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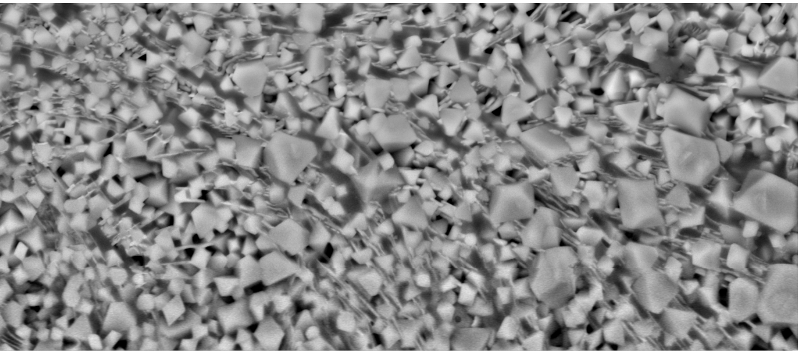

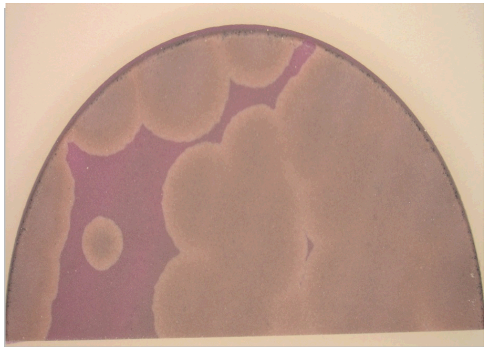

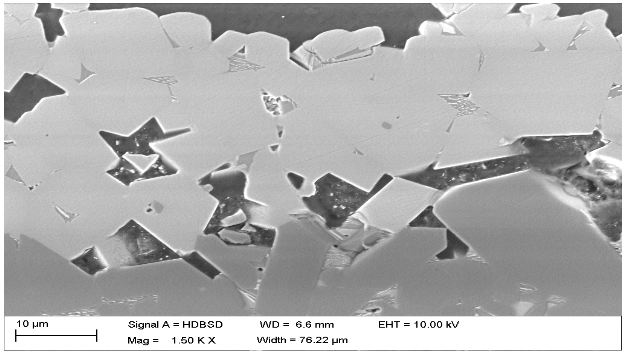

Microstructural Characterization of Semi Conductive Coatings on Ceramic Insulators for Improved High Voltage Hold off Performance

Sandra Stangebye

Brittany Muntifering, Elizabeth Paisley, Rajan Tandon

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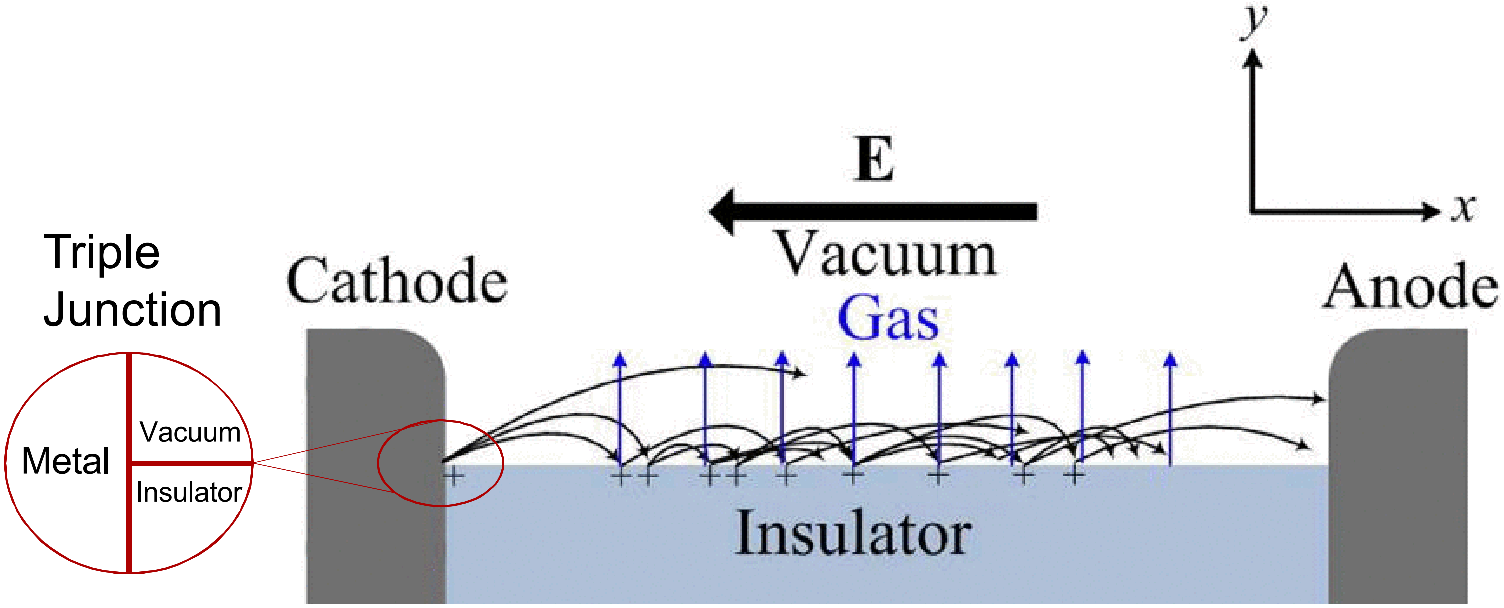
Outline

- Background
  - Characteristics of solid insulators in vacuum
- Characteristics of bulk ceramic
- Procedure
- Ti/Mn coating microstructure analysis
  - Optical gradation
  - SEM, EDS, and TEM data
- Ti/Cr coating microstructure analysis
- Compare Ti/Mn and Ti/Cr coatings
- Preliminary electrical property results and future work

High Voltage Performance of Solid Insulators

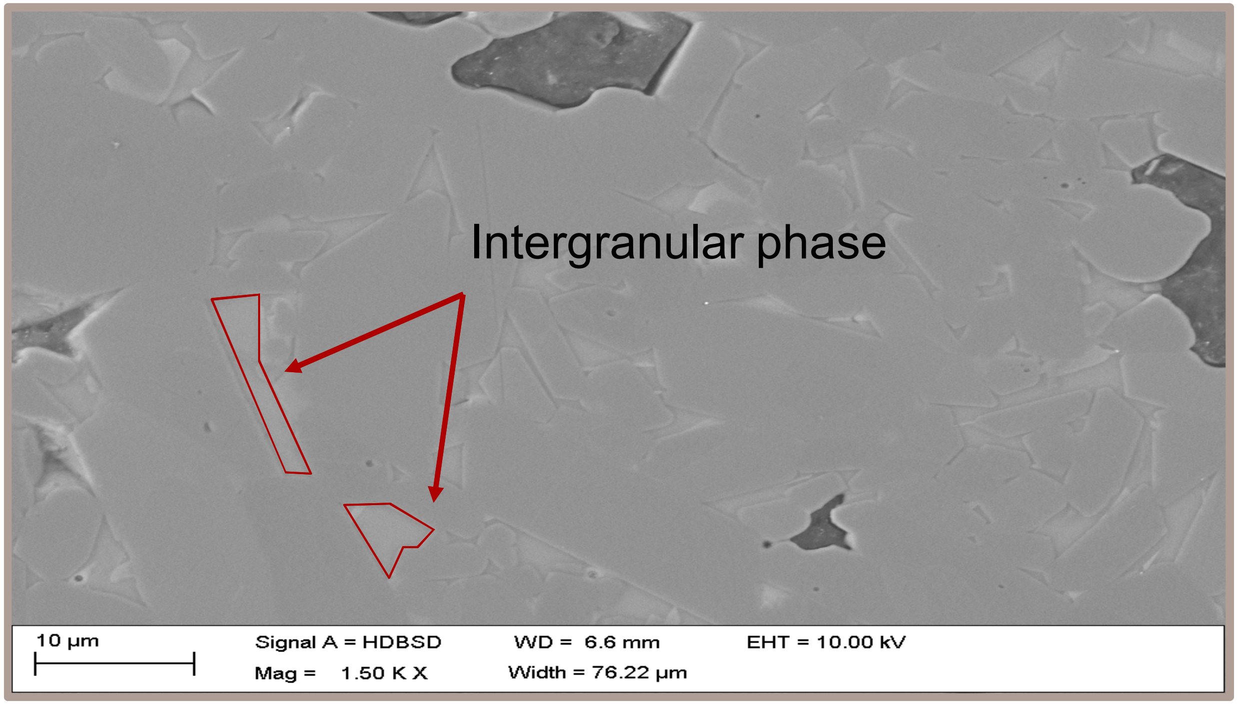


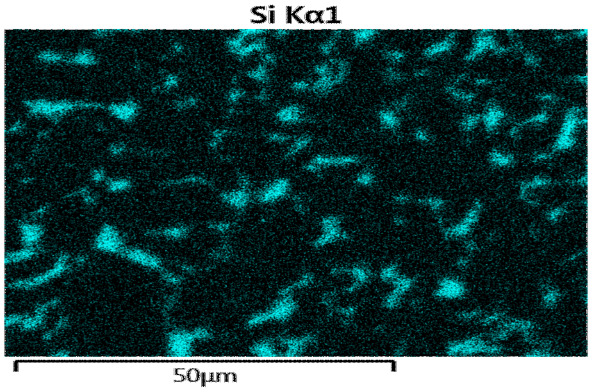
- Secondary electron emission (SEE) leads to voltage breakdown
- Positive feedback loop can cause continuation of SEE

