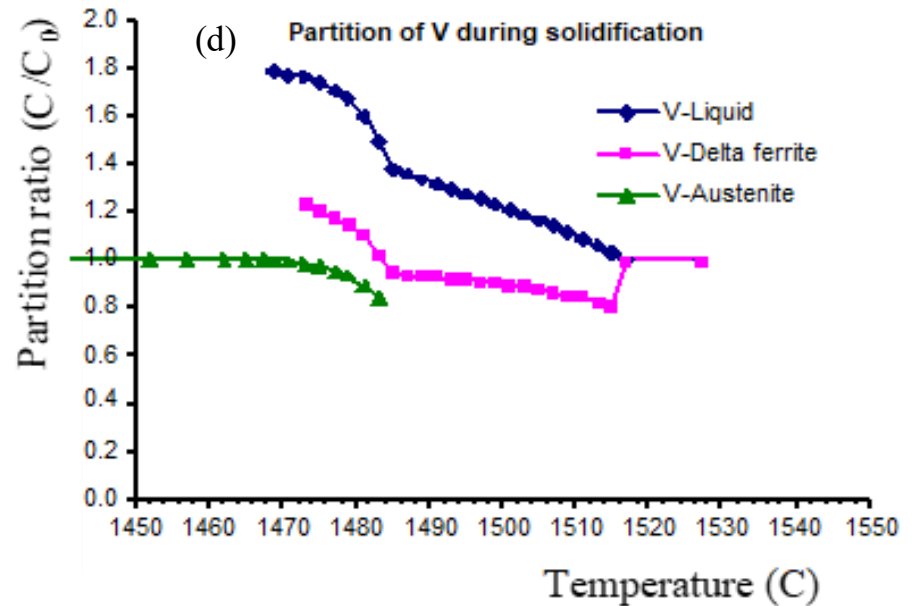
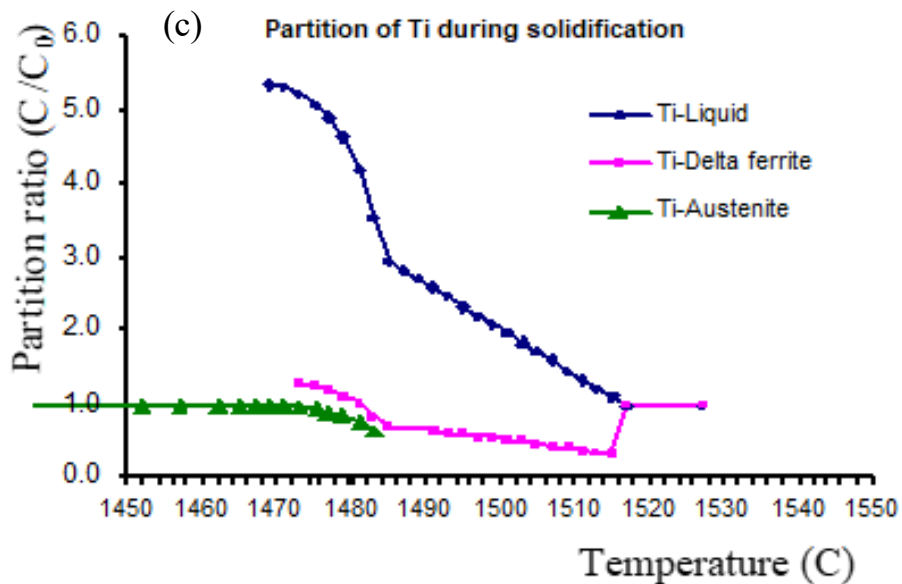
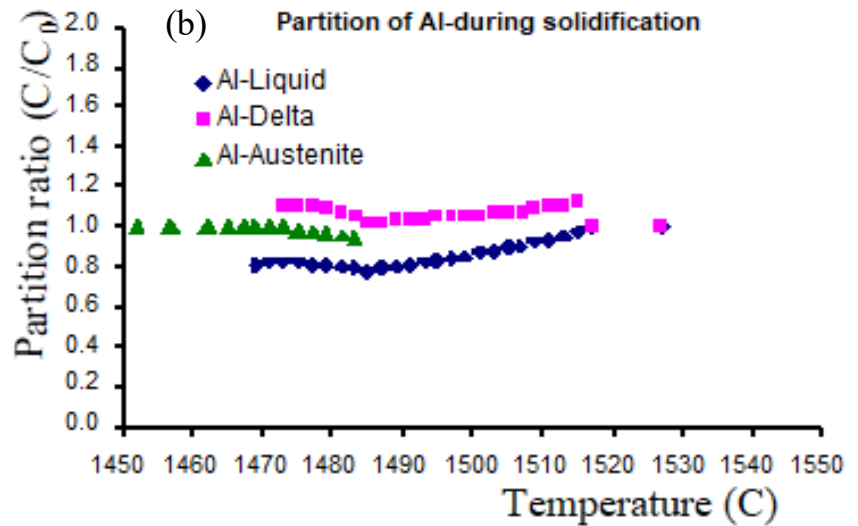
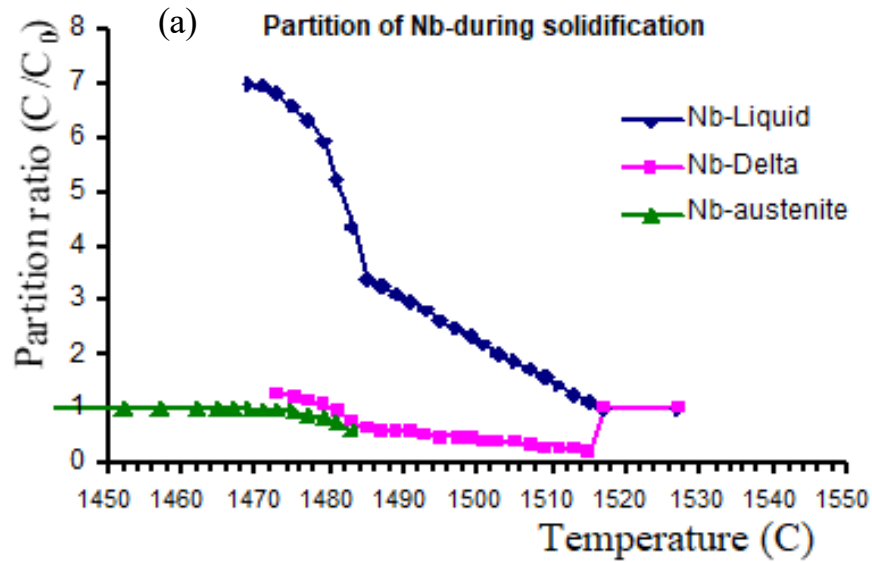


Partitioning of Nb: Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) – A. J. Koch, Univ. of Leeds, UK 9

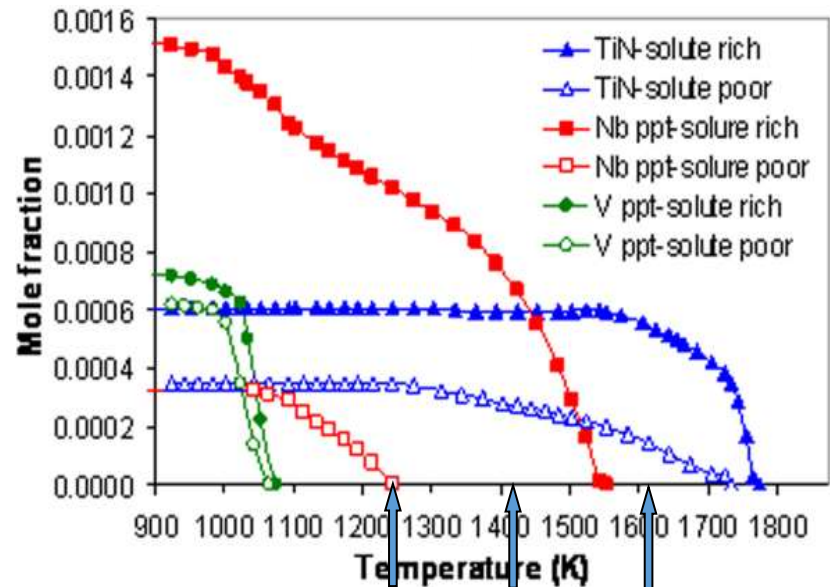
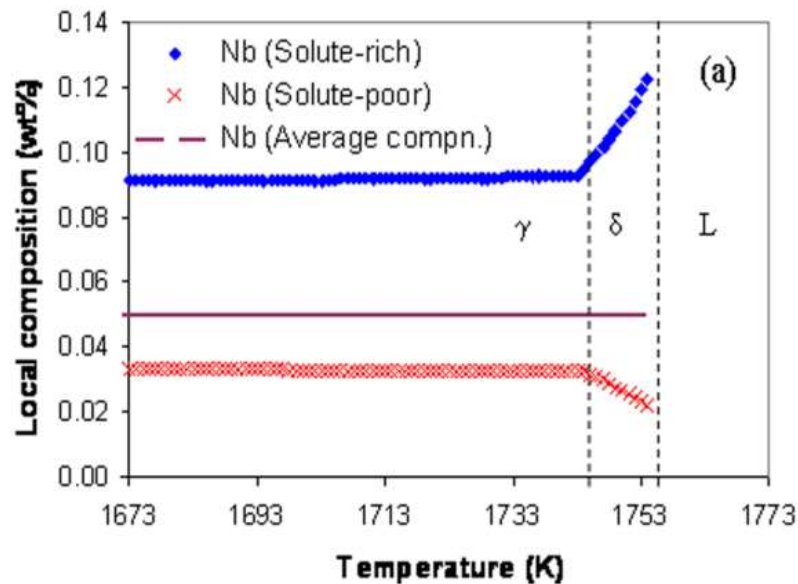
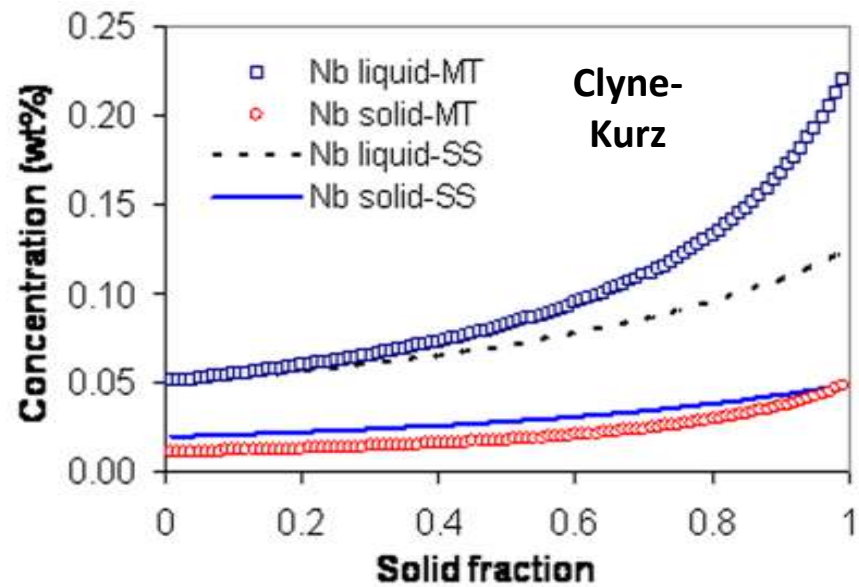
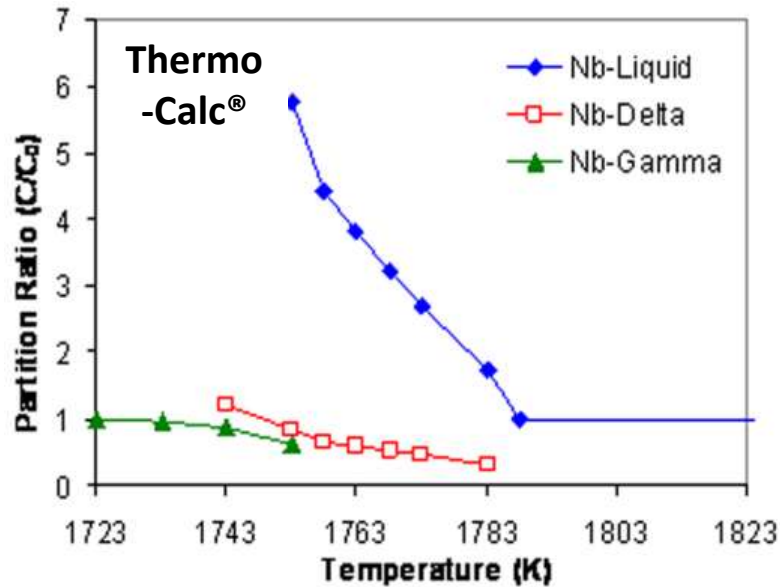


