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Enhancing Grain Refinement of Austenitic Steel with Ti Additions by Melt Treatment Sequence Optimization

Gun Ge

Semen Naumovich Lekakh
Missouri University of Science and Technology, lekakhs@mst.edu

Ronald J. O'Malley
Missouri University of Science and Technology, omalleyr@mst.edu

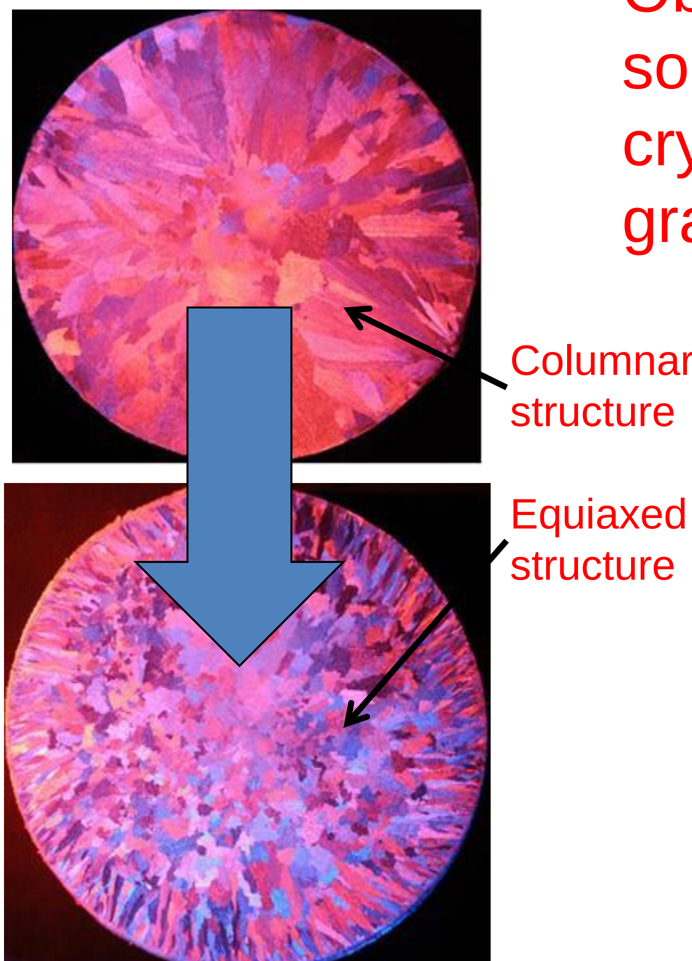
Enhancing grain refinement of austenitic steel with Ti additions by melt treatment sequence optimization

Jun Ge, Simon Lekakh, Von Richards, Ron O'Malley
Missouri University of Science and Technology
Peaslee Steel Manufacturing Research Center (PSRMC)

Objective

Grain size control is one of the most important aspects in the cast alloys processing

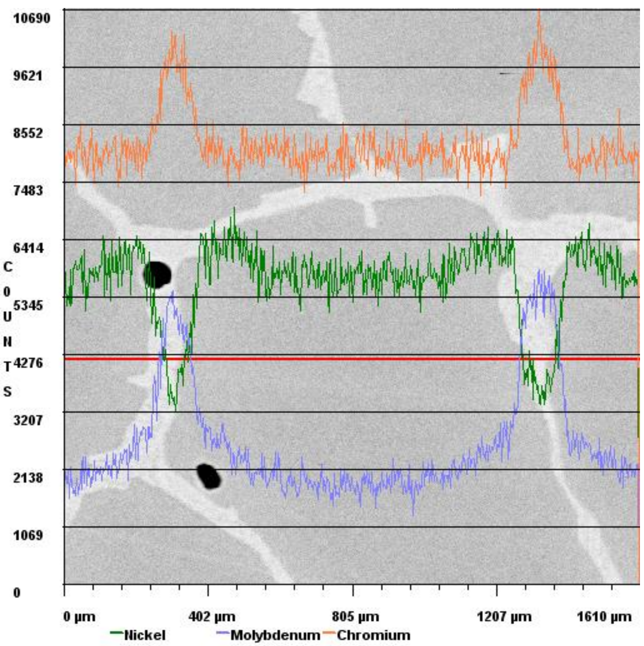
Objective: To develop an advanced solidification process for controlling the crystallization structure of austenitic grades of cast steels in heavy sections

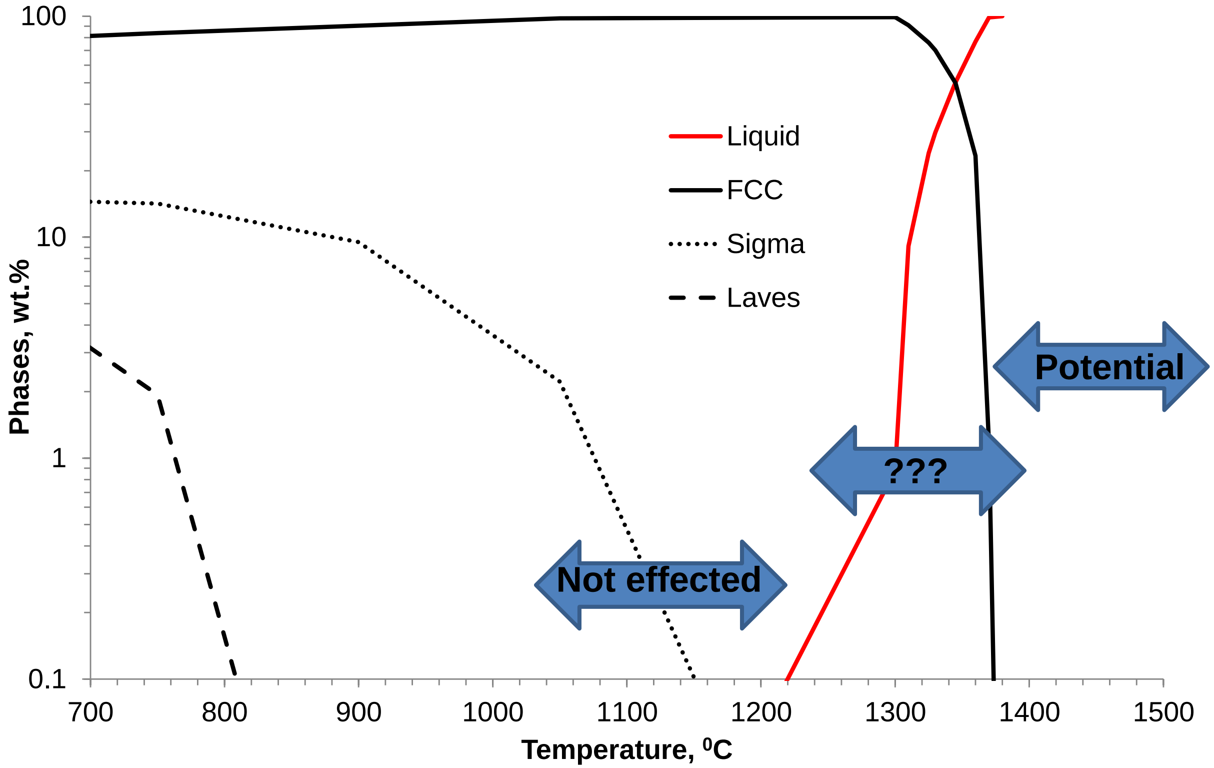


- High alloyed austenitic steels are used in both the as-cast condition and heat treated conditions
- The as cast grain size is important for all applications as it determines the minimum grain size achievable in these cast alloys