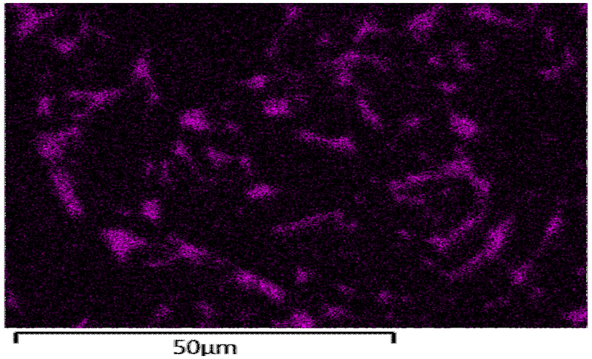
<u>Goals</u>

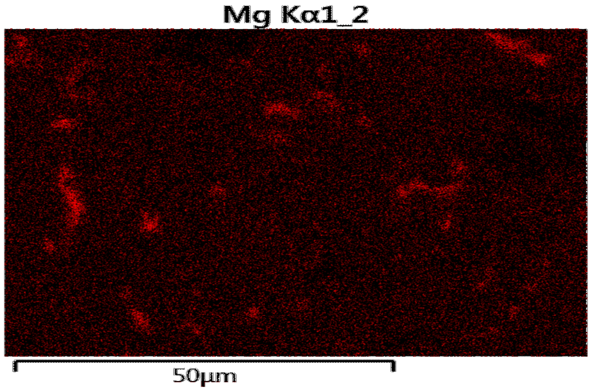
- Decrease secondary electron emission
- Increase surface electrical uniformity
- Decrease surface resistivity

Bulk Ceramic Insulator


Intergranular phase


Si Kα1

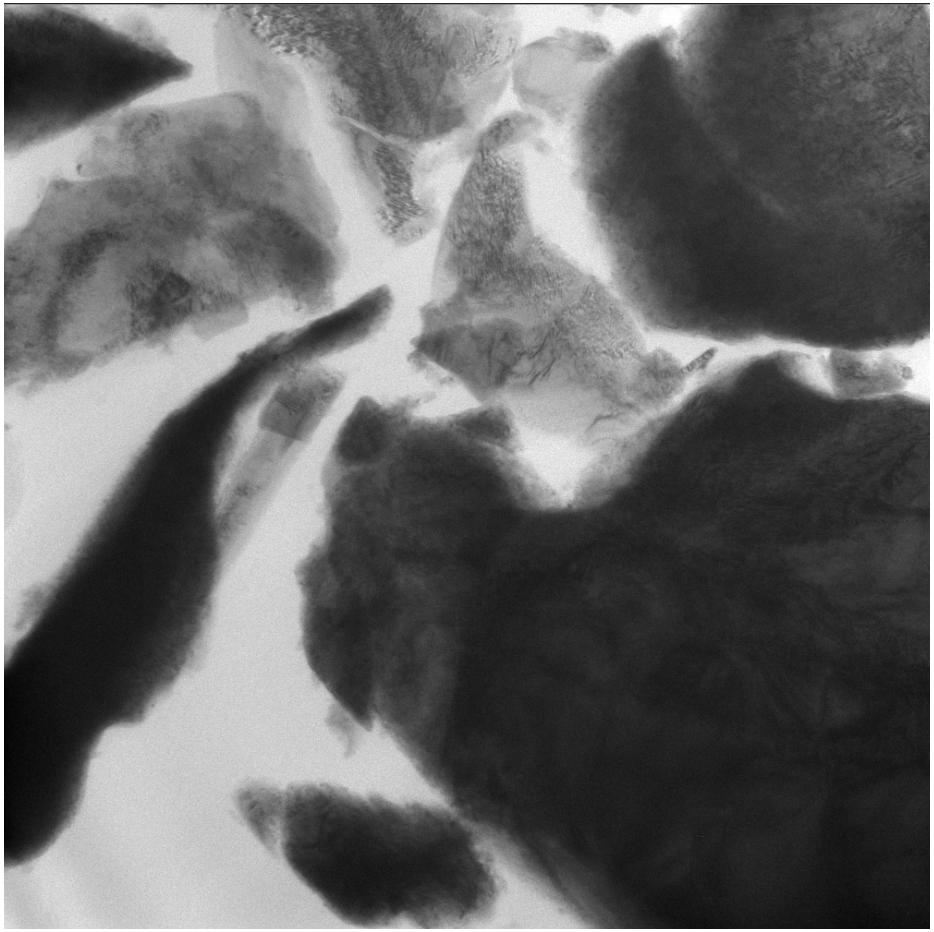



Mg Kα1_2

Bulk: 94% Alumina (Al_2O_3)
Intergranular Phases:
Primarily SiO_2 and CaO (some MgO and Cr_2O_3)

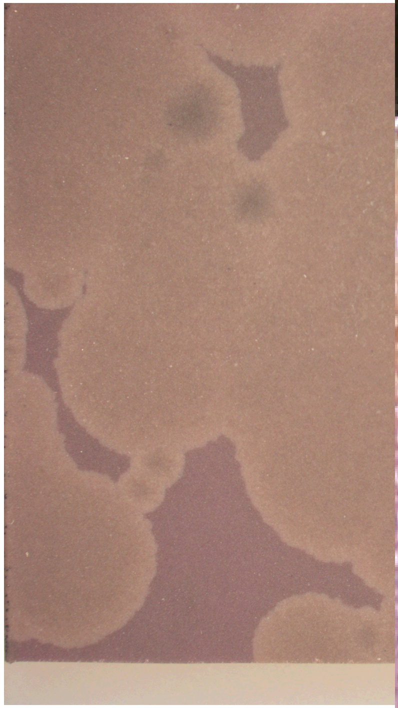
Procedure

- Ti/Mn and Mn/Cr powders
- Powders in solvent painted onto ceramic and fired at temperatures above 1300 C
- Compared Ti/Cr and Ti/Mn coatings