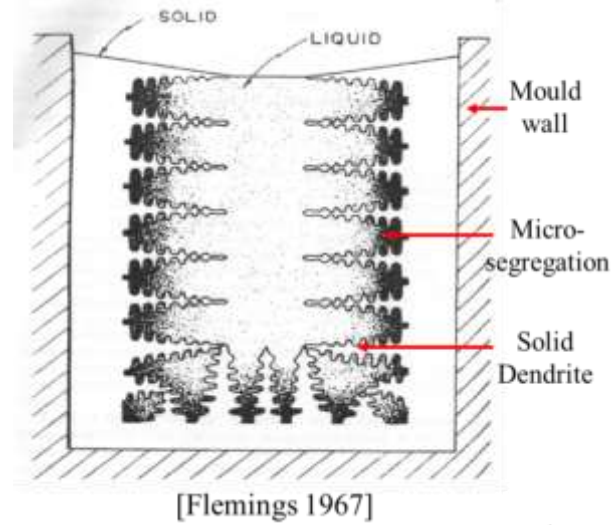
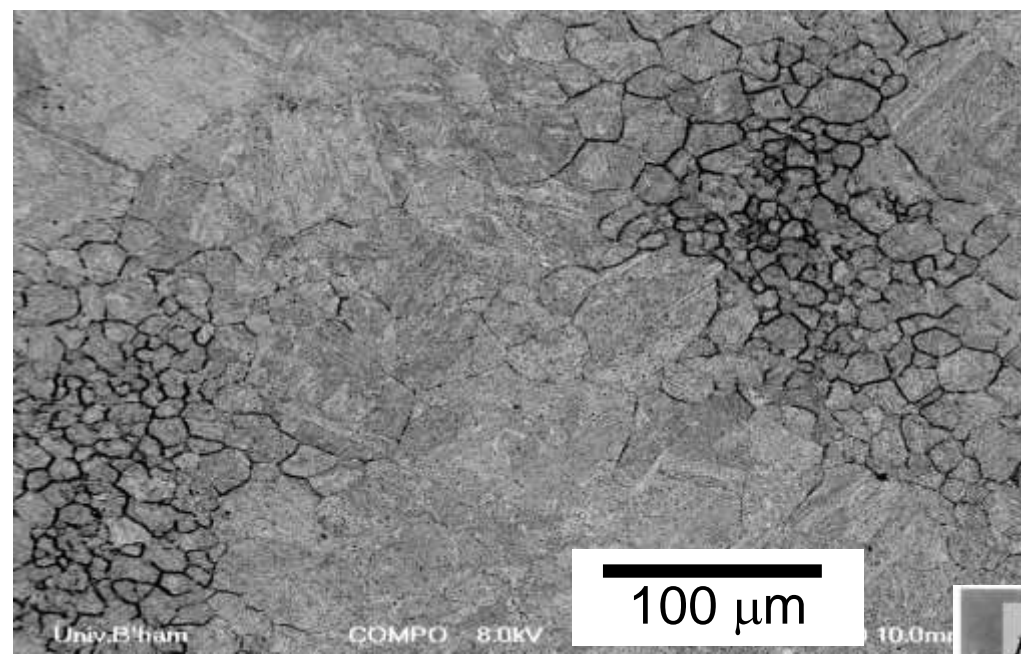
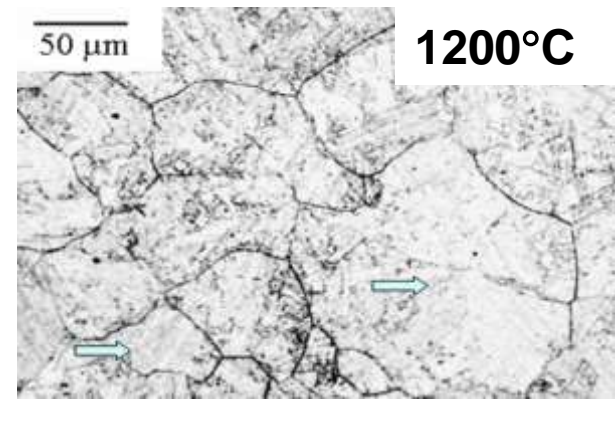
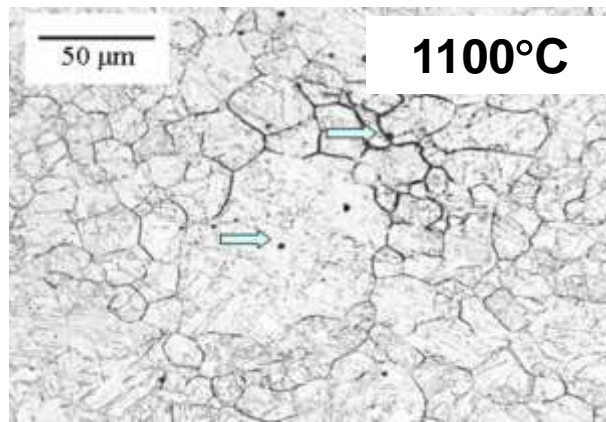
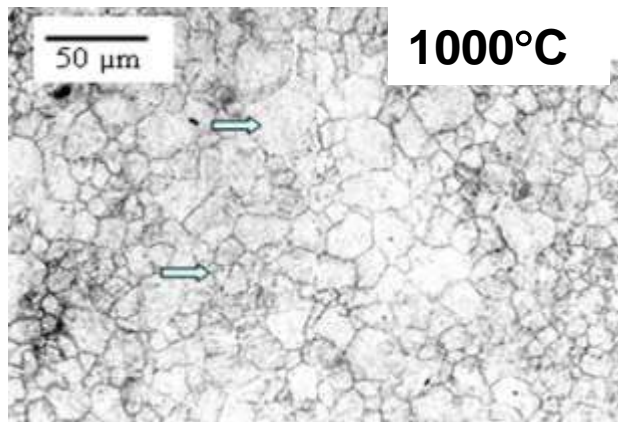
Uses an Inductively coupled plasma to ionize the sample. It atomizes the sample and creates atomic and small polyatomic ions, which are then detected. It is known and used for its ability to detect metals and several non-metals in liquid samples at very low concentrations.

Proneness to segregation of different elements

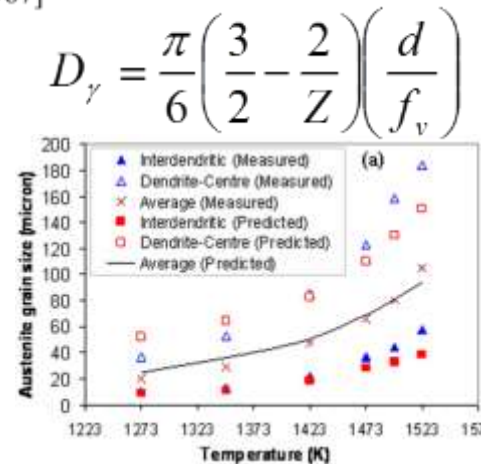
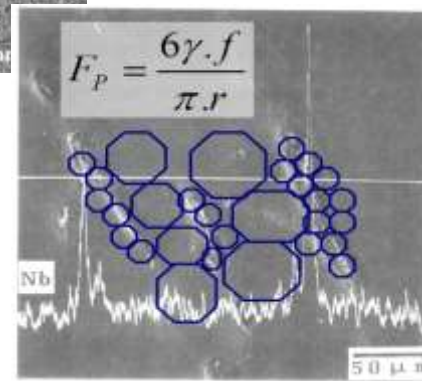
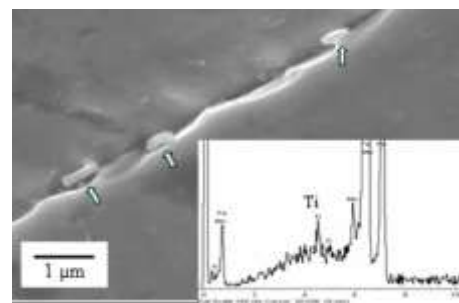
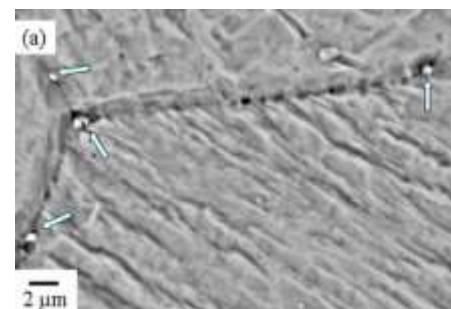