Potential heterogeneous nuclei in base steel

Factor stability in the melt

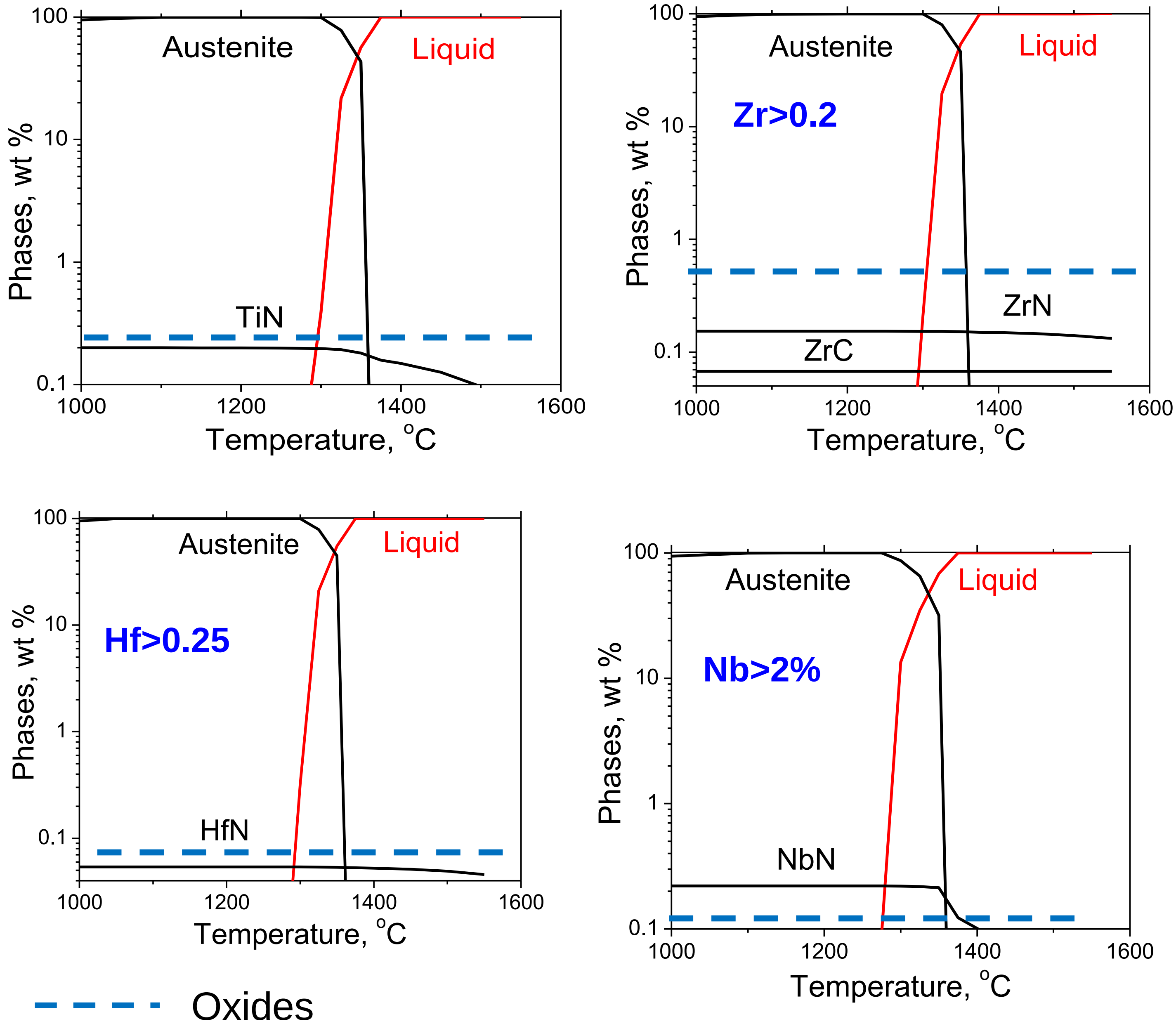




19Cr18Ni superaustenitic stainless steel

Calculated stability of potential nuclei

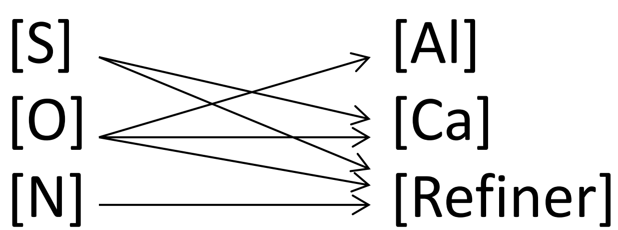
Ti>0.2



Effect of additional de-oxidation

- What is the sequence of reactions during processing?
- How sequence of treatment will change composition of reaction products?
- What will be optimal sequence of melt treatment?

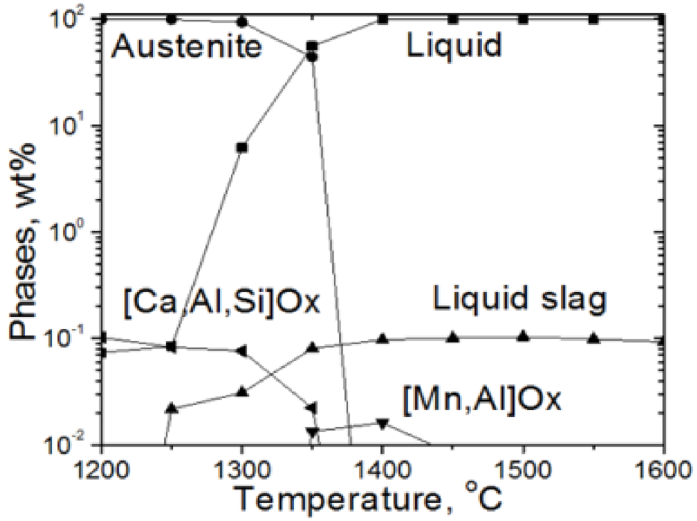
One step	Complex	Sequential
Refiner	De-ox +Refiner	De-ox
		Refiner



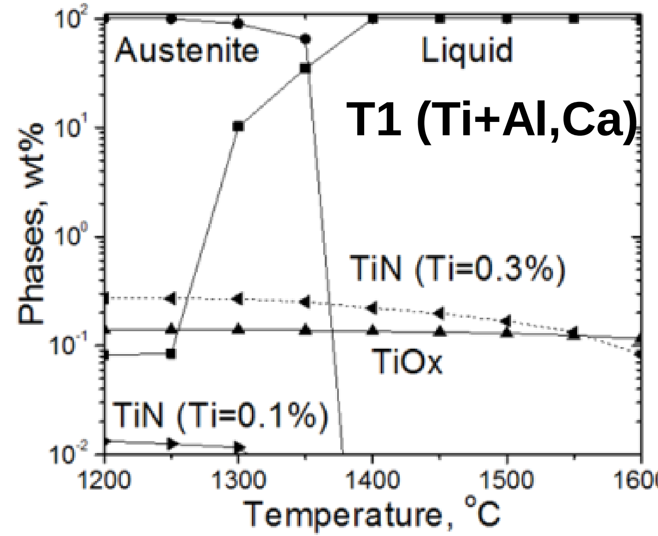
Simulated cases and experimental heats

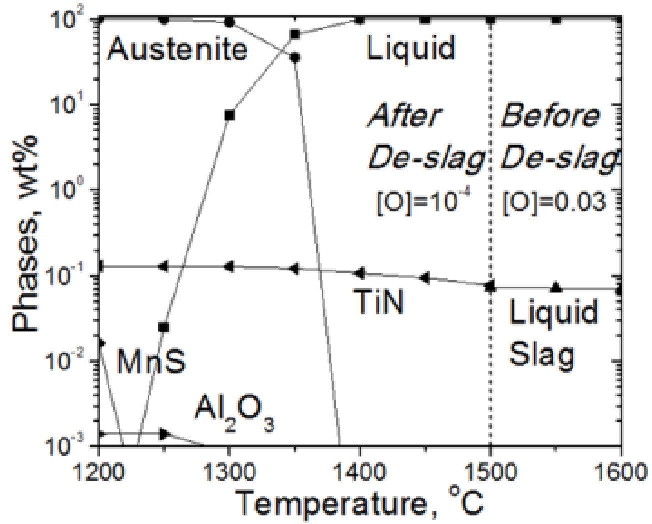
Heat #	Treatment	
	First	Second
B	-	Al, Ca
T1	Ti	Al, Ca
T2	Al, Ca	Ti
T3	Ca	Al, Mg, Ti