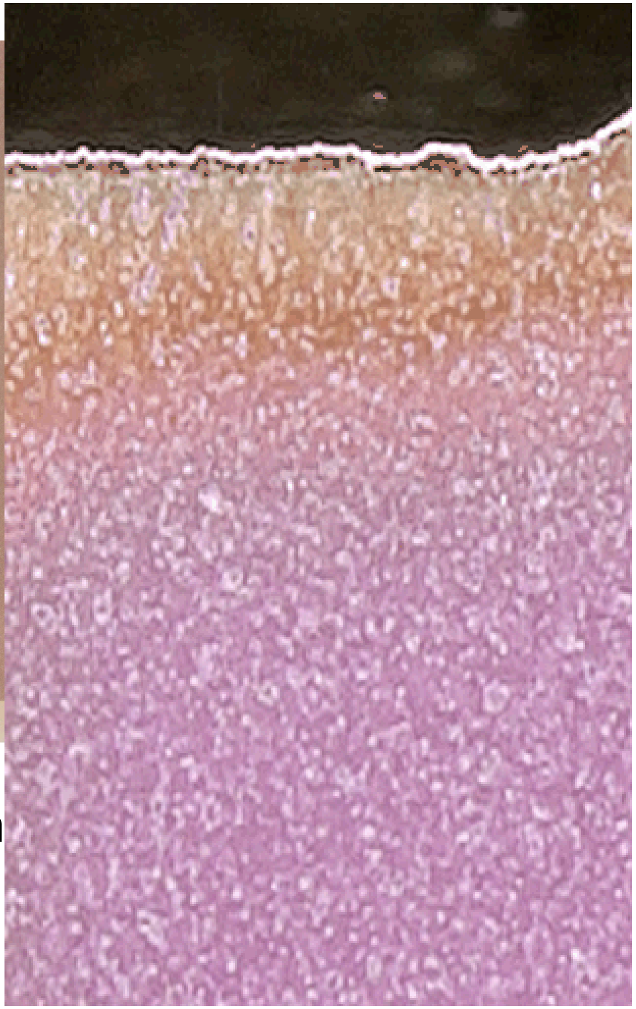


TEM Images of semi-conductive powder

Ti/Mn Coating

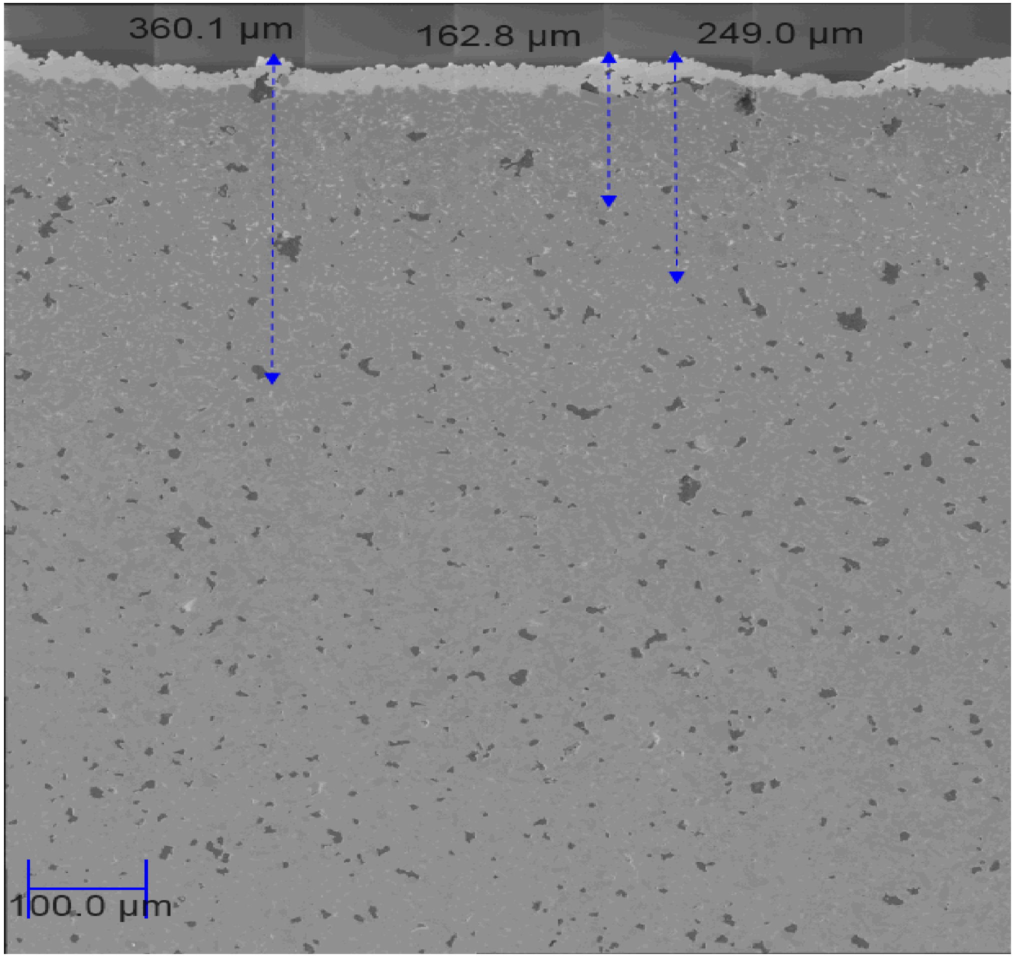


Top view of Alum



5 colors observed

SEM Cross Section



~<20-45µm

~120µm

~85µm

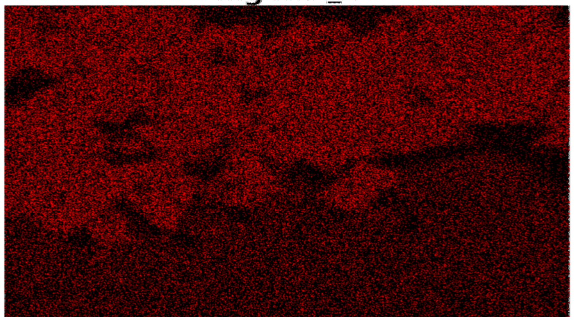
~110µm

Bulk

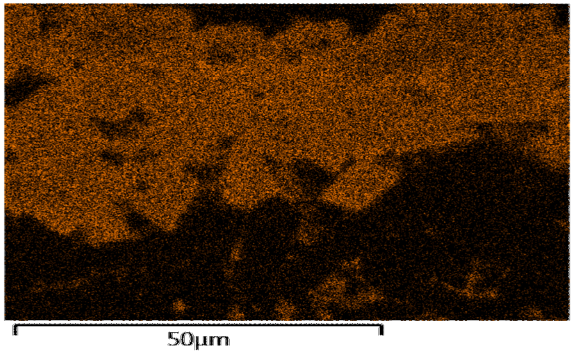
Top Layer

- Mg has diffused to surface where it interacts with $MnAl_2O_4$ leaving denuded zone
- Al has also diffused to surface to form a $(Mn,Mg)Al_2O_4$ spinel structure.
- Ti is align with Ca and Si phases