Prediction of segregation and homogenization of Nb

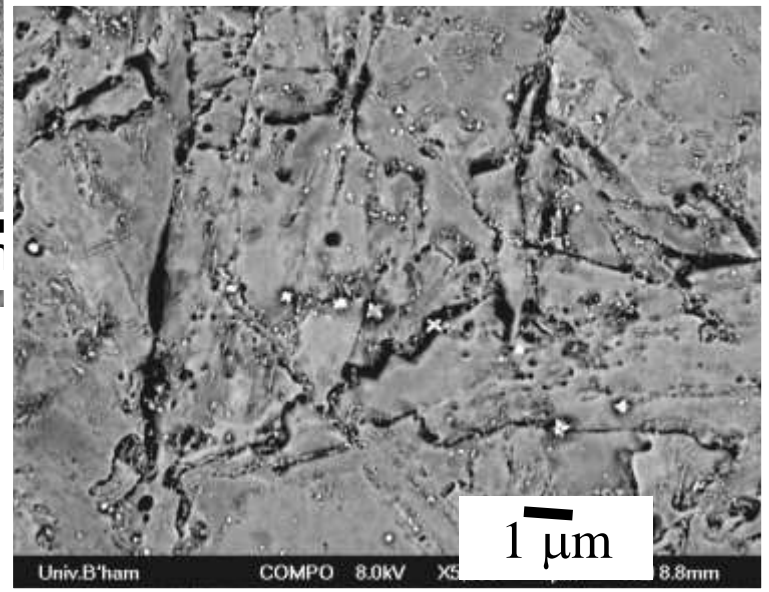
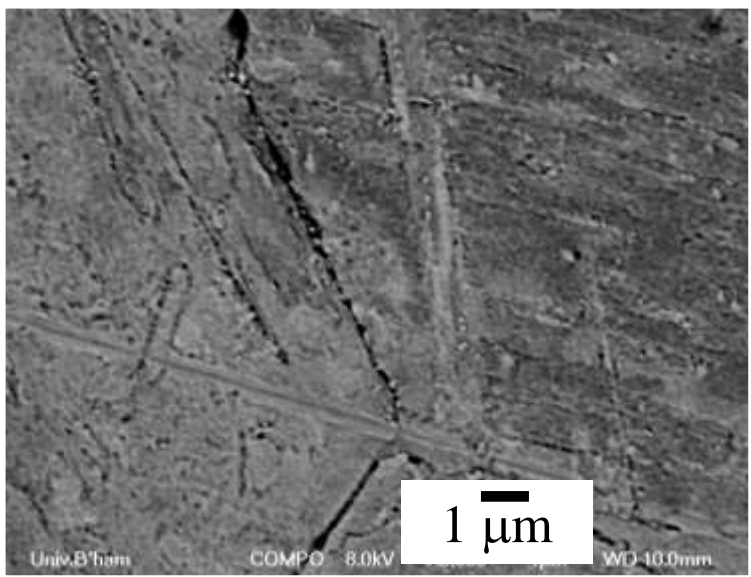
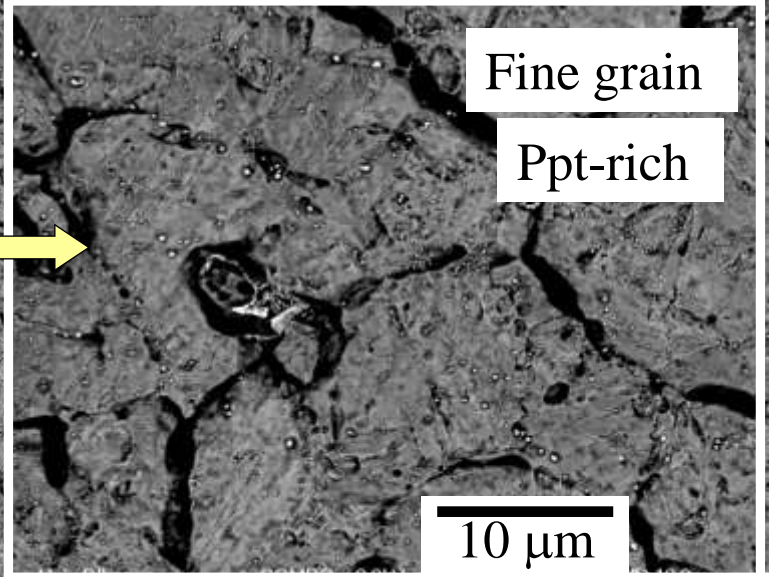
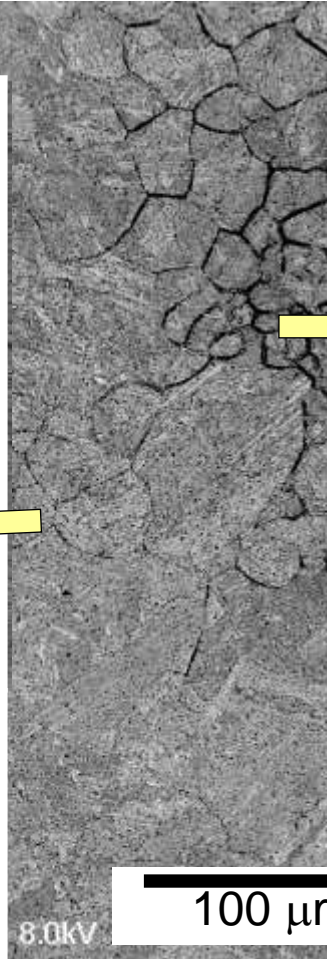
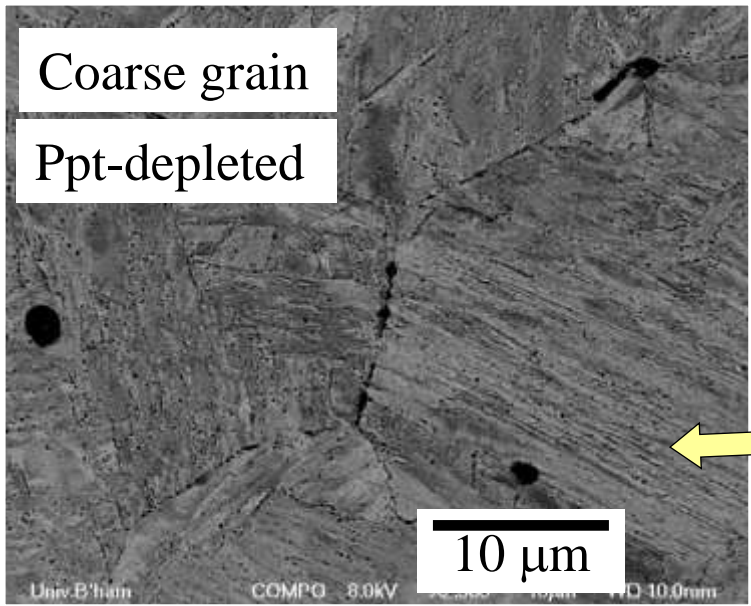