Effect of treatment sequences on precipitations

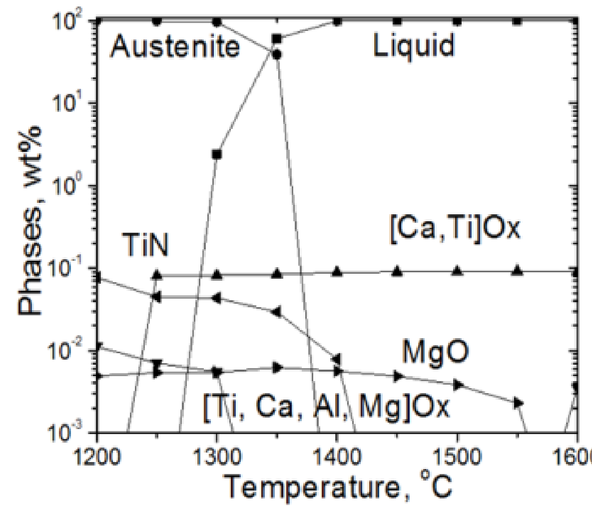


B0 (Al+Ca)



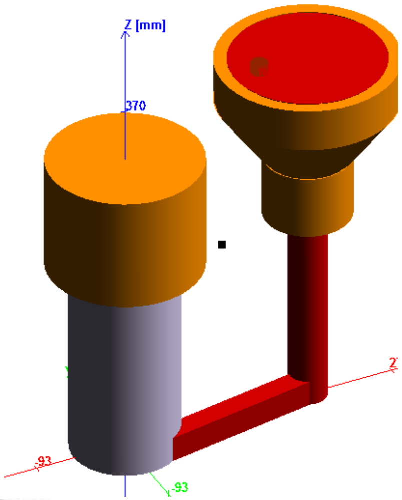


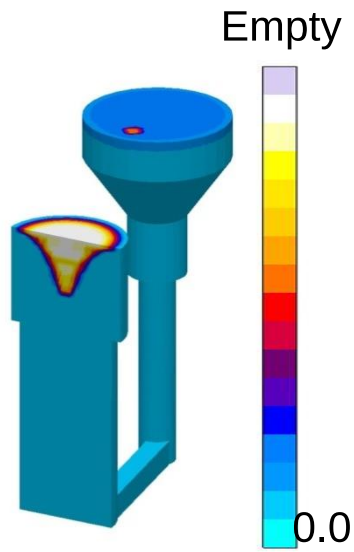
T2 (Ti+Al,Ca)

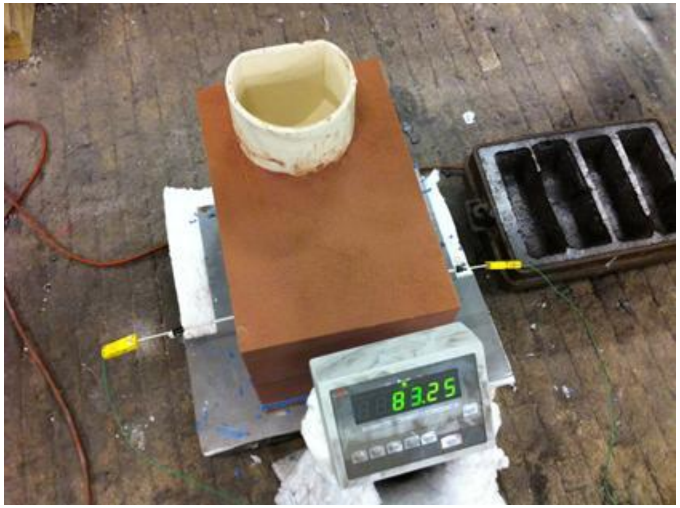


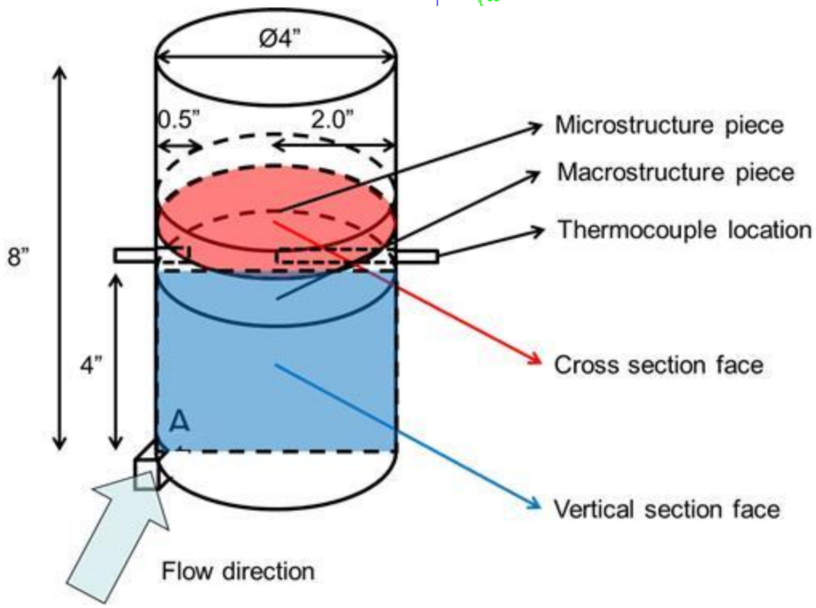
T3 (Ca+Al,Mg,Ti)