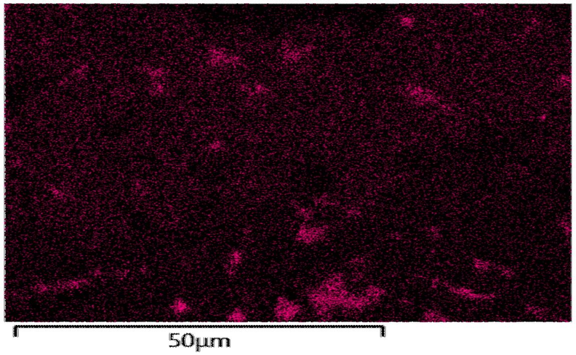
Mg Kα1_2



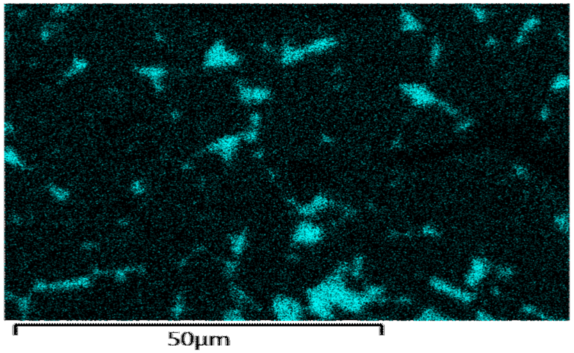
Mn Kα1



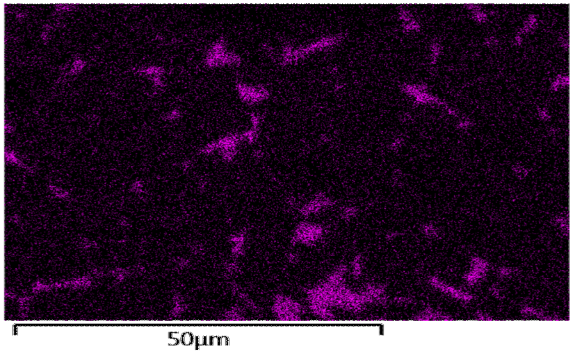
Ti Kα1

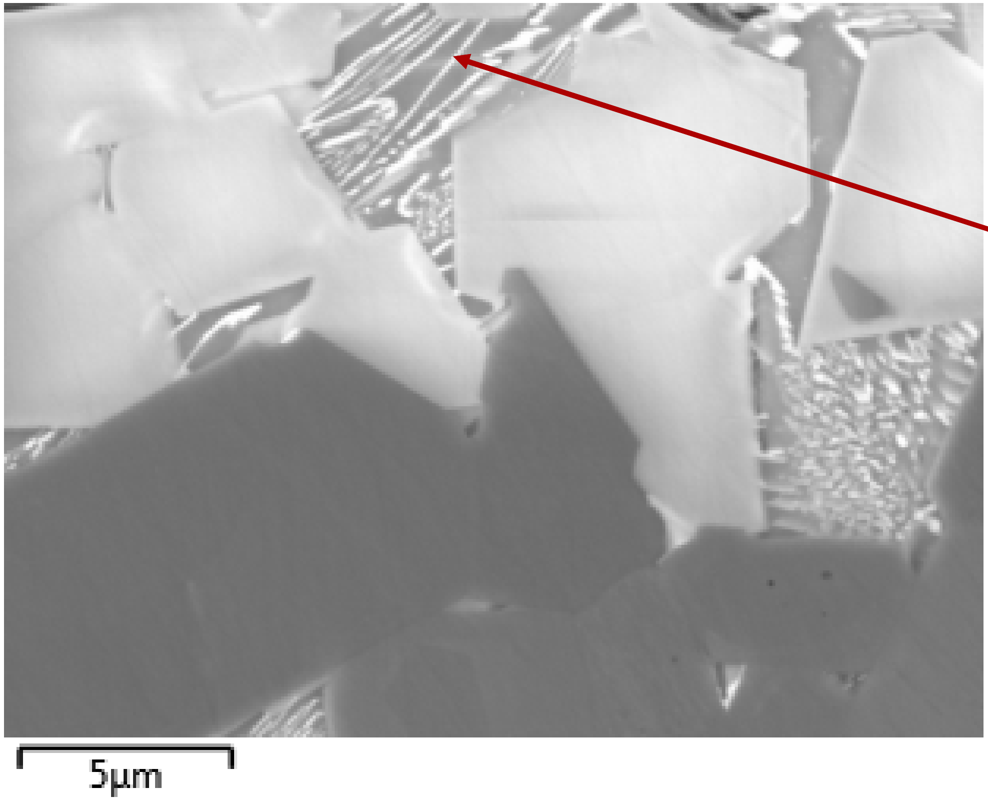


Si Kα1

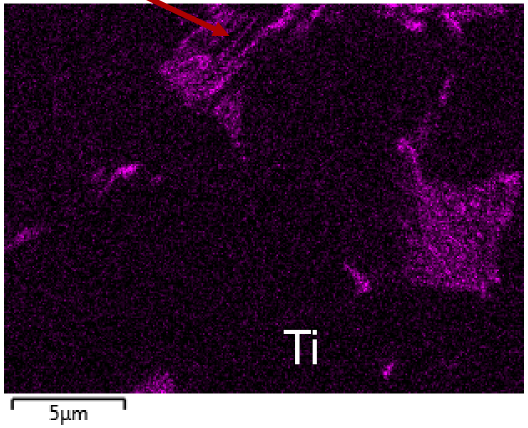


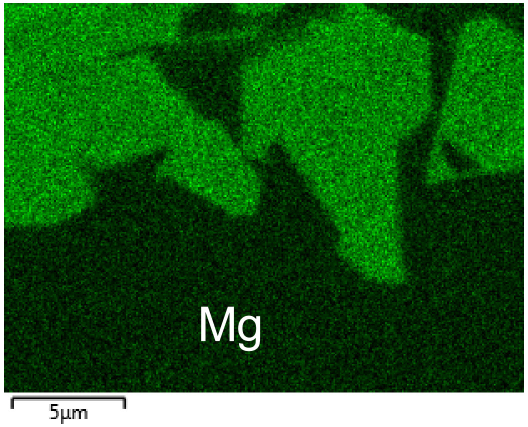
Ca Kα1

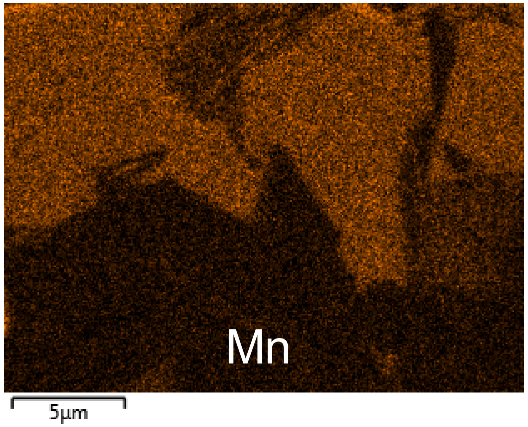


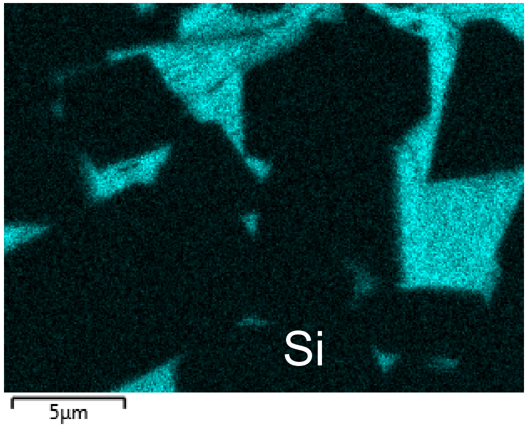


Higher mag shows Ti/Mn rich precipitates in intergranular phase

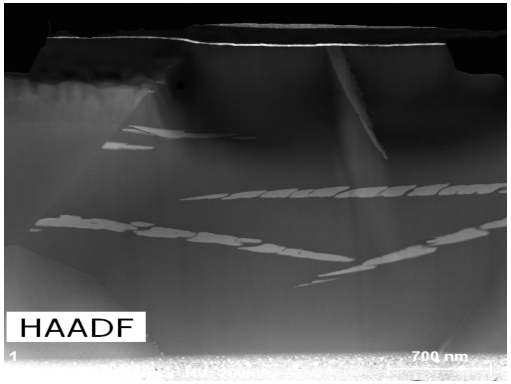


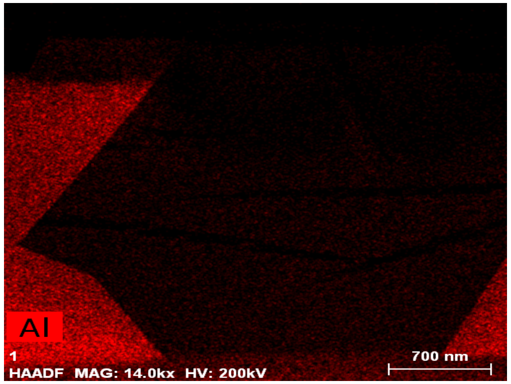


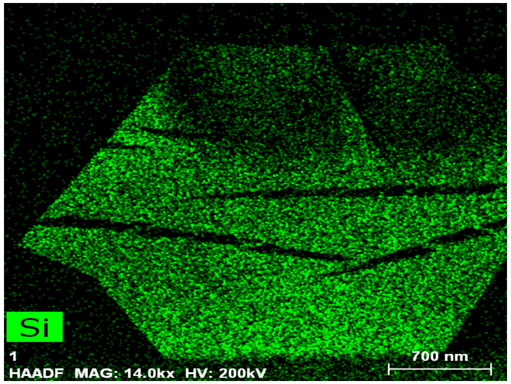


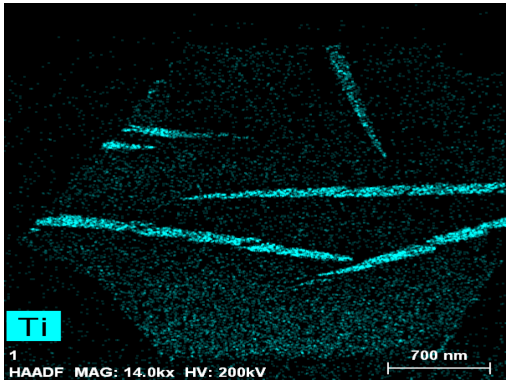


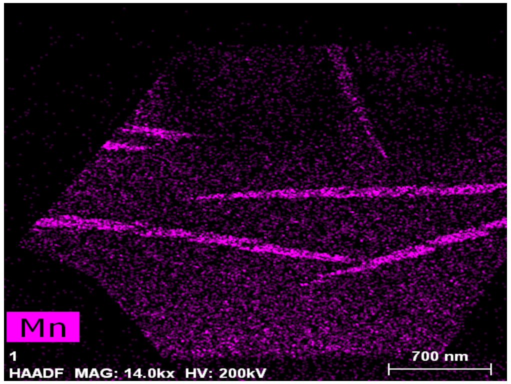
TEM Analysis of Ti rich precipitates