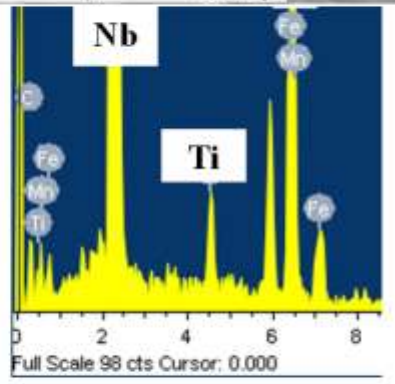
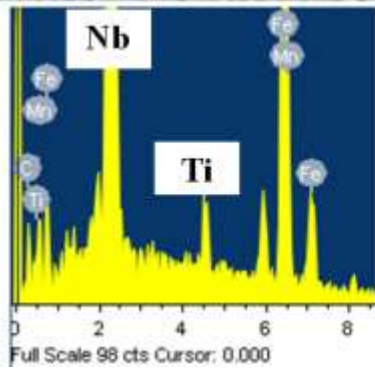
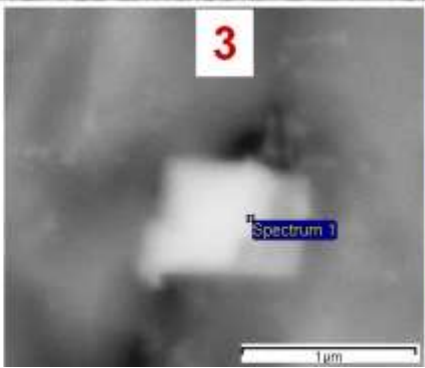
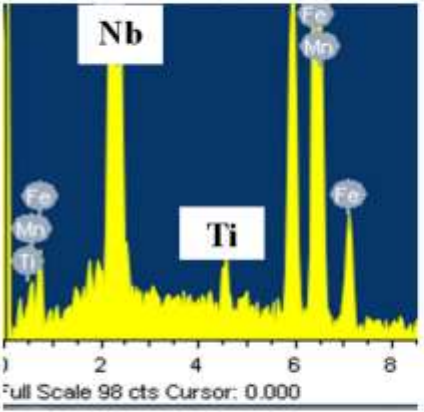
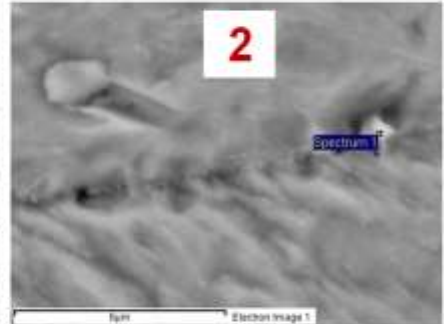
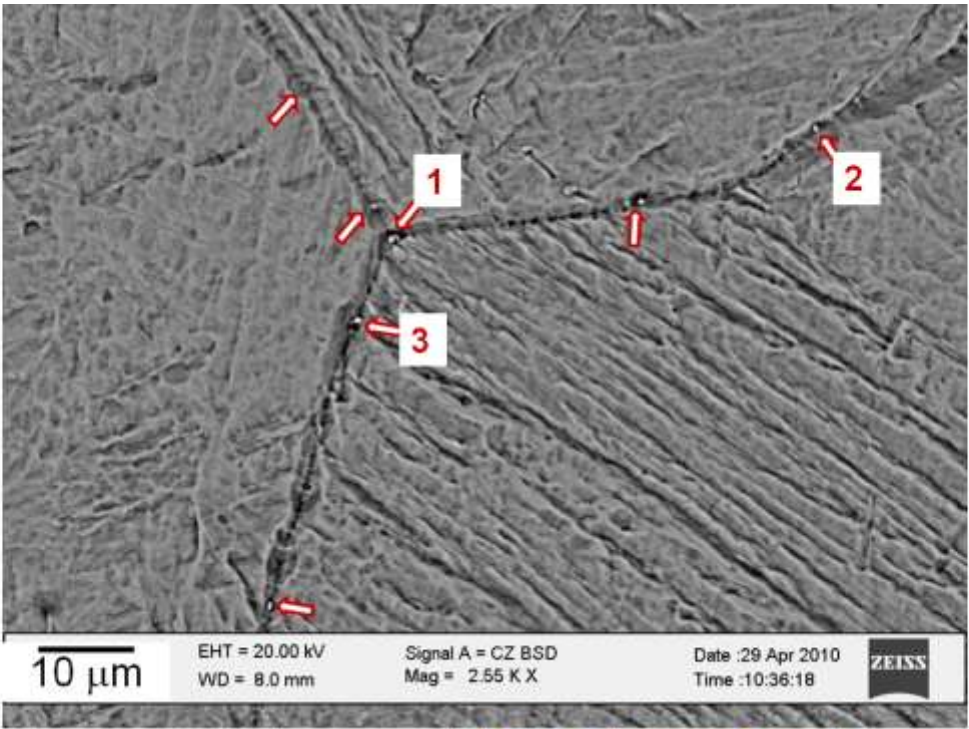
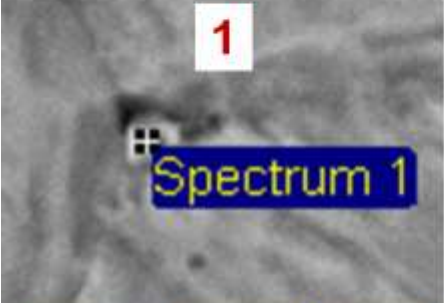
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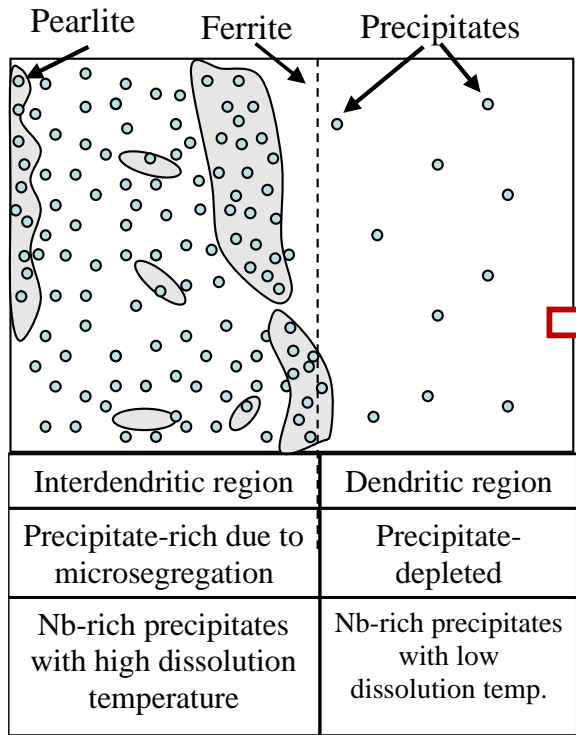
1150°C-WQ



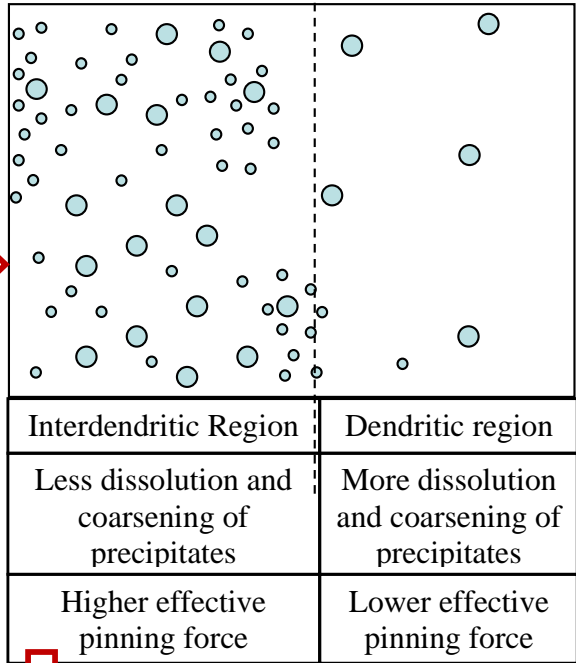
Precipitates pinning the austenite grain boundaries



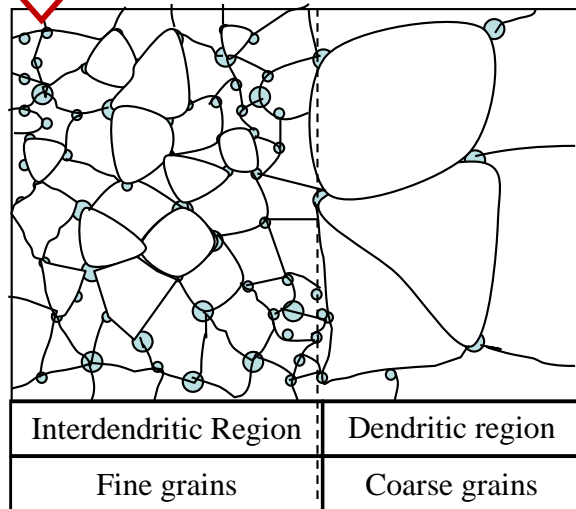
(a) Precipitates in as-cast slab



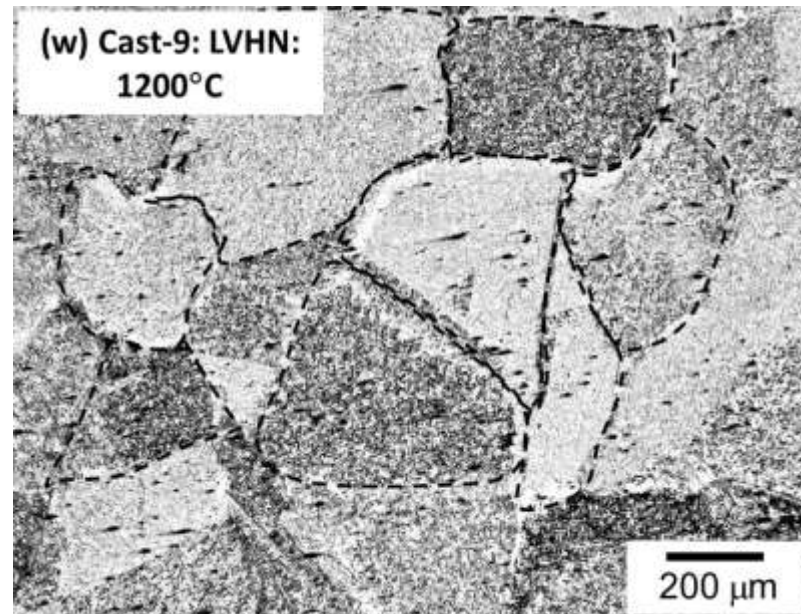
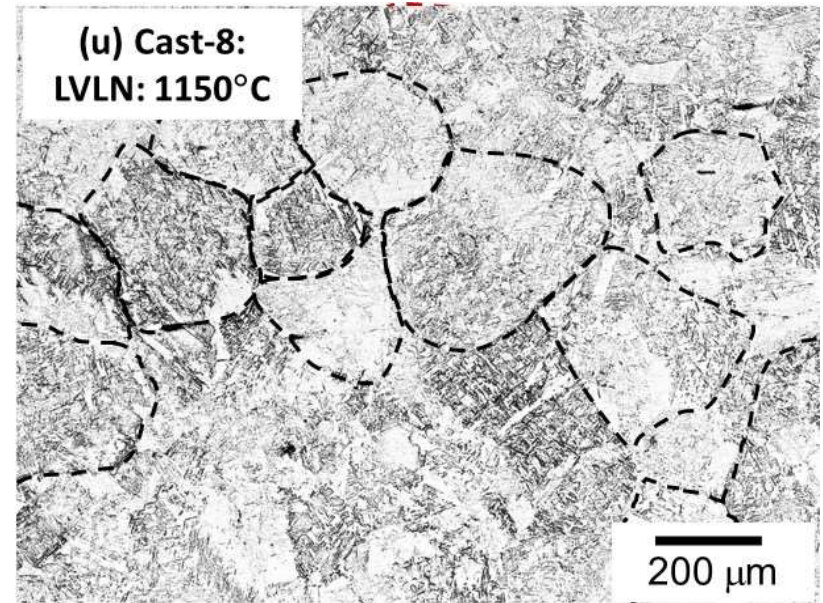
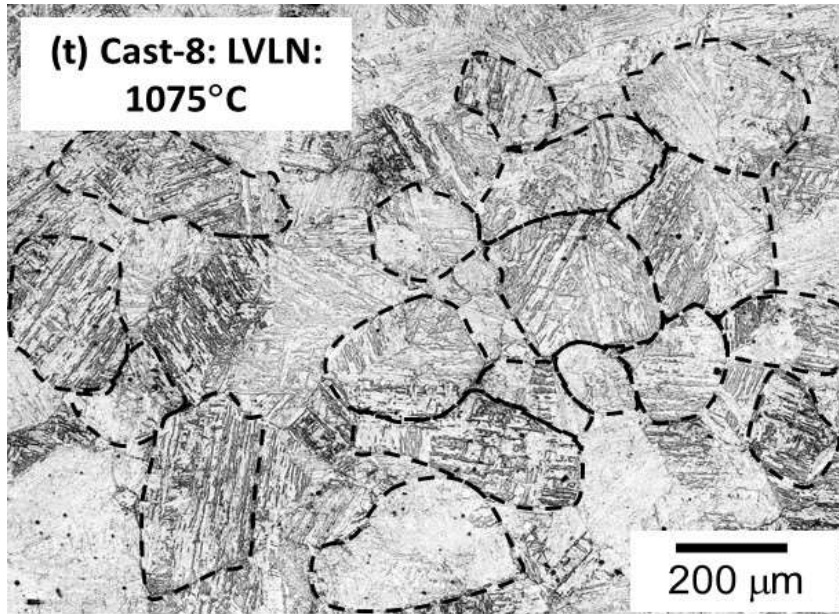
(b) Precipitates during reheating and soaking