Experimental procedure: heavy section casting



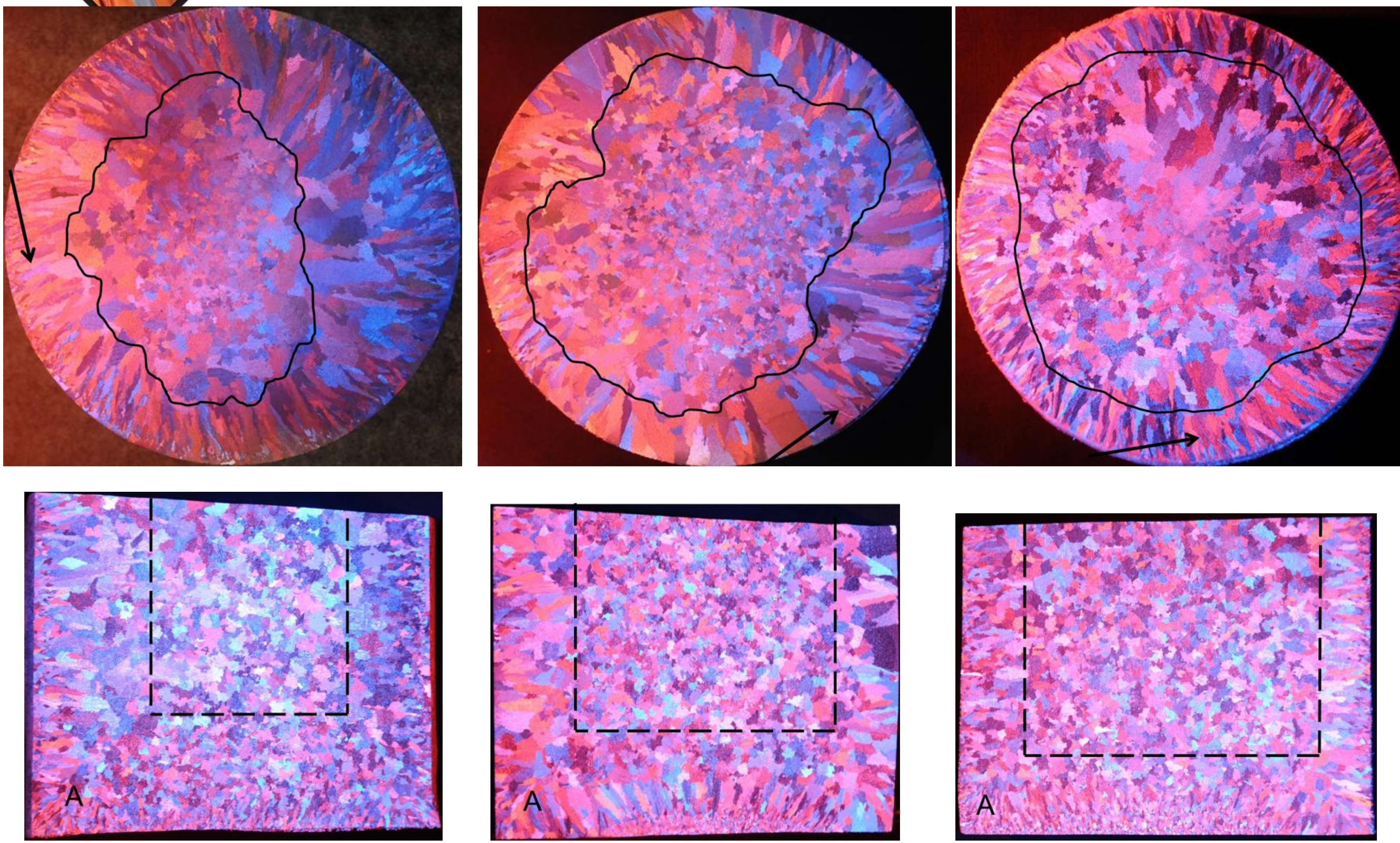




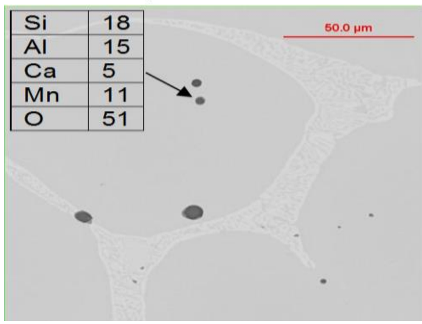


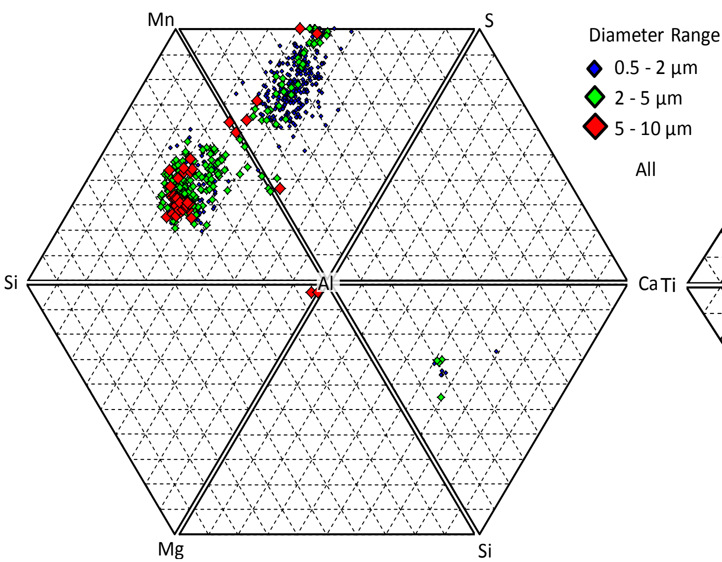
Macrostructure

B2 base | T1 (IF: Ti, Ladle: deox) | T2 (Ladle: deox + Ti)