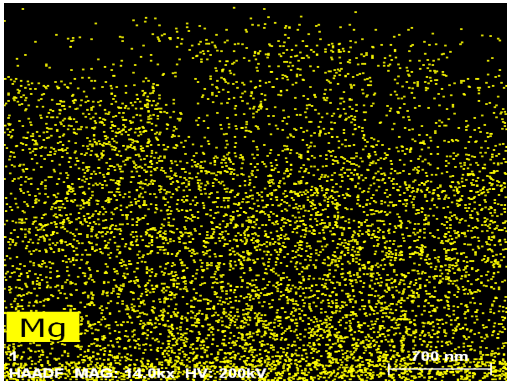




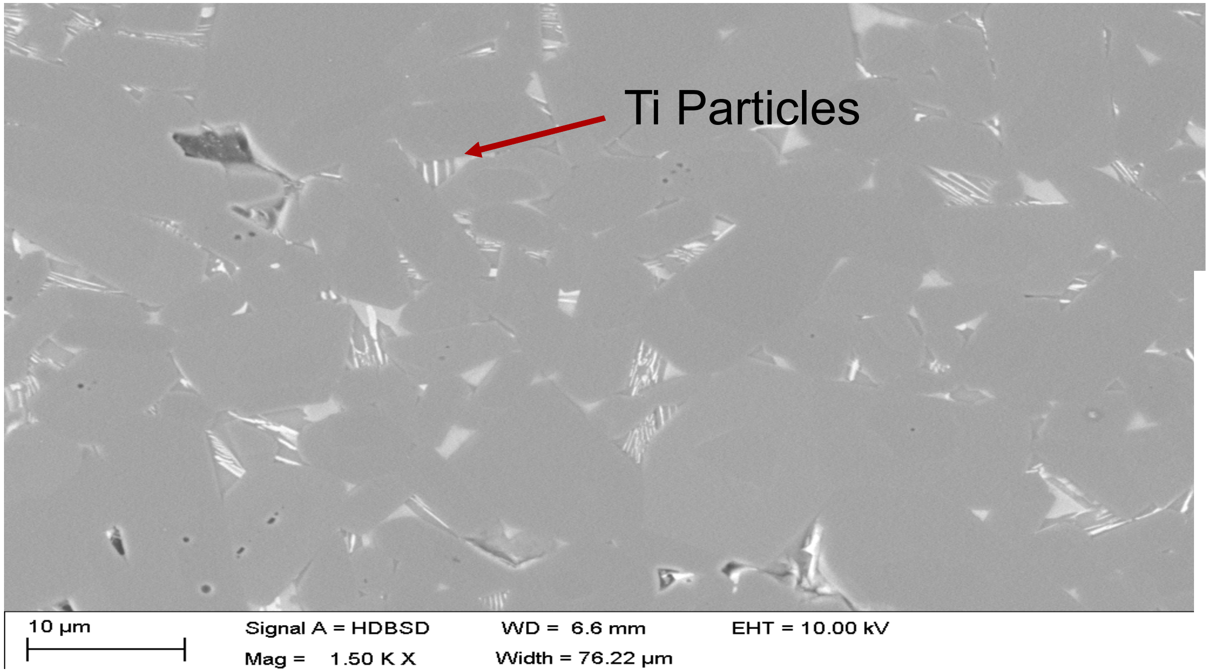


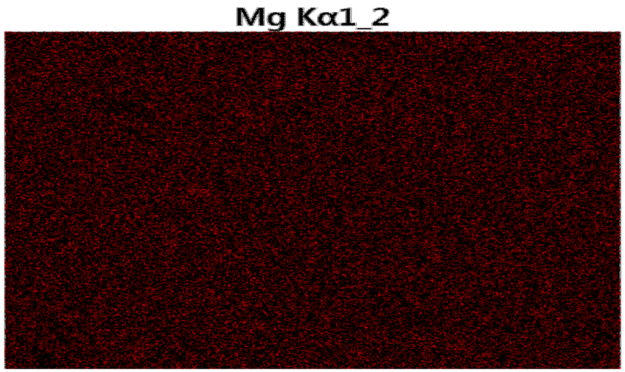


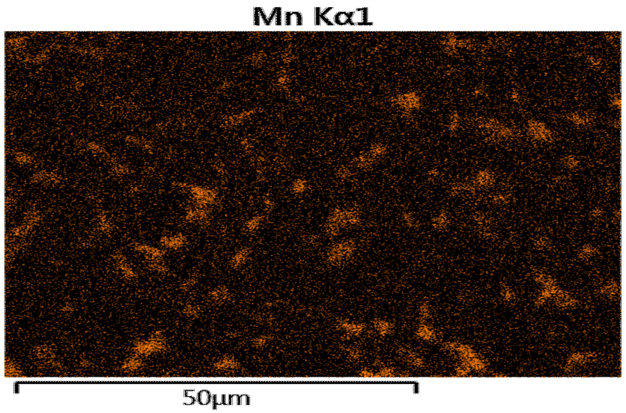


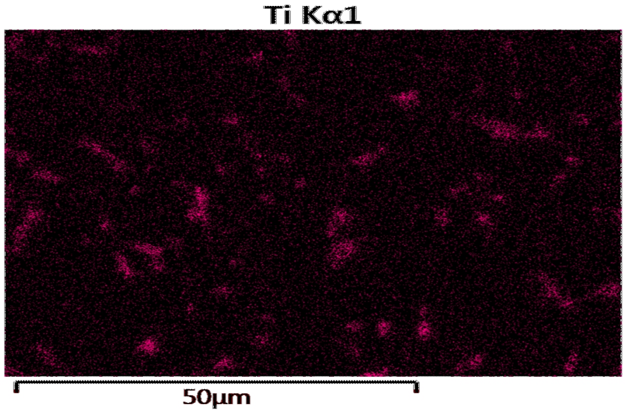


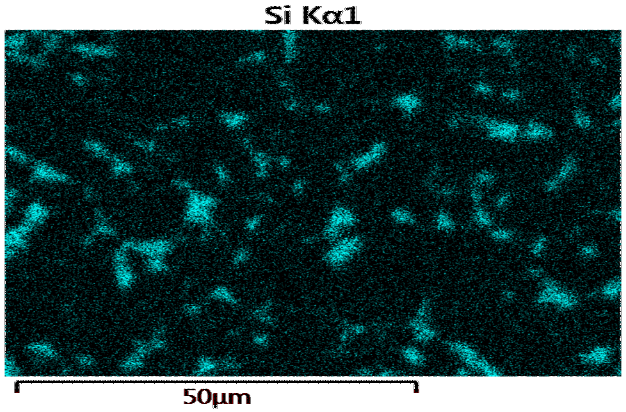
“Light-Orange” Layer

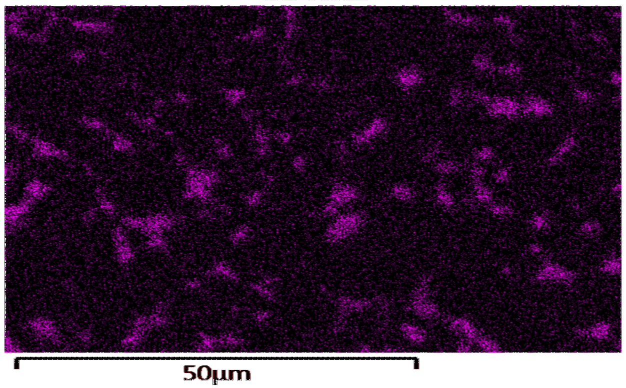

Ti Particles



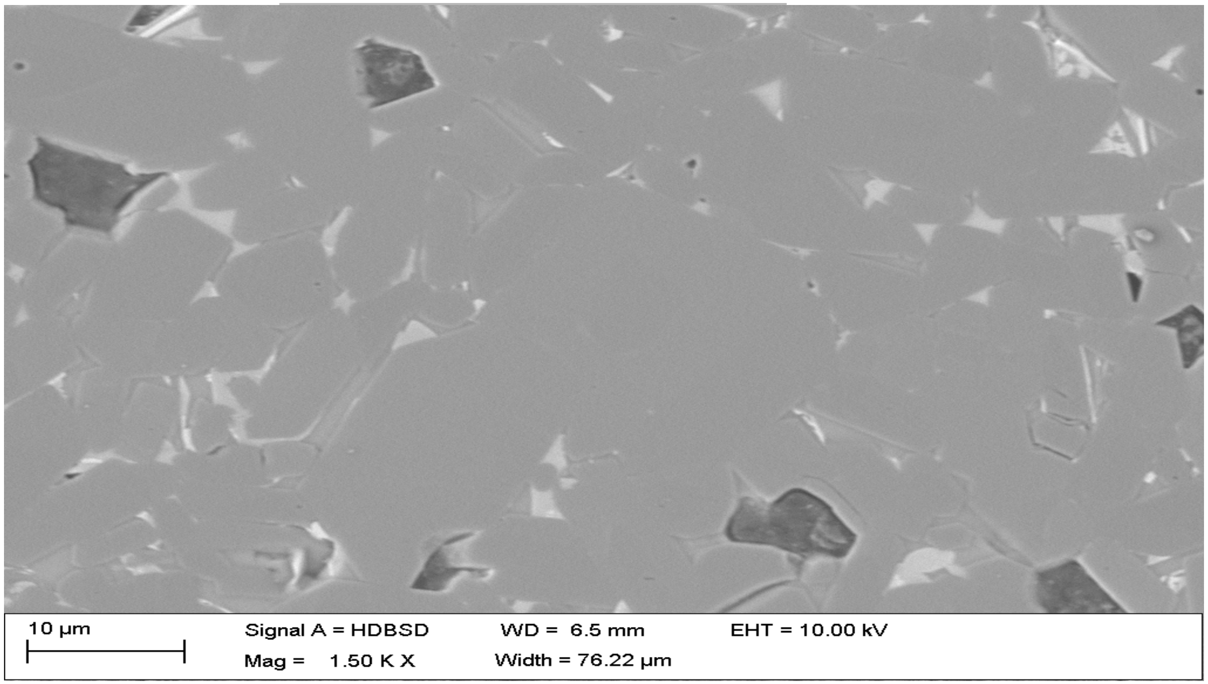


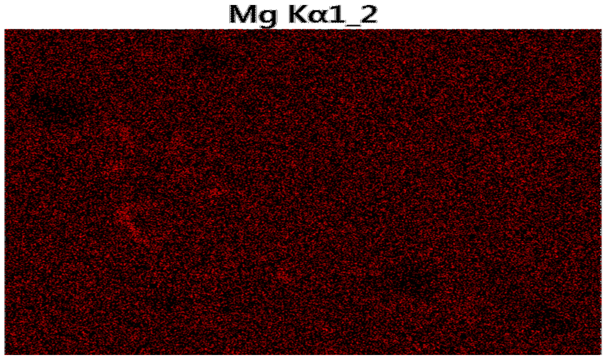


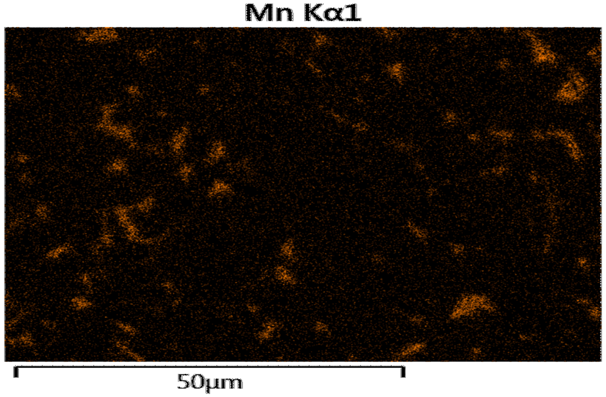


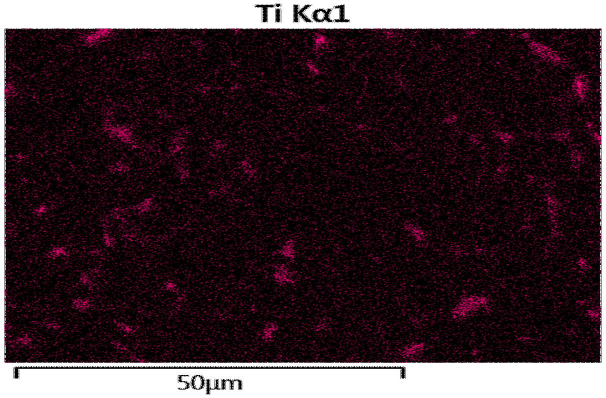


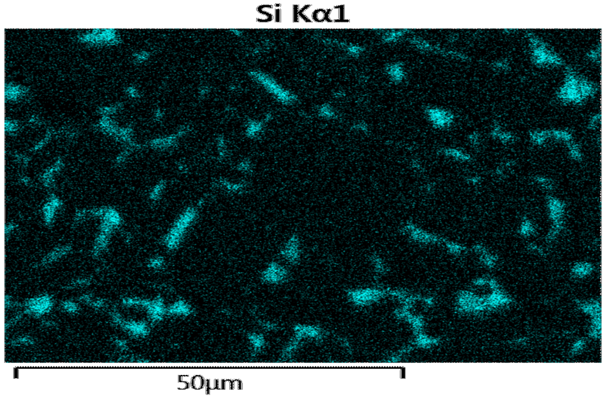
“Brown” Layer

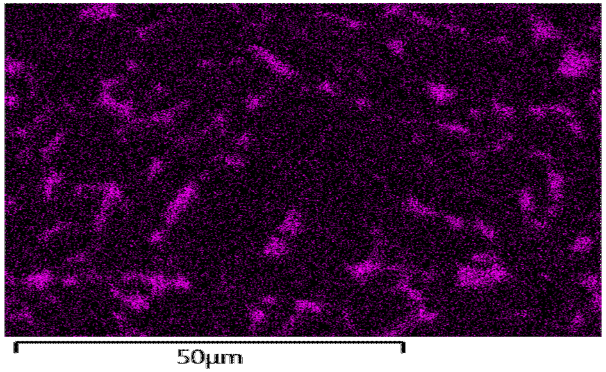

10 µm
Signal A = HDBSD
Mag = 1.50 K X
WD = 6.5 mm
Width = 76.22 µm
EHT = 10.00 kV