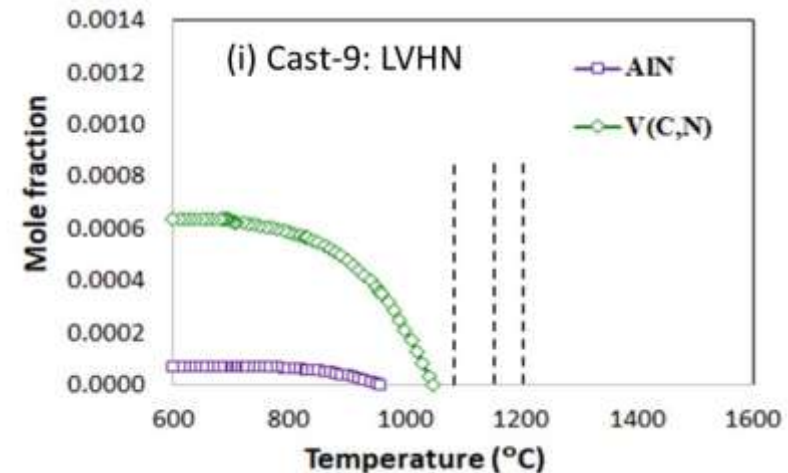
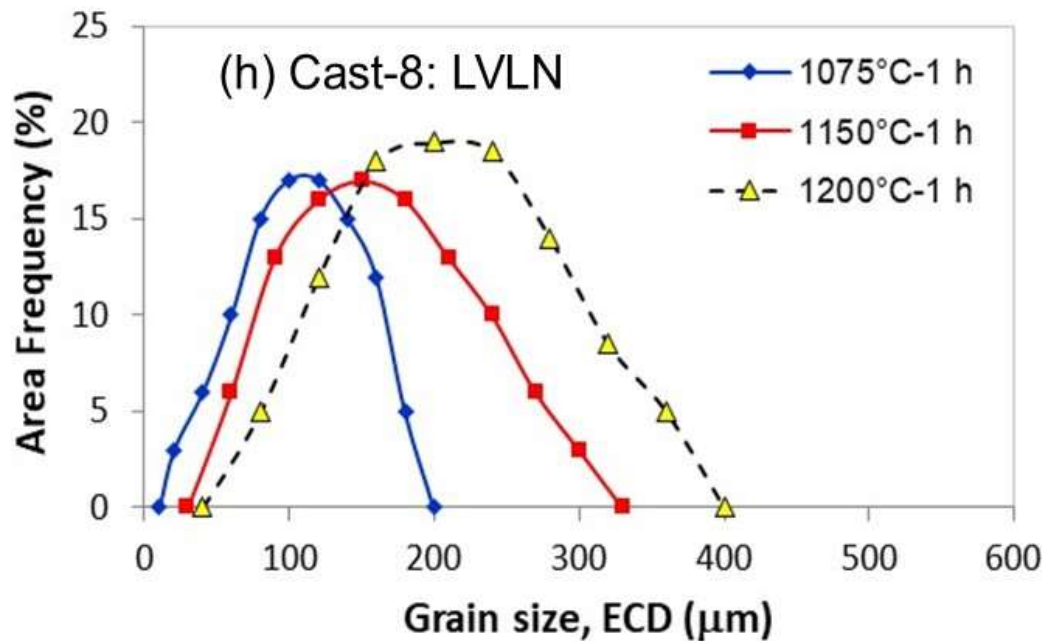
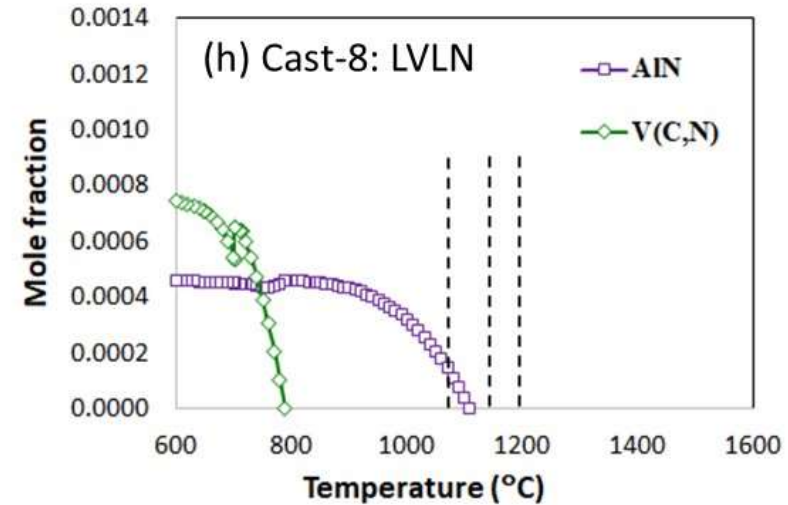
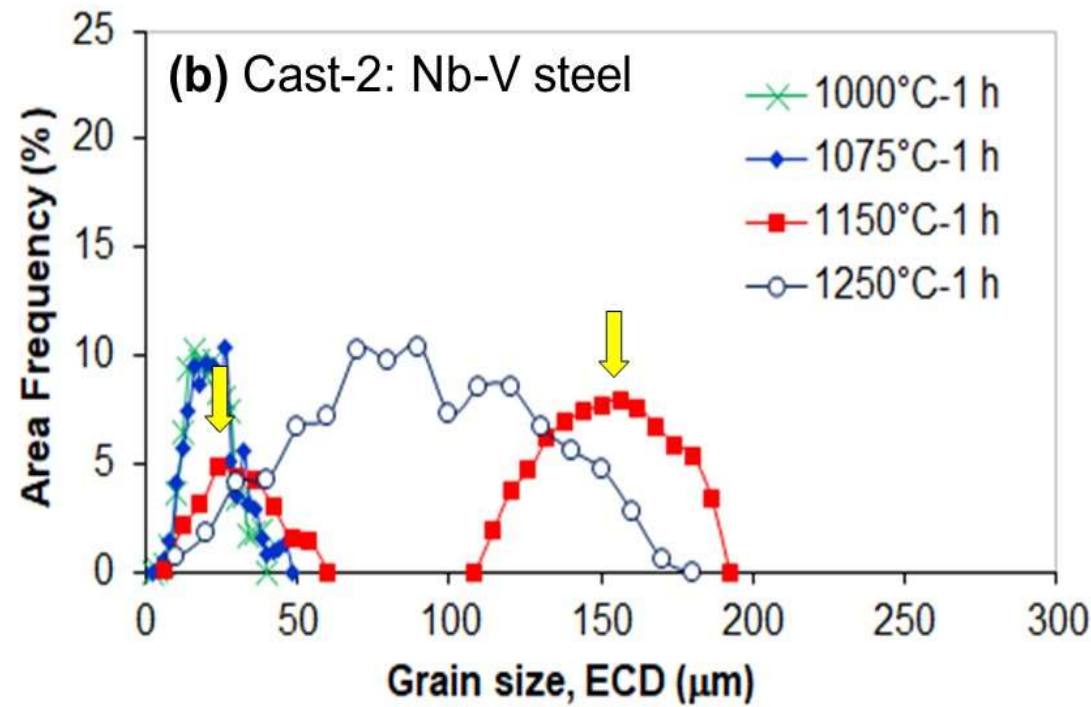
(c) Austenite grains after reheating and soaking