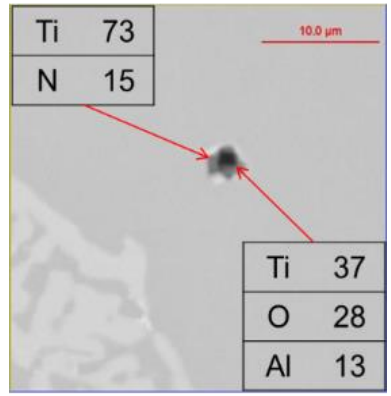


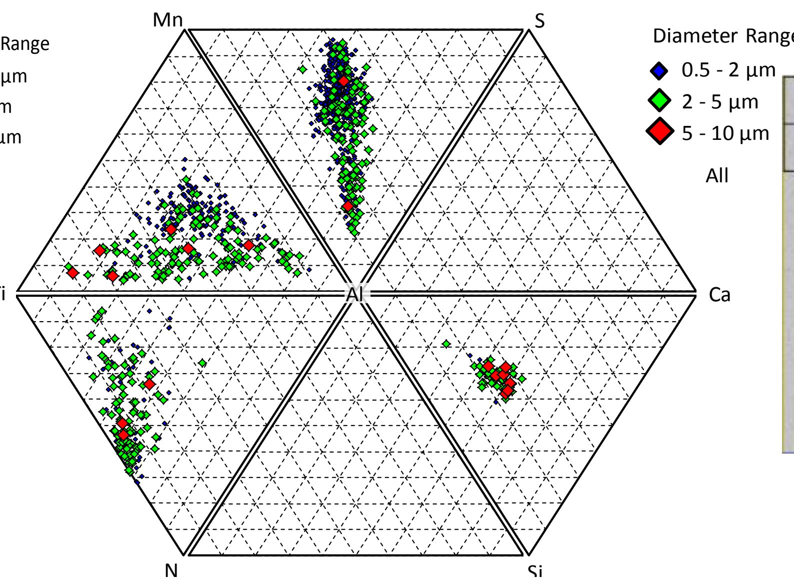
Chemistry of precipitates



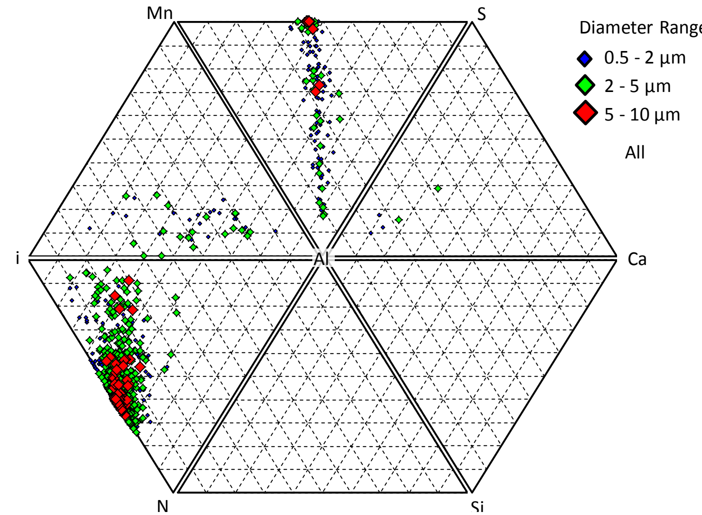


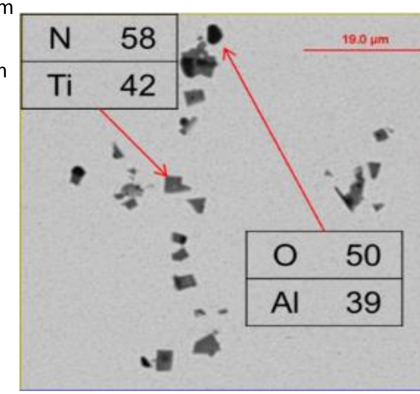
B2 base





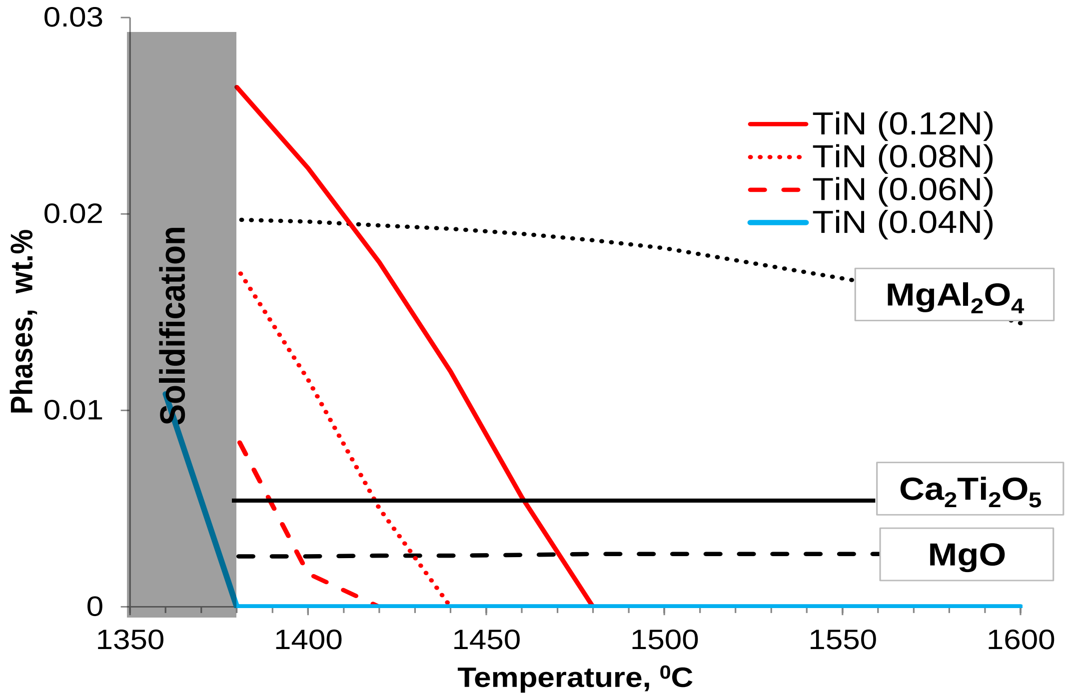
T1 (Ti + deox)





T2 (Deox + Ti)

Co-precipitation grain refinement approach



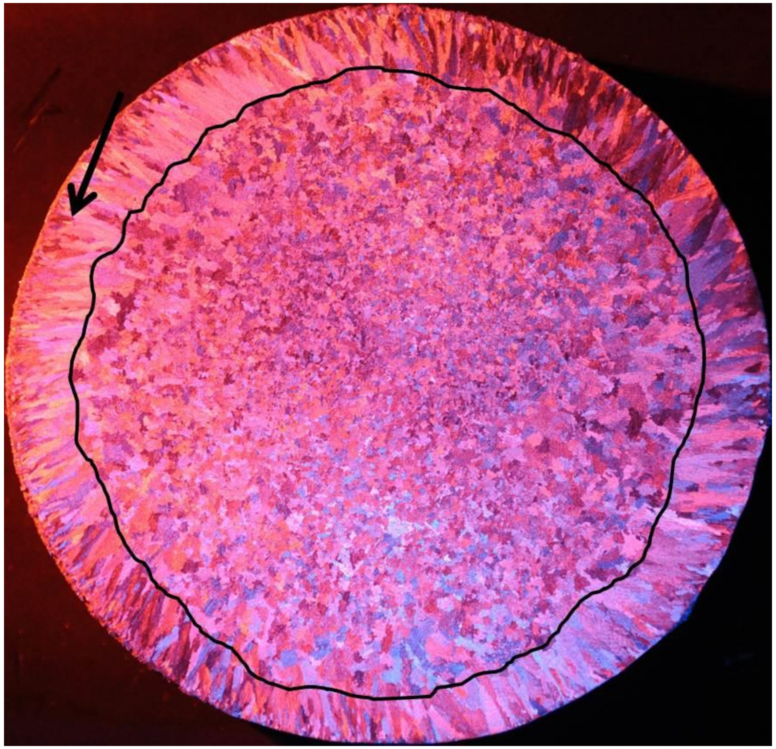
CET

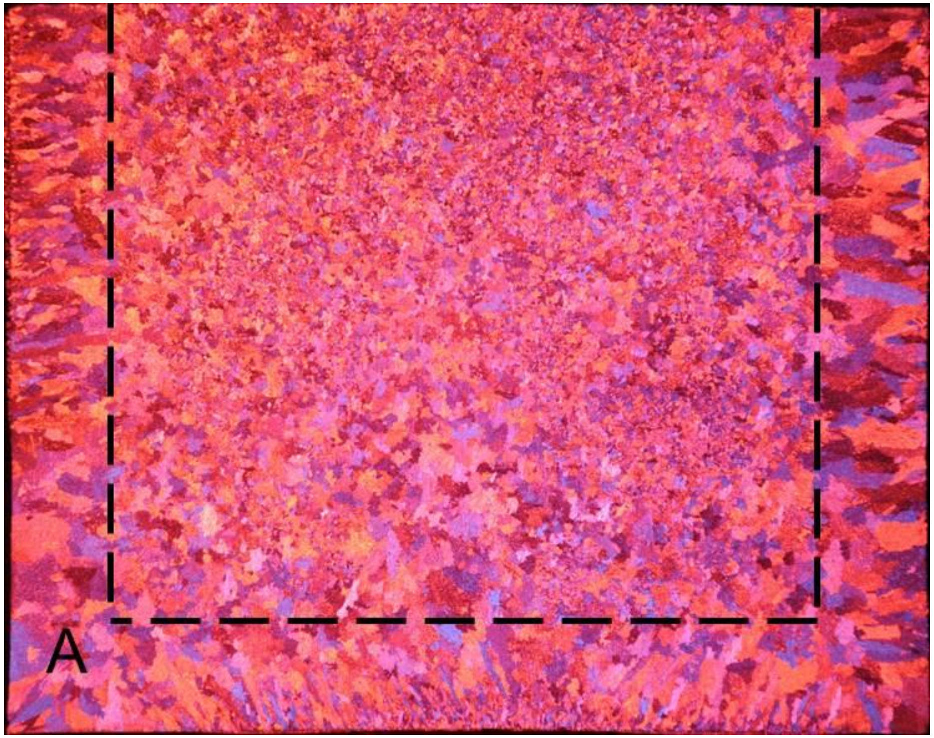
Compound	Lattice parameter α_0 at 2800 ˚F, Å	Planar disregistry with TiN, %
TiN	4.308	-
$MgAl_2O_4$	4.098	4.9
MgO	4.310	0.0053
Ti_2O_3	5.225	16.2
Al_2O_3	4.825	17.48