Mg Kα1_2

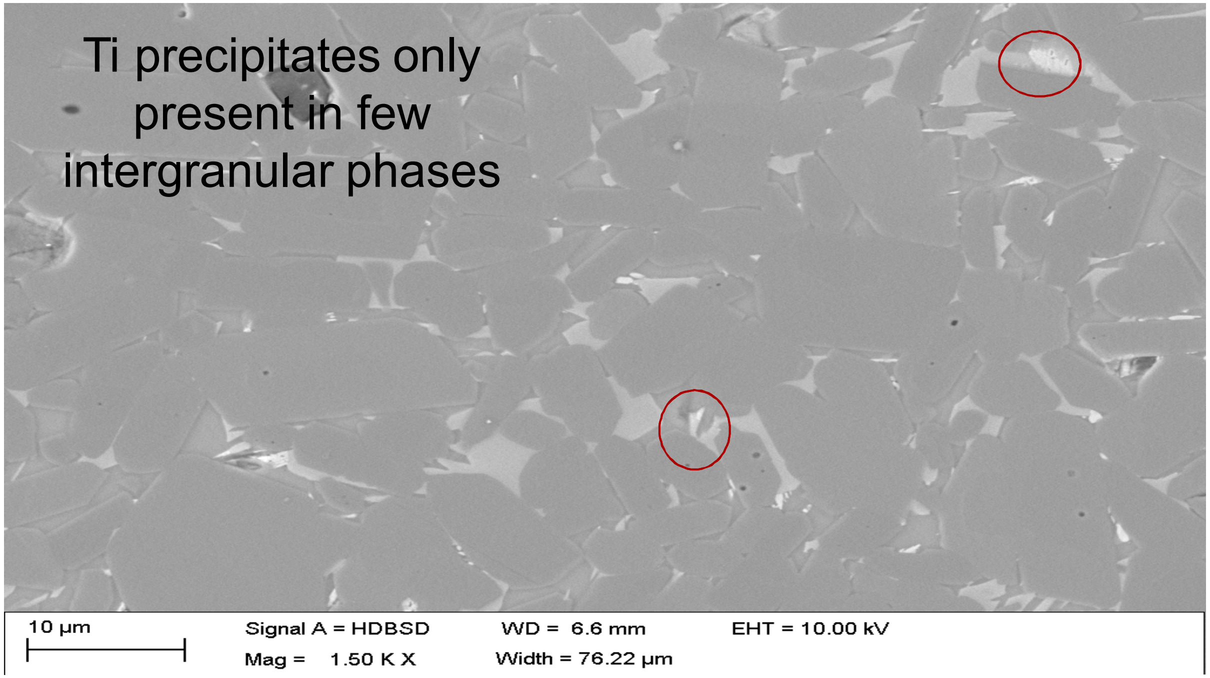

Mn Kα1
50µm


Ti Kα1
50µm

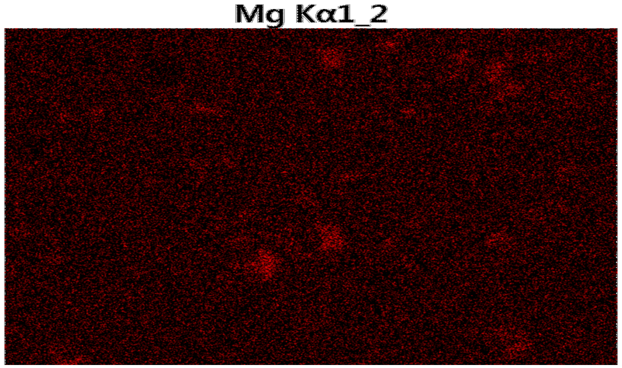

Si Kα1
50µm

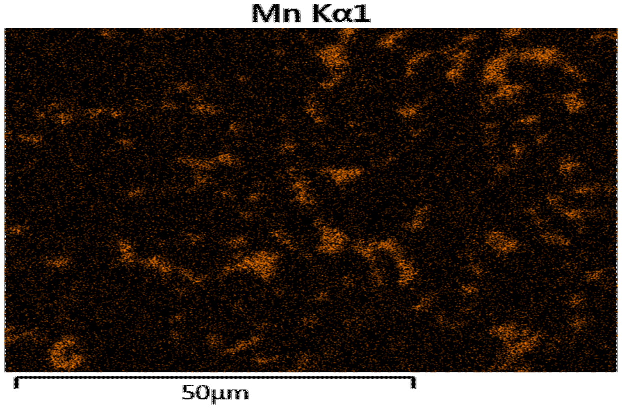

50µm

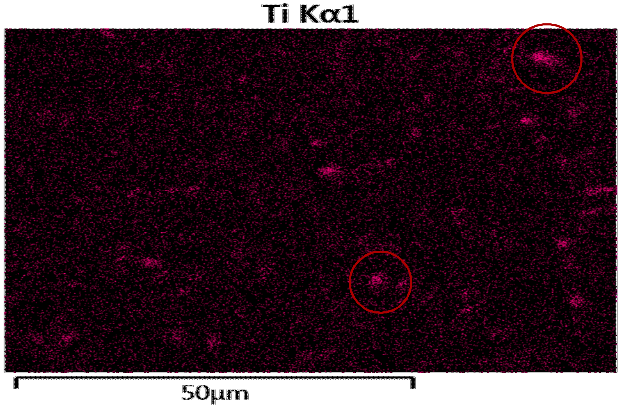
“Light Pink” Layer

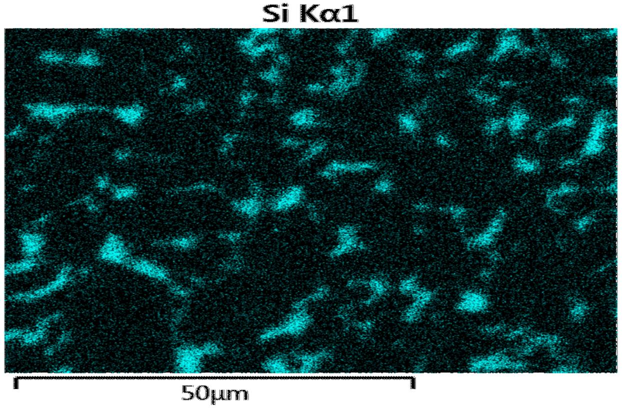


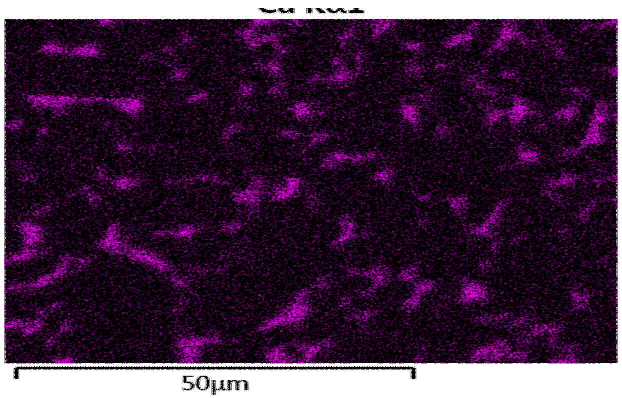
Ti precipitates only present in few intergranular phases