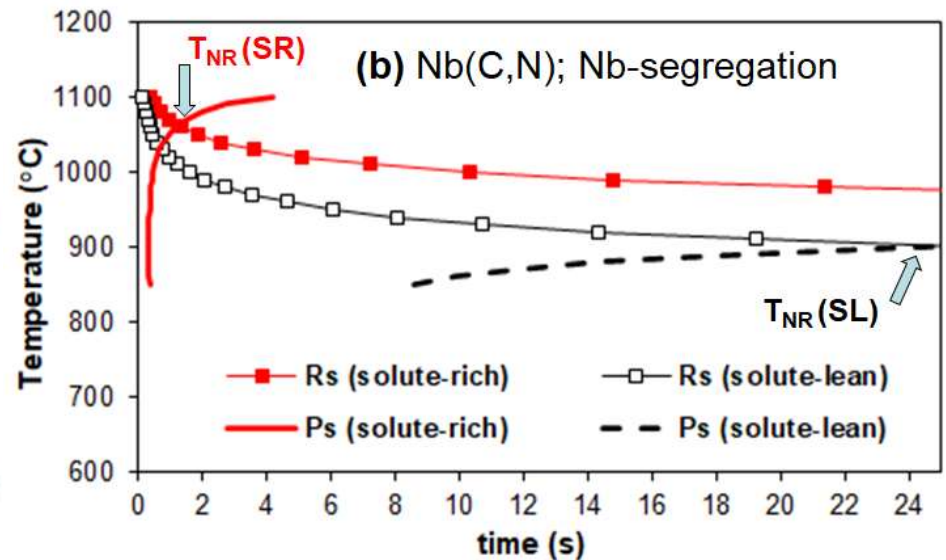
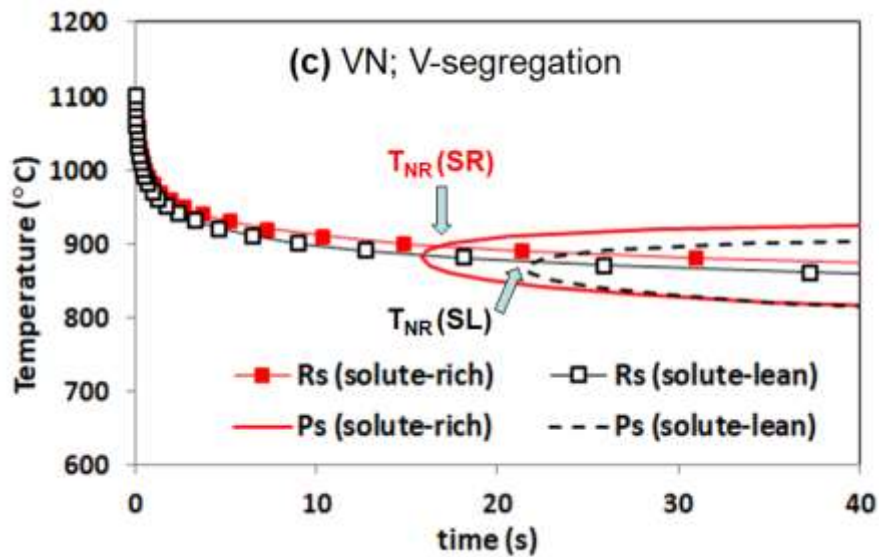
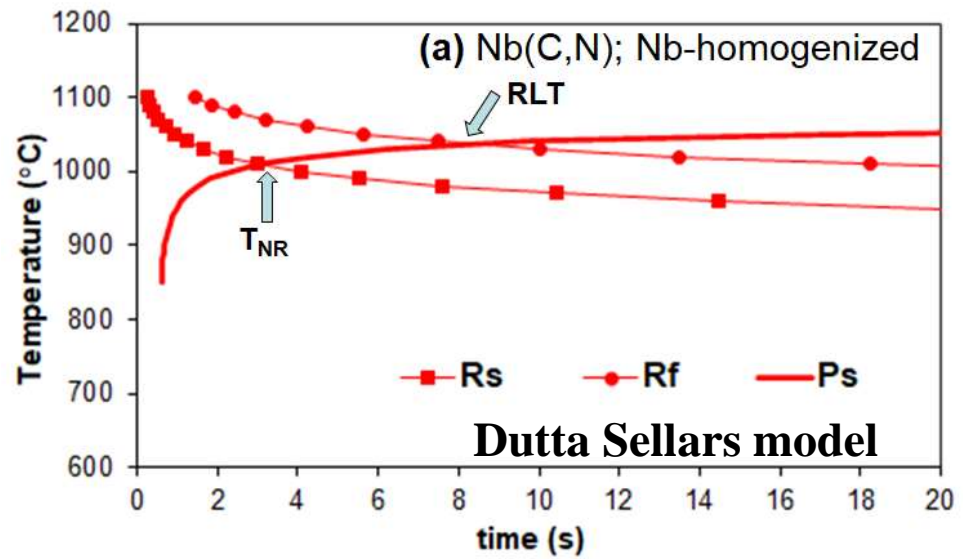
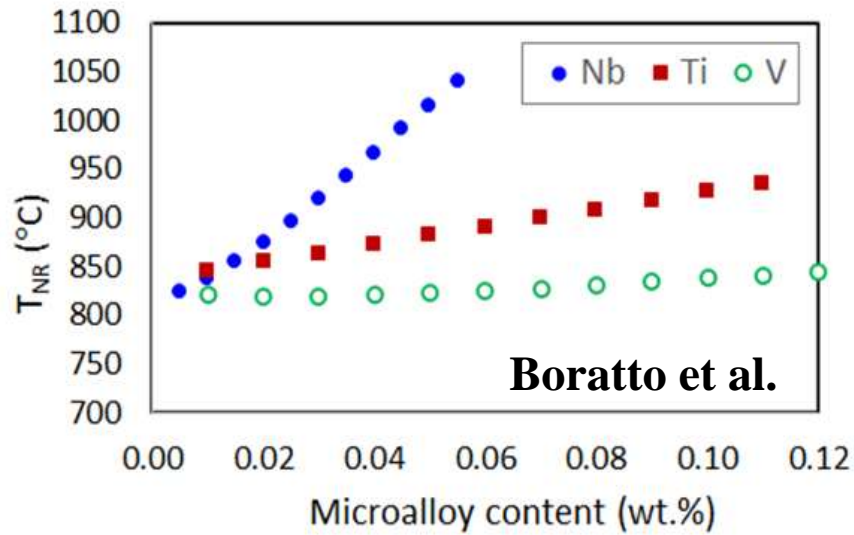
Austenite grain structures in reheated sample of V steel 17

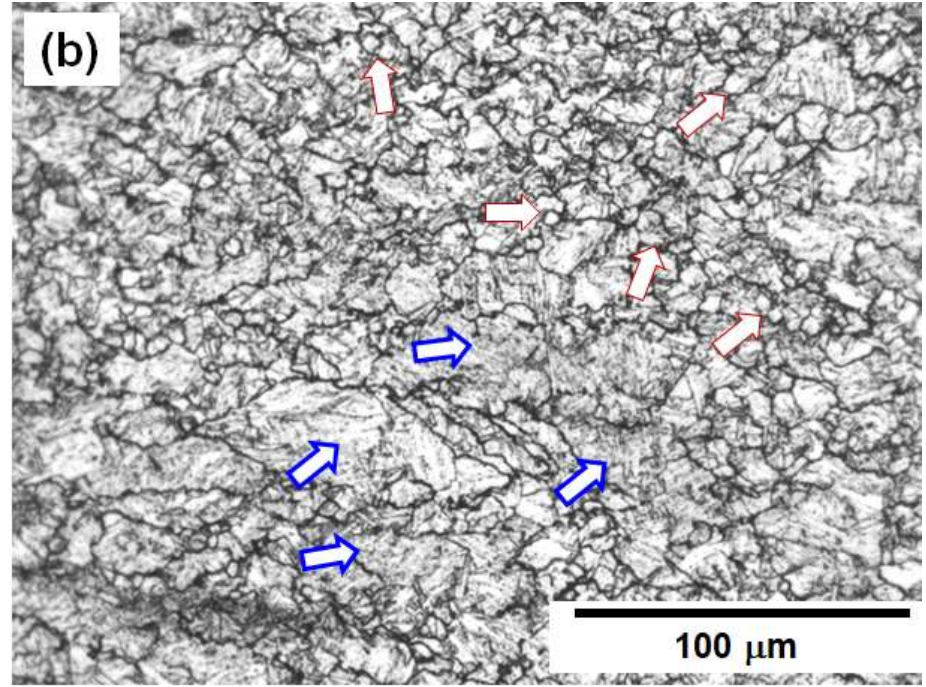
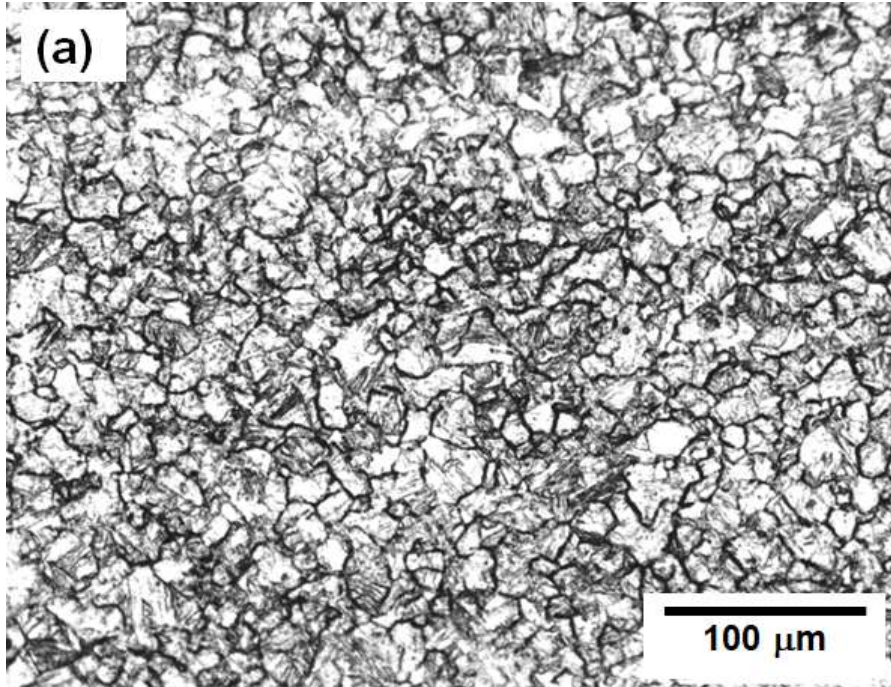