J. S. Park, Steel Research Int., 85 (2014) No. 9999

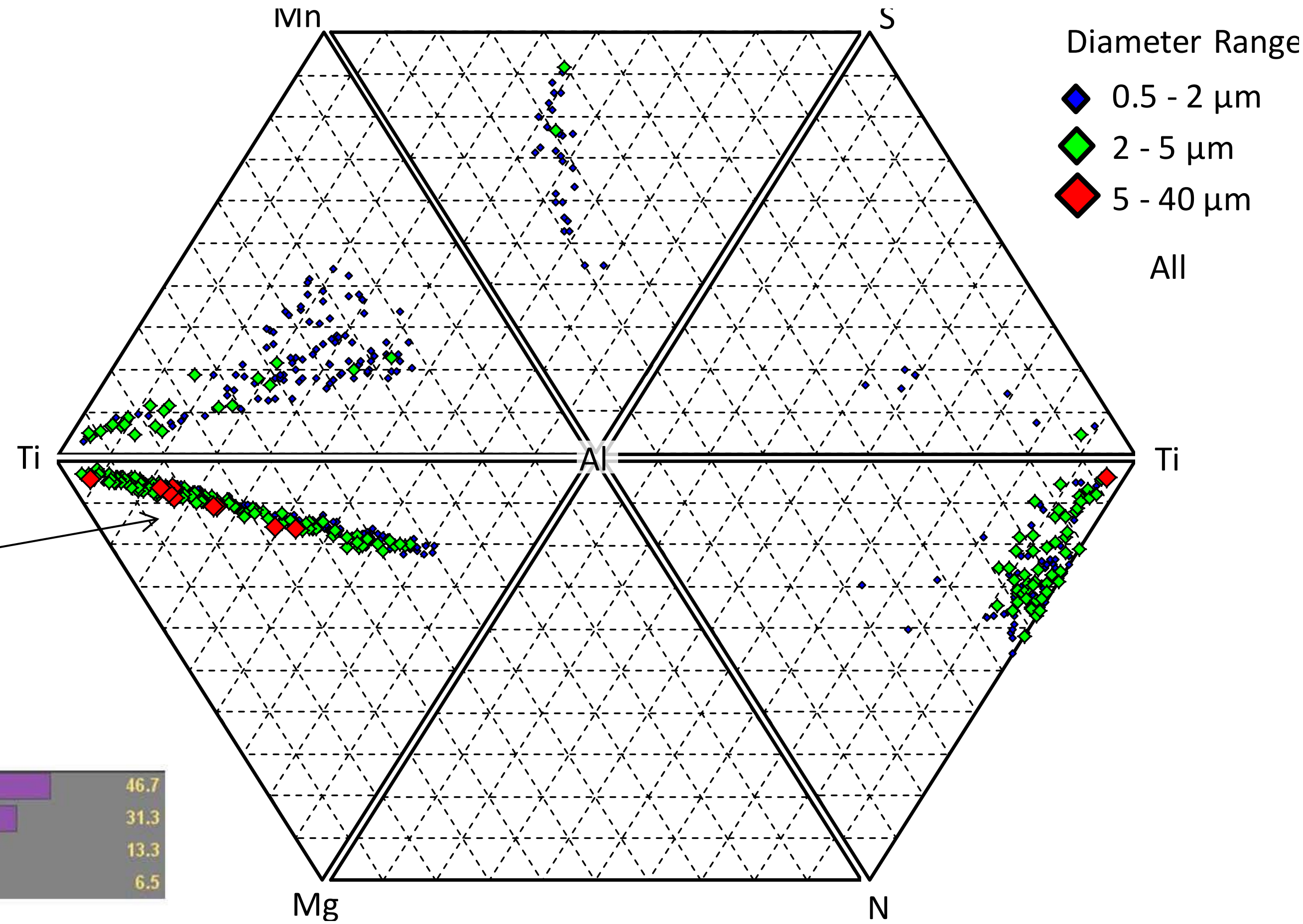
Experimental heat T3 for concept verification