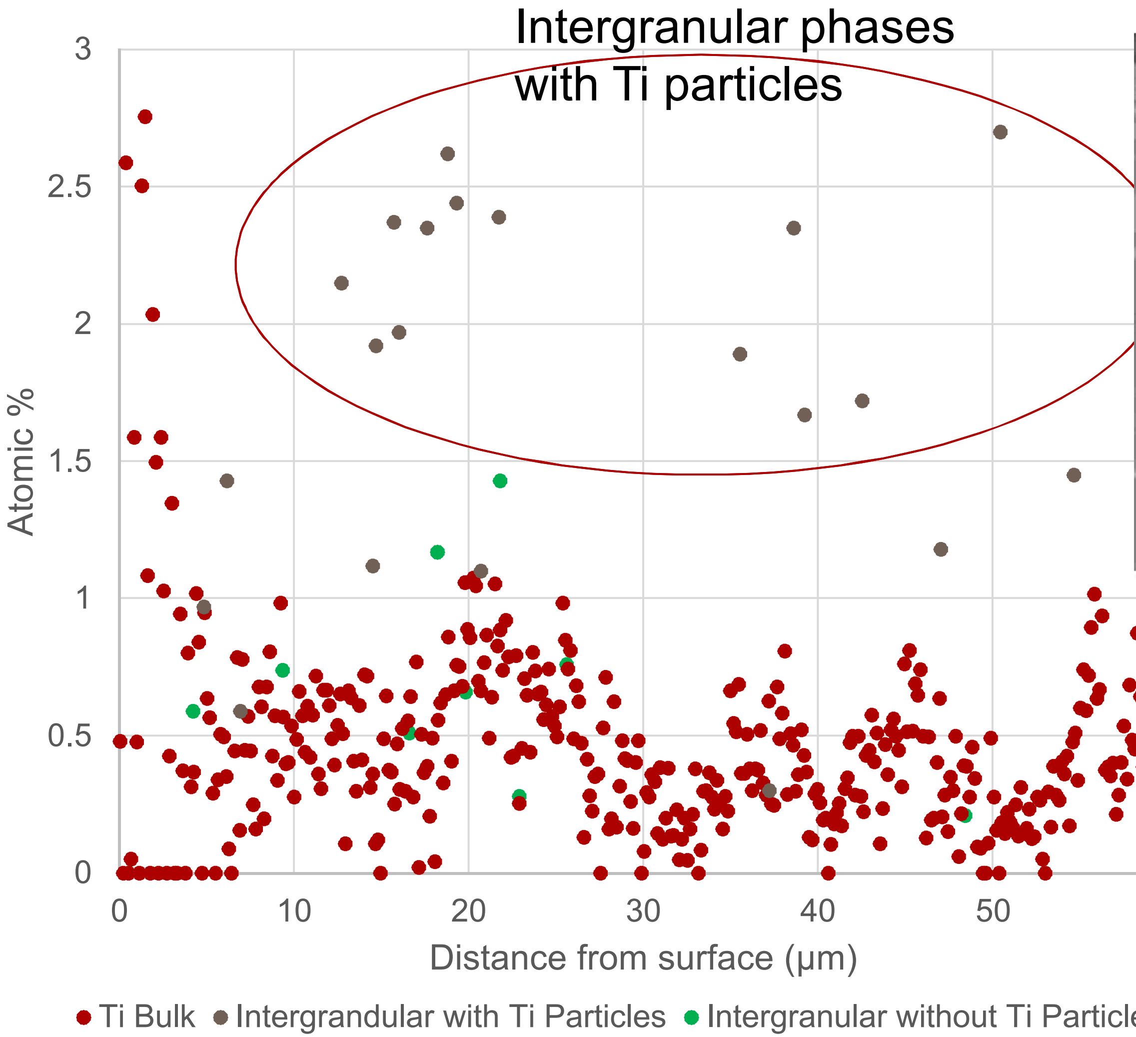


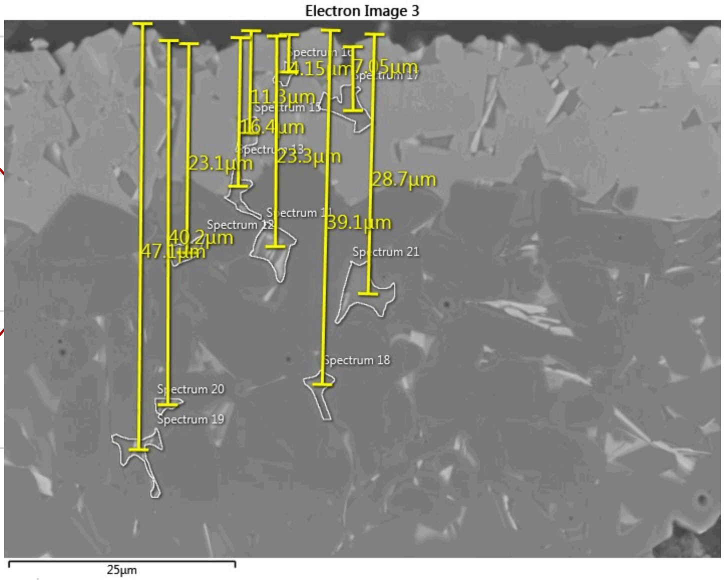






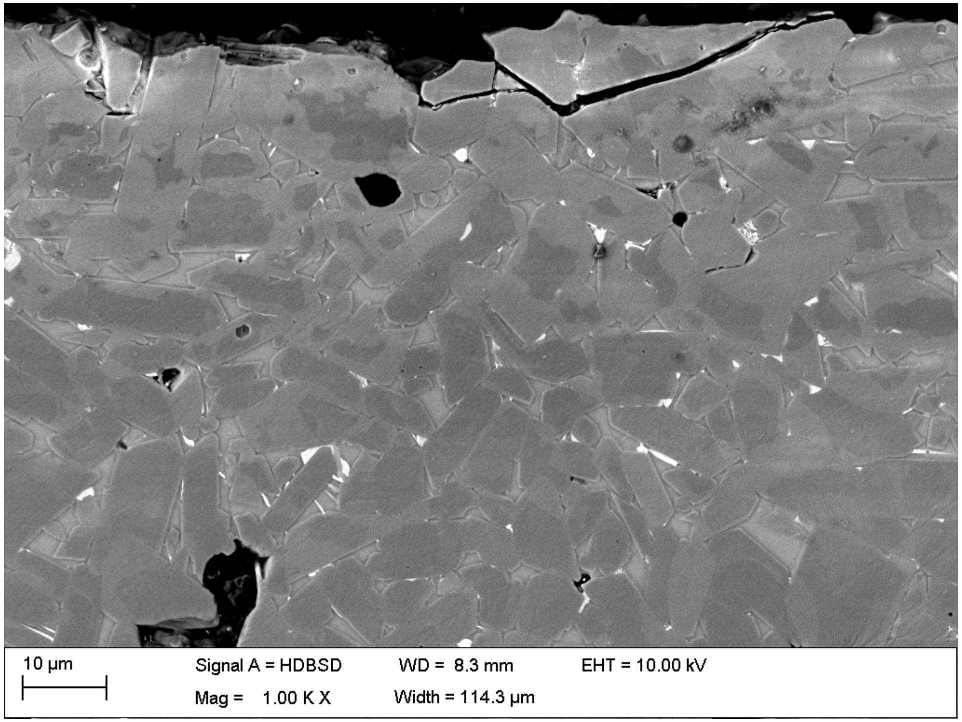
Ti Atomic %



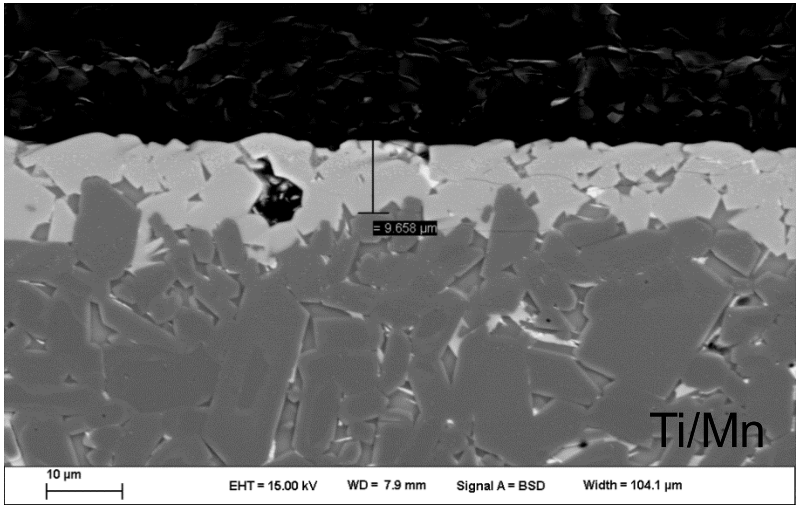


	Atomic %
Bulk	0.46% ± 0.34
Intergranular without Ti particles	0.71% ± 0.36
Intergranular with Ti particles	1.75% ± 0.66

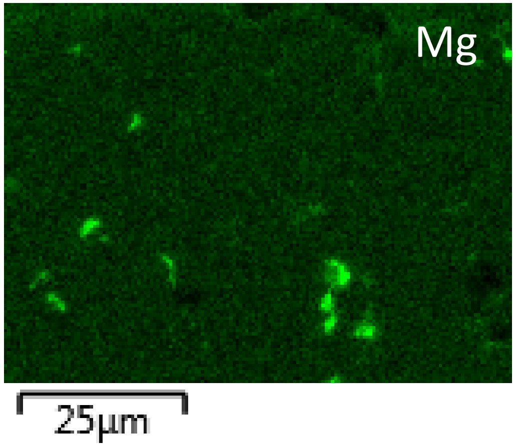
Ti/Cr Coating

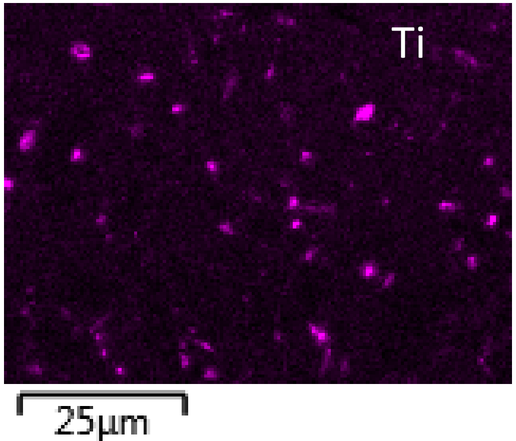


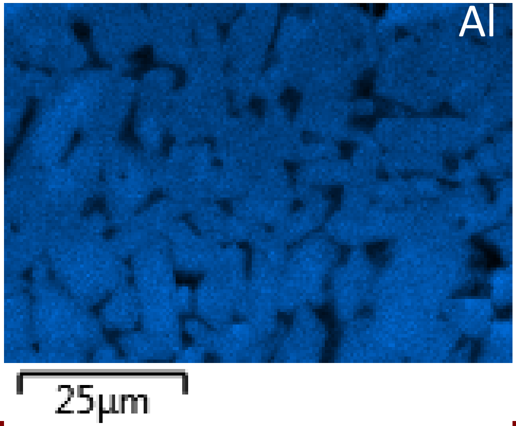
No visible reaction layer

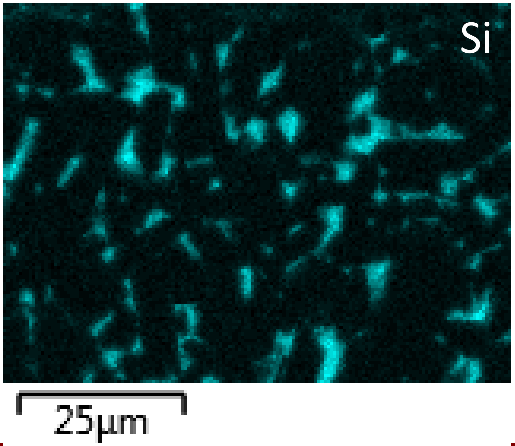


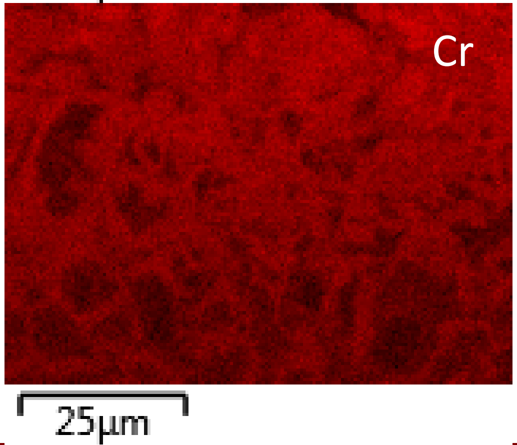
- Mg does not segregate to surface but instead into intergranular phases
- Ti segregation in in intergranular phases is not the same as Mg
- Cr substitutes for Al
- Core-shell type grains



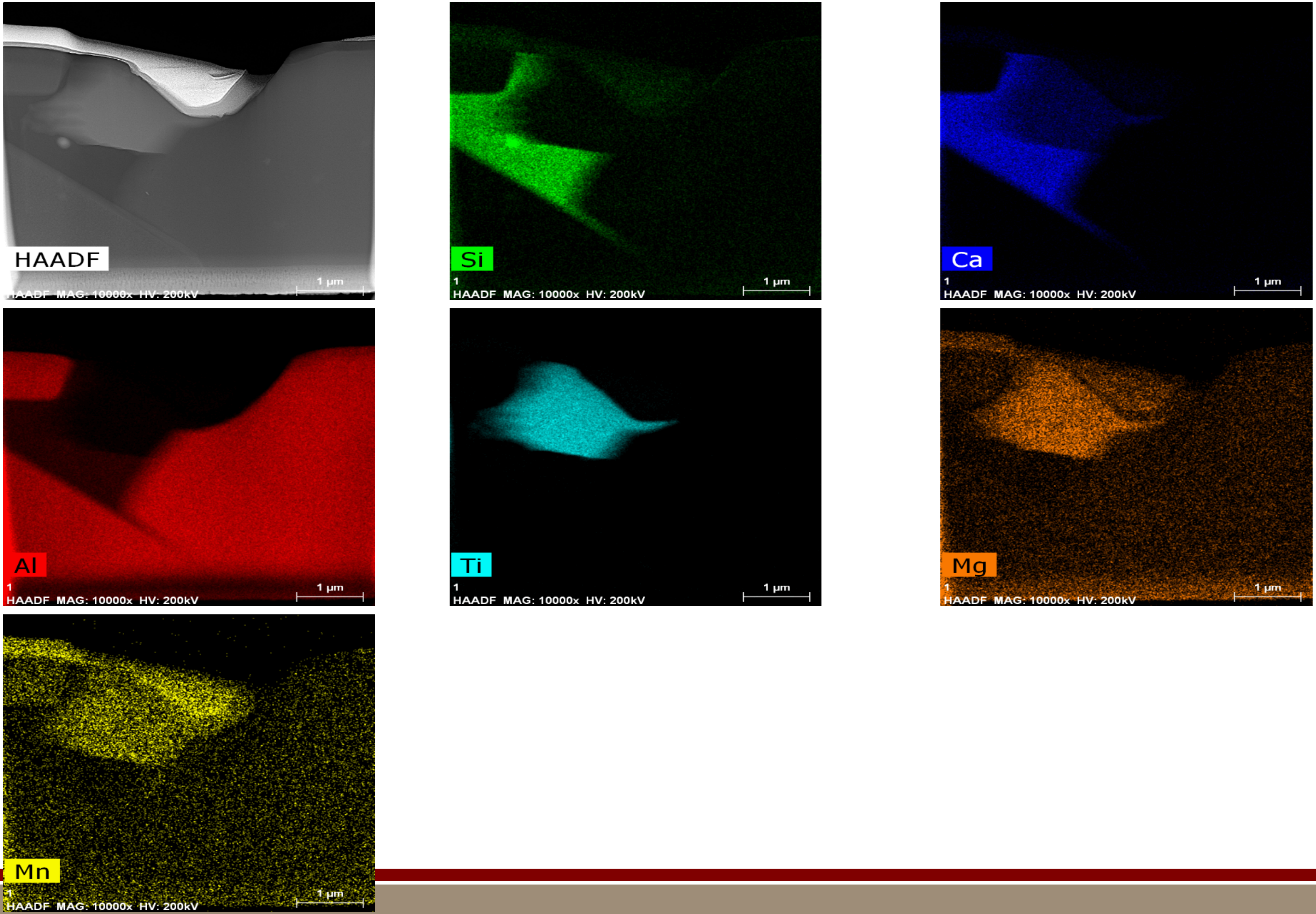






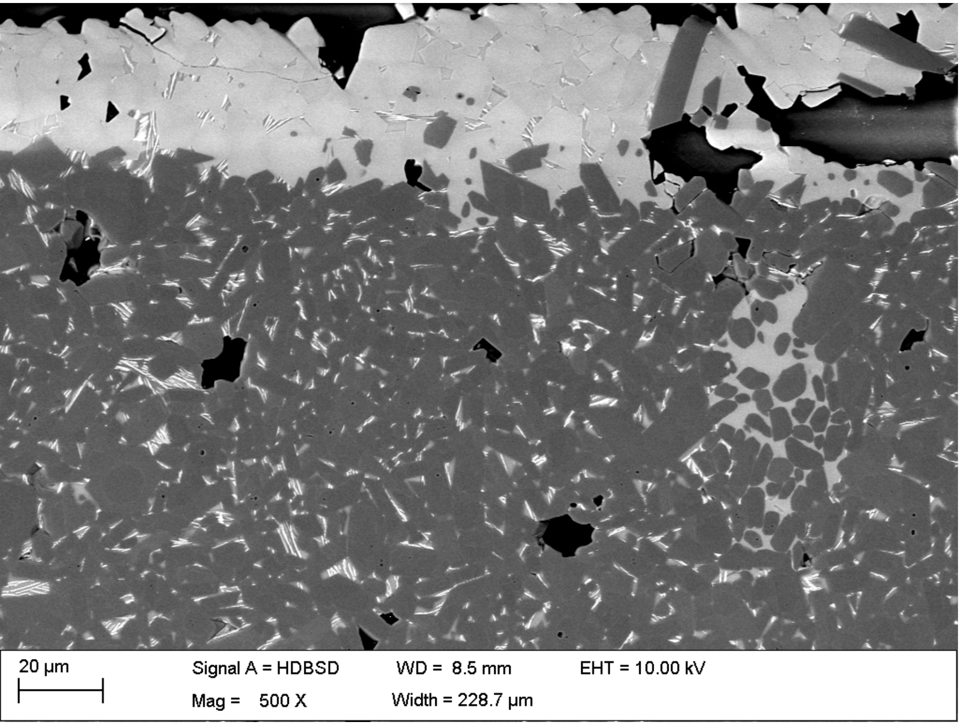


TEM of Ti rich phase

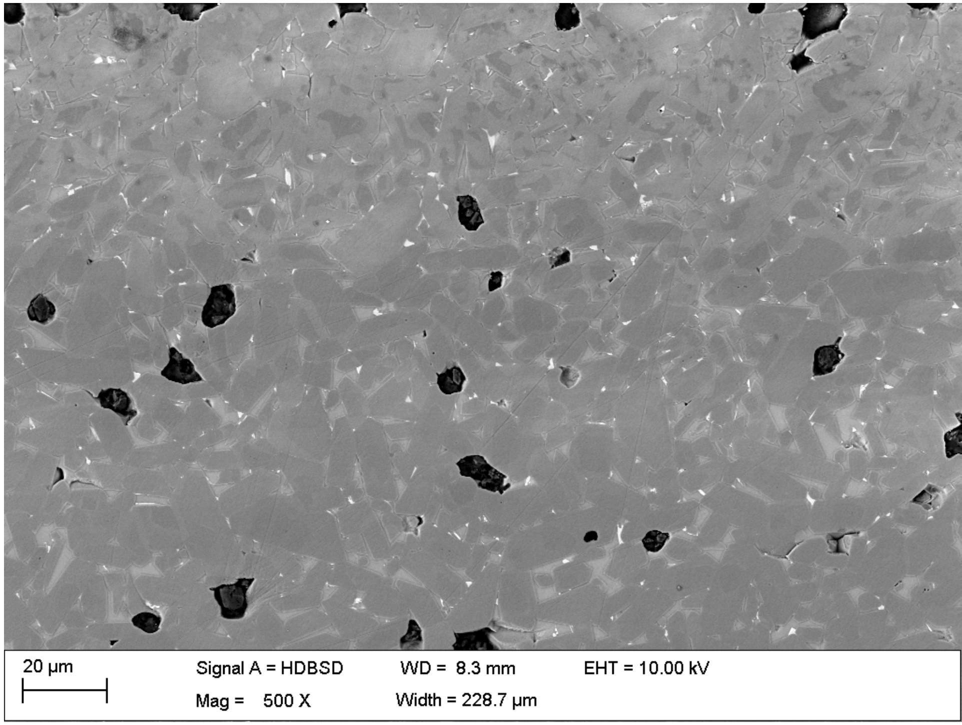


Comparison of Microstructure