Austenite grain size variation in Nb and V containing steels

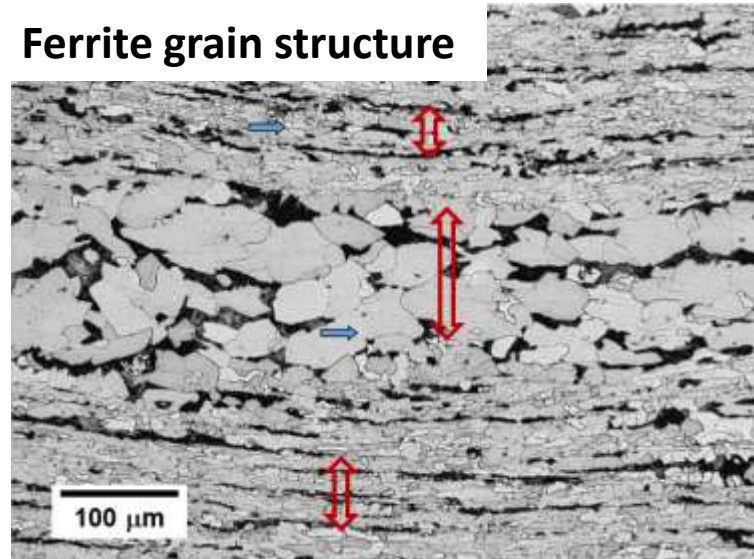


Effect of compositional variation on T_{NR}

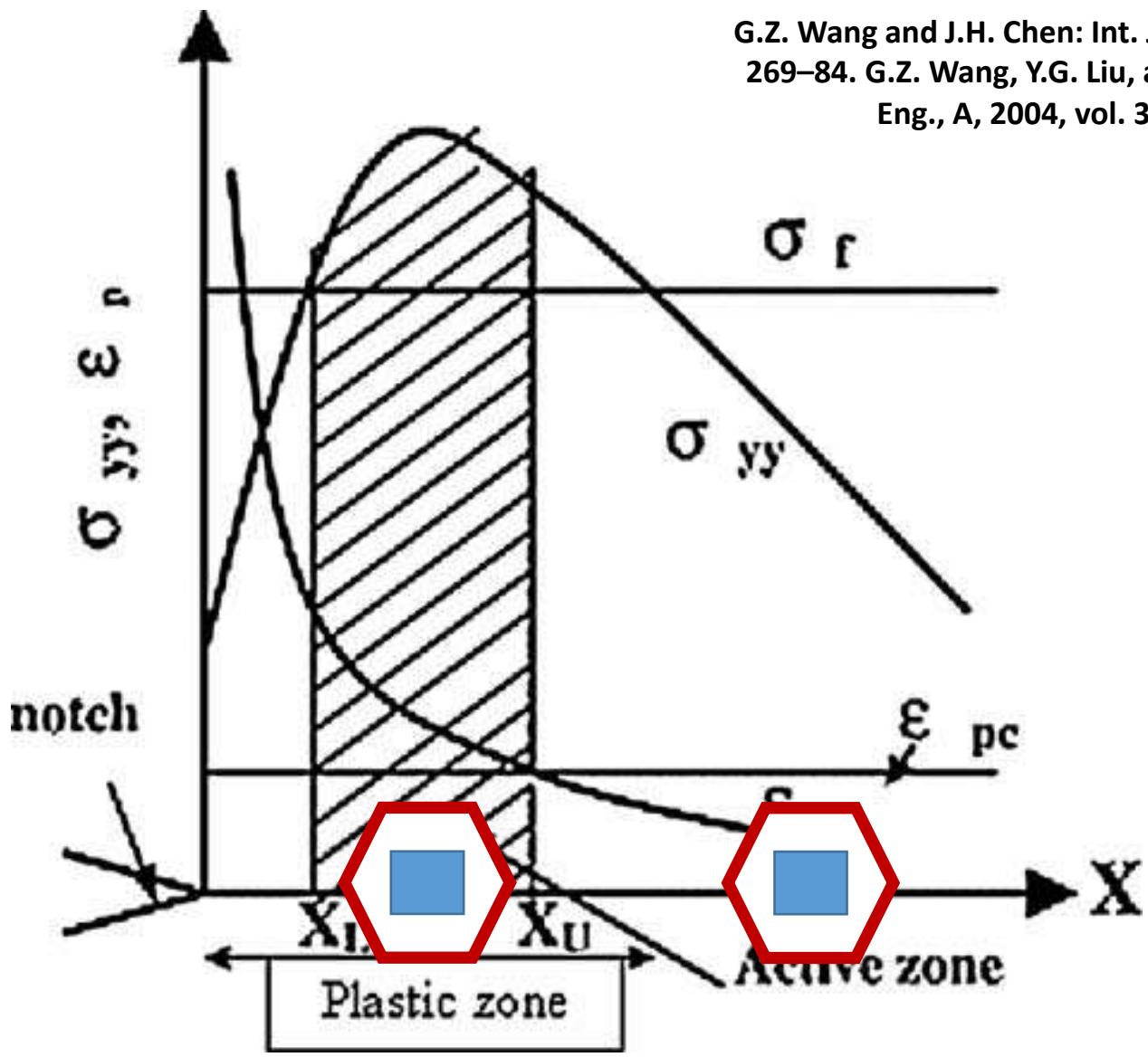




Ferrite grain structure



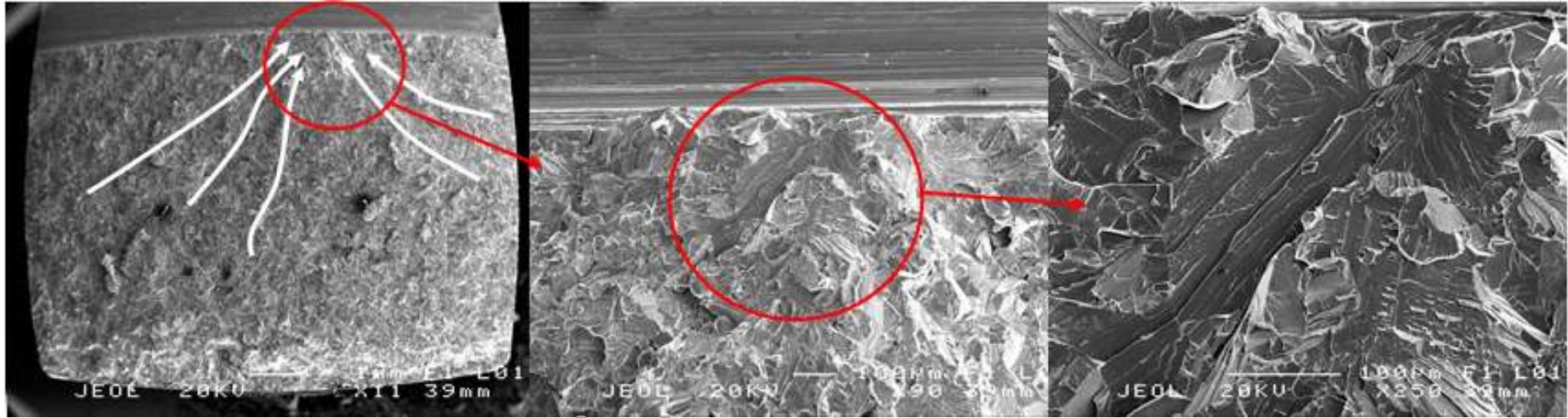
G.Z. Wang and J.H. Chen: Int. J. Fract., 1998, vol. 89, pp. 269–84. G.Z. Wang, Y.G. Liu, and J.H. Chen: Mater. Sci. Eng., A, 2004, vol. 369, pp. 181–91.



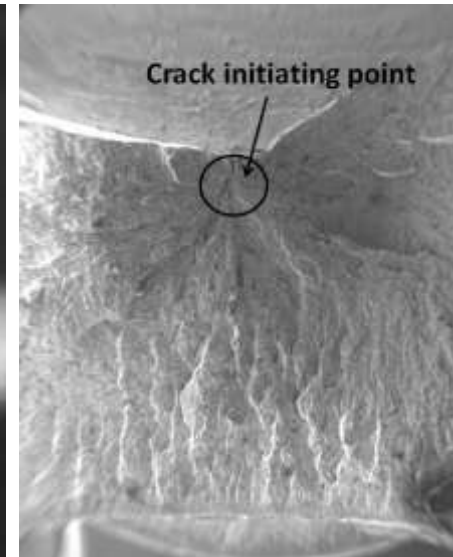
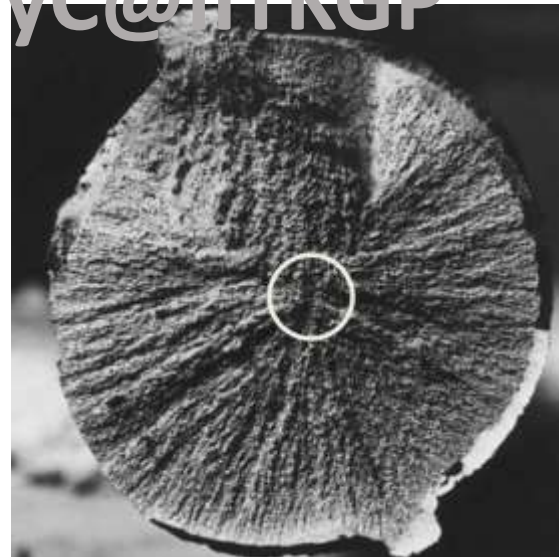
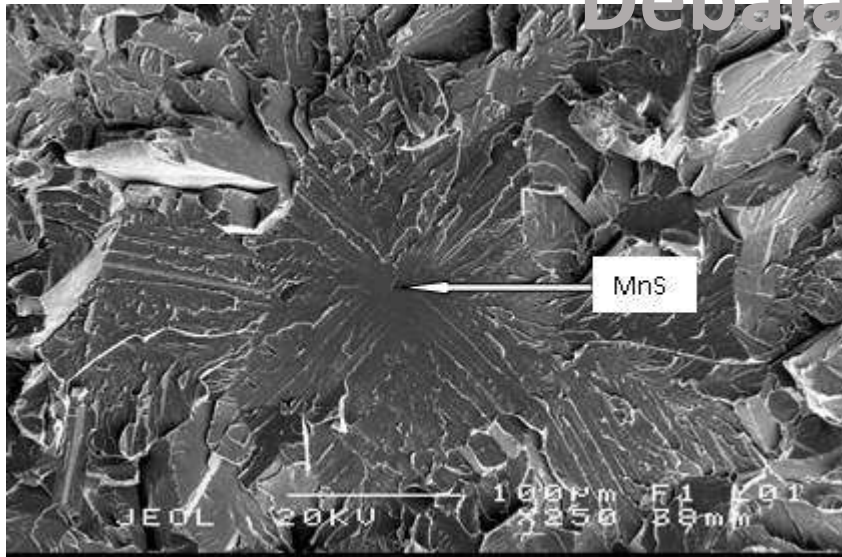
Active zone for cleavage crack initiation