Heat #	Treatment	
	IF	Ladle
T3	Ca	Al, Mg, Ti

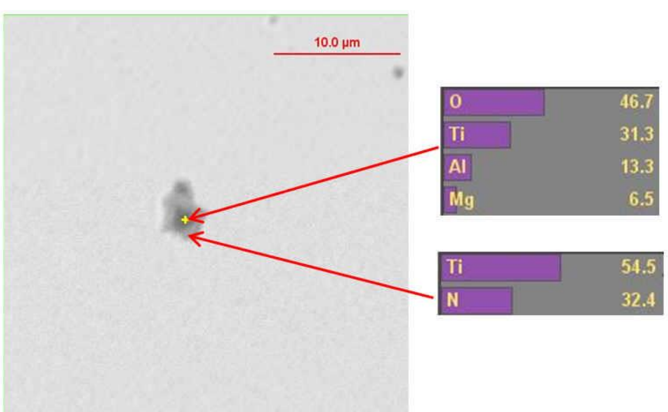




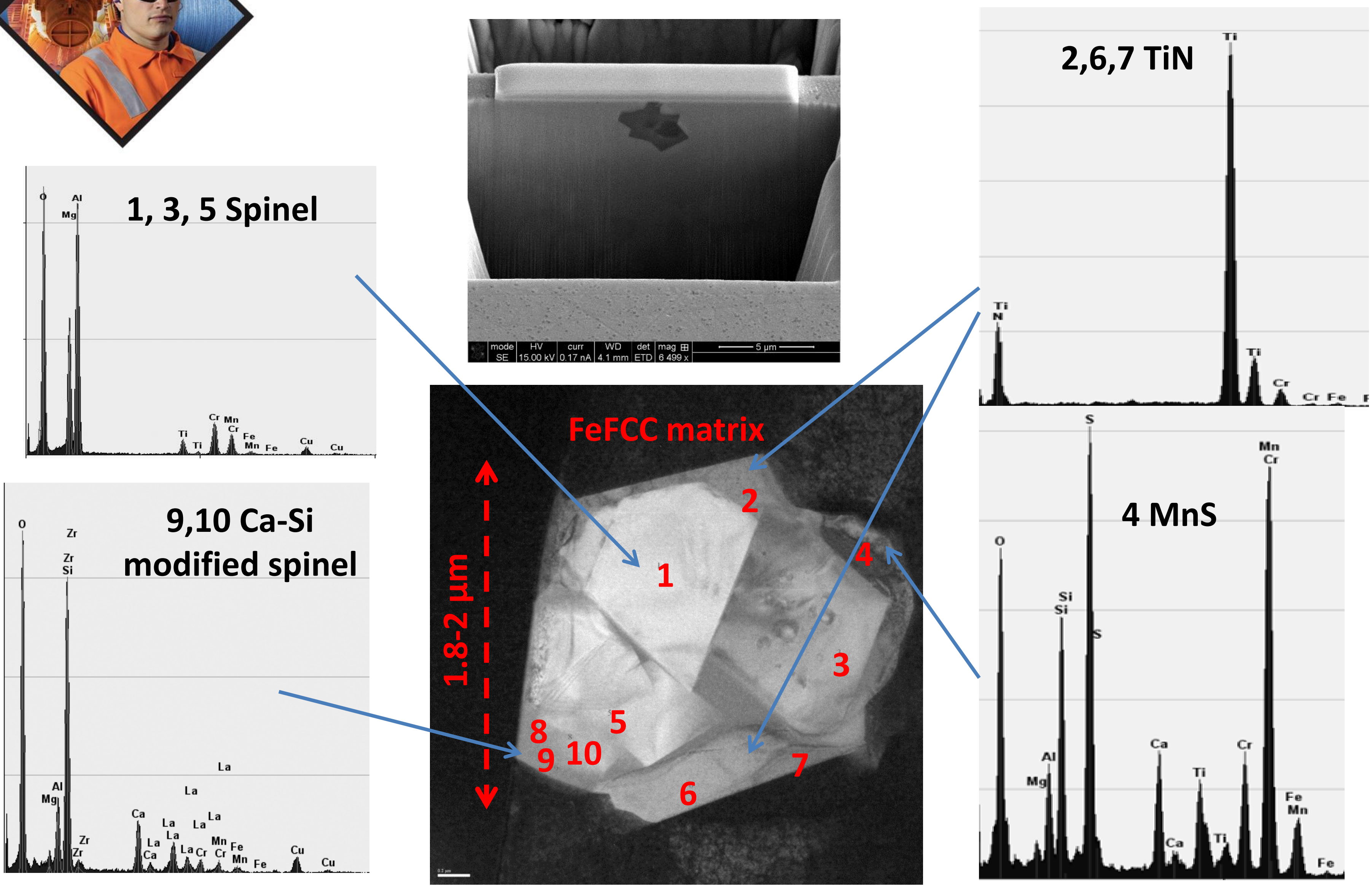
Precipitations - Heat T3



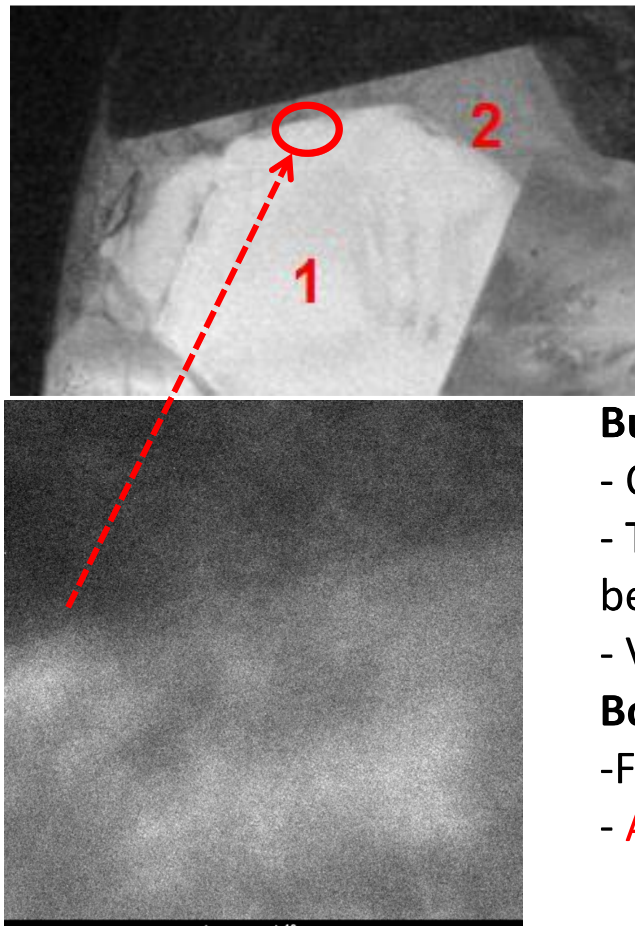
$MgAl_2O_4$ with TiN

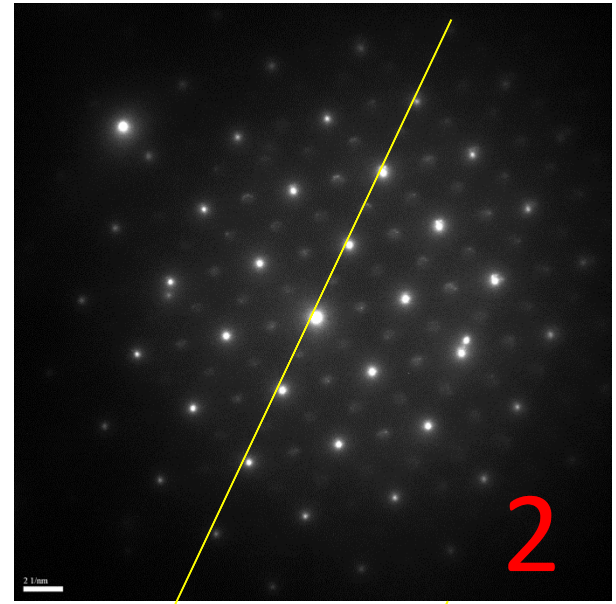


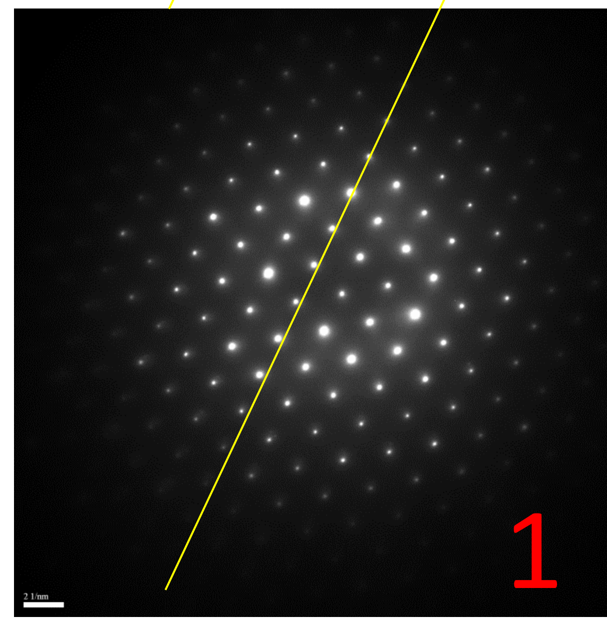
TEM of complex precipitate



Spinel – TiN boundary







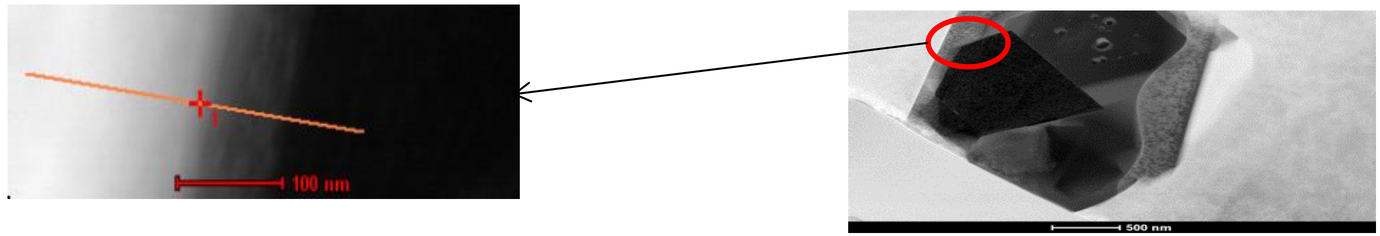
Bulk:

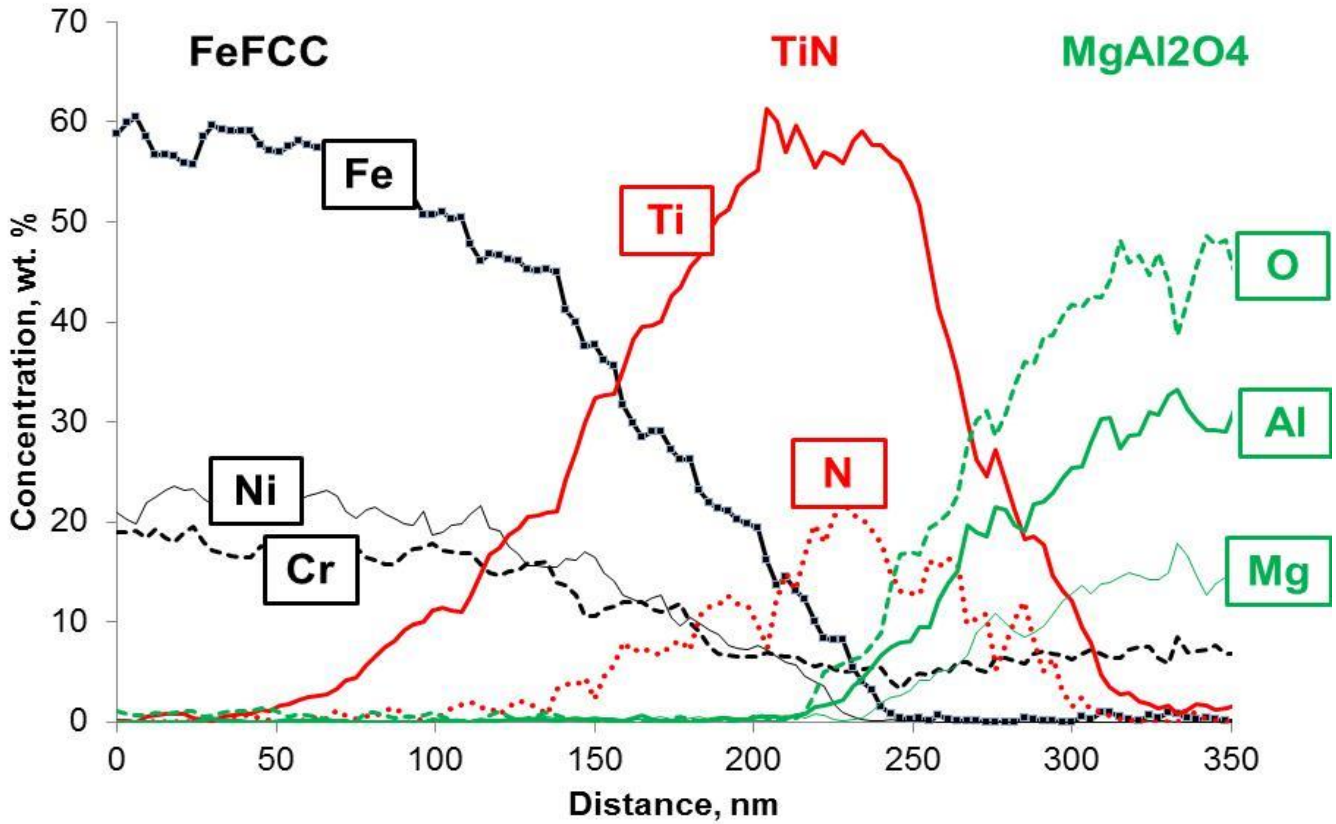
- Constant zone axes angles
- The same [011] planes in beam direction
- Very close orientation

Boundary:

-Flat topology
- Almost epitaxial

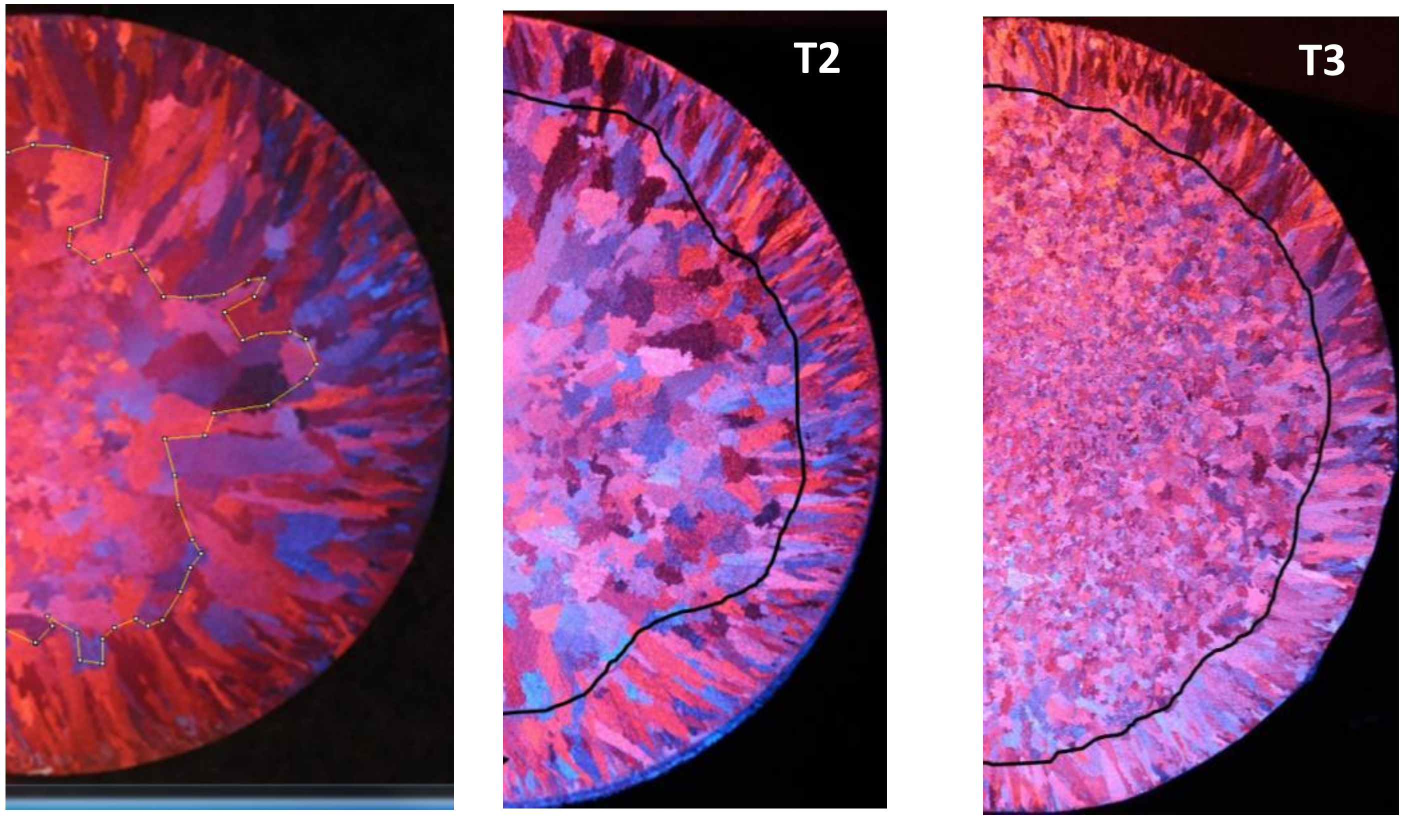
High resolution Matrix-TiN-Spinel line scan





Step size – 5 nm, spot size ≈ 10 nm

Comparison of achieved grain refinement



	R	Equiaxed grains, , mm
G2 (base)	0.57	2.4
T2 (N+Deox+Ti)	0.78	2.2
T3 (Al+Mg+Ti)	0.82	0.5

Findings

- Optimized sequence of de-oxidation and refinement provides increase grain refinement efficiency
- Co-precipitation of targeted nucleation sites by inclusion engineering is the effective way to enhance heterogeneous nucleation
- The well-refined as-cast structure was achieved in experimental heavy section castings

Acknowledgements

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