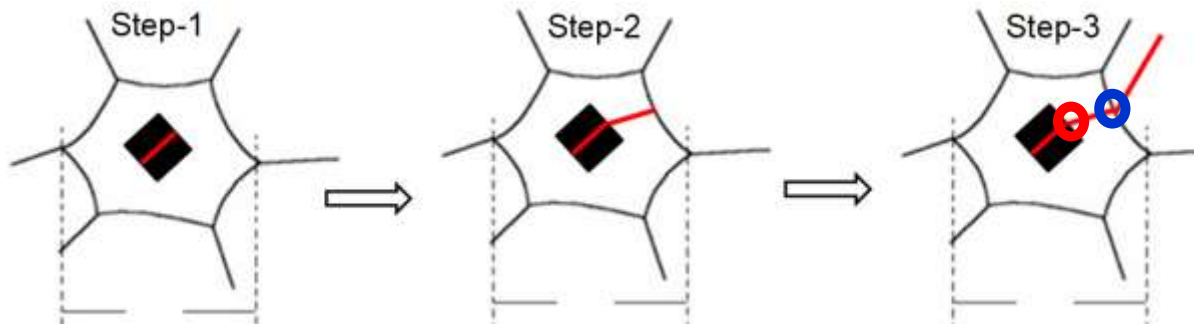
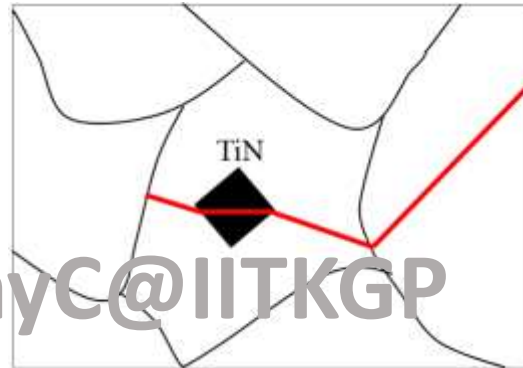
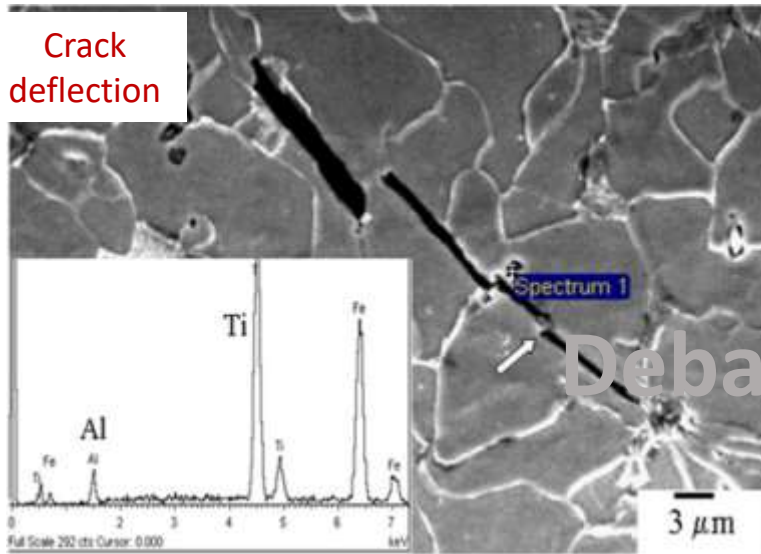
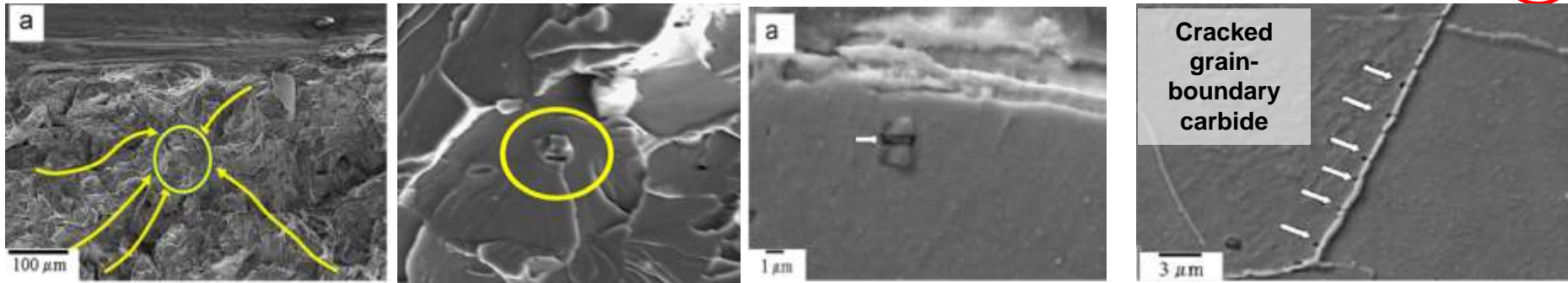
Sufficiently high local stress and strain requirement at notch-tip

Finding the origin of 'transgranular' cleavage fracture



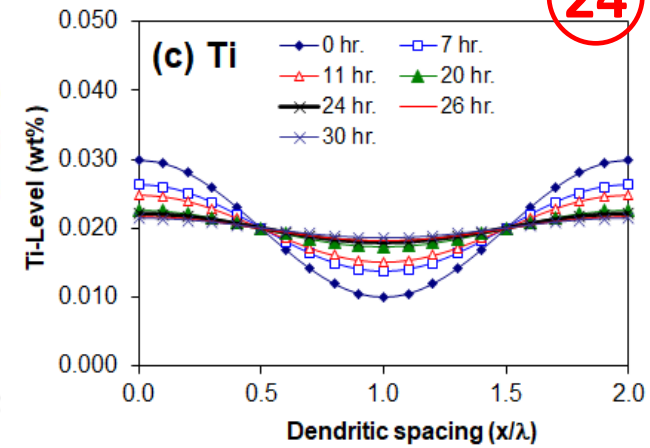
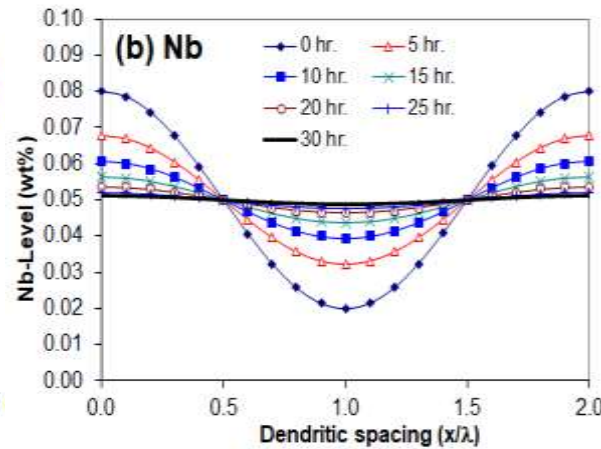
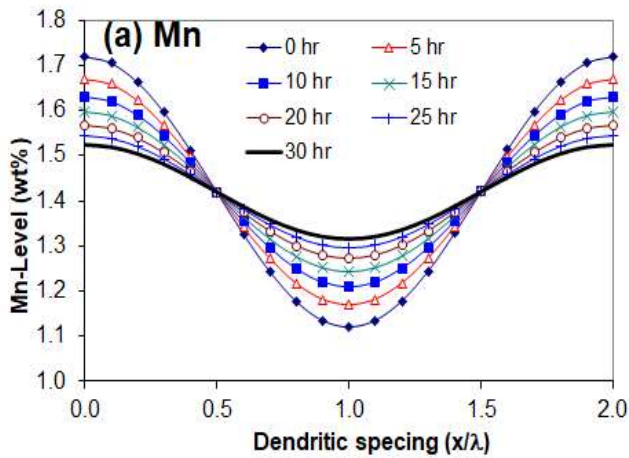
DebalayC@IITKGP



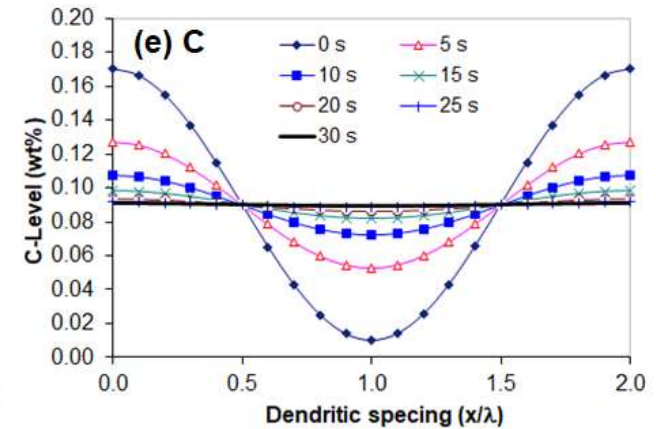
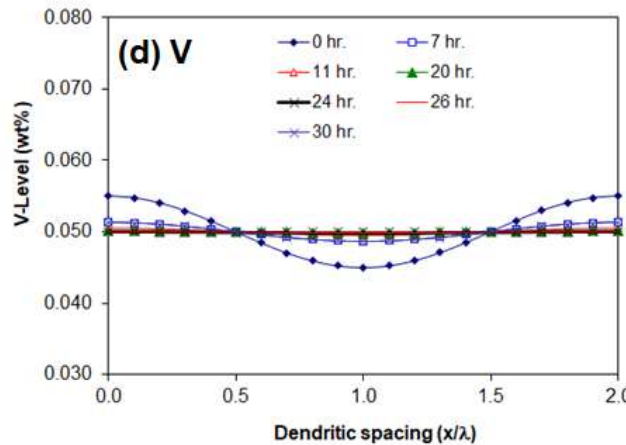


$$\sigma_f = \left[\frac{4E\gamma_{eff}}{\pi(1-\nu^2).x} \right]^{\frac{1}{2}}$$

γ_{pm} (red) and γ_{mm} (blue) are indicated by arrows pointing to γ_{eff} .
 t (red) and D (blue) are indicated by arrows pointing to x .



Homogenization during soaking



- Nb is strongly prone to segregation, its homogenization takes ~ 30 h soaking at 1200°C . The partition ratio of Nb reduces from 4.0 (in the as-cast slab) to 1.04 after 30 h soaking at 1200°C .
- For V the partition ratio decreases from 1.22 in the as-cast slab to 1.1 after just 3 h of soaking and complete homogenization is expected after 12 h soaking at 1200°C .
- For Ti, the partition ratio decreases from 3.0 in as-cast slab to 1.15 after 30 h soaking at 1200°C .
- The partition ratio of Mn reduces from 1.54 in as-cast slab to 1.15 after 30 h soaking at 1200°C .

1. S. Roy, S. Patra, S. Neogy, A. Laik, S.K. Choudhary, **D. Chakrabarti**: Prediction of Inhomogeneous Distribution of Microalloy Precipitates in Continuous-Cast High-Strength, Low-Alloy Steel Slab, **Metallurgical and Materials Transactions A**, Vol. 43A, (2012), pp. 1845-1860.
2. S. Roy, **D. Chakrabarti**, G. K. Dey, Austenite Grain Structures in Ti- and Nb-Containing High-Strength Low-Alloy Steel During Slab Reheating, **Metallurgical and Materials Transactions A**, Vol. 44A, (2013), pp. 717-728.
3. **D. Chakrabarti**, C. L. Davis, M. Strangwood: Development of bimodal grain structures in Nb-containing high strength low alloy steels during slab reheating, **Metallurgical and Materials Transactions A**, Vol 39, No. 8, (2008), pp. 1963-1977.
4. **D. Chakrabarti**, M. Strangwood, C. L. Davis: Effect of bimodal grain size distribution on the scatter in toughness, **Metallurgical and Materials Transactions A**, Vol. 40A, (2009), pp. 780-795.
5. **D. Chakrabarti**, C. L. Davis, M. Strangwood: Effect of deformation and Nb segregation on the grain size bimodality in HSLA steel, **Materials Science and Technology**, Vol. 25, (2009), pp. 8939-8946.
6. **D. Chakrabarti**, C. L. Davis, M. Strangwood: Characterisation of bimodal grain structures in HSLA-steels', **Materials Characterization**, Vol. 58, No. 5, (2007), pp. 423-438.



DebalayC@IITKGP



Thank you



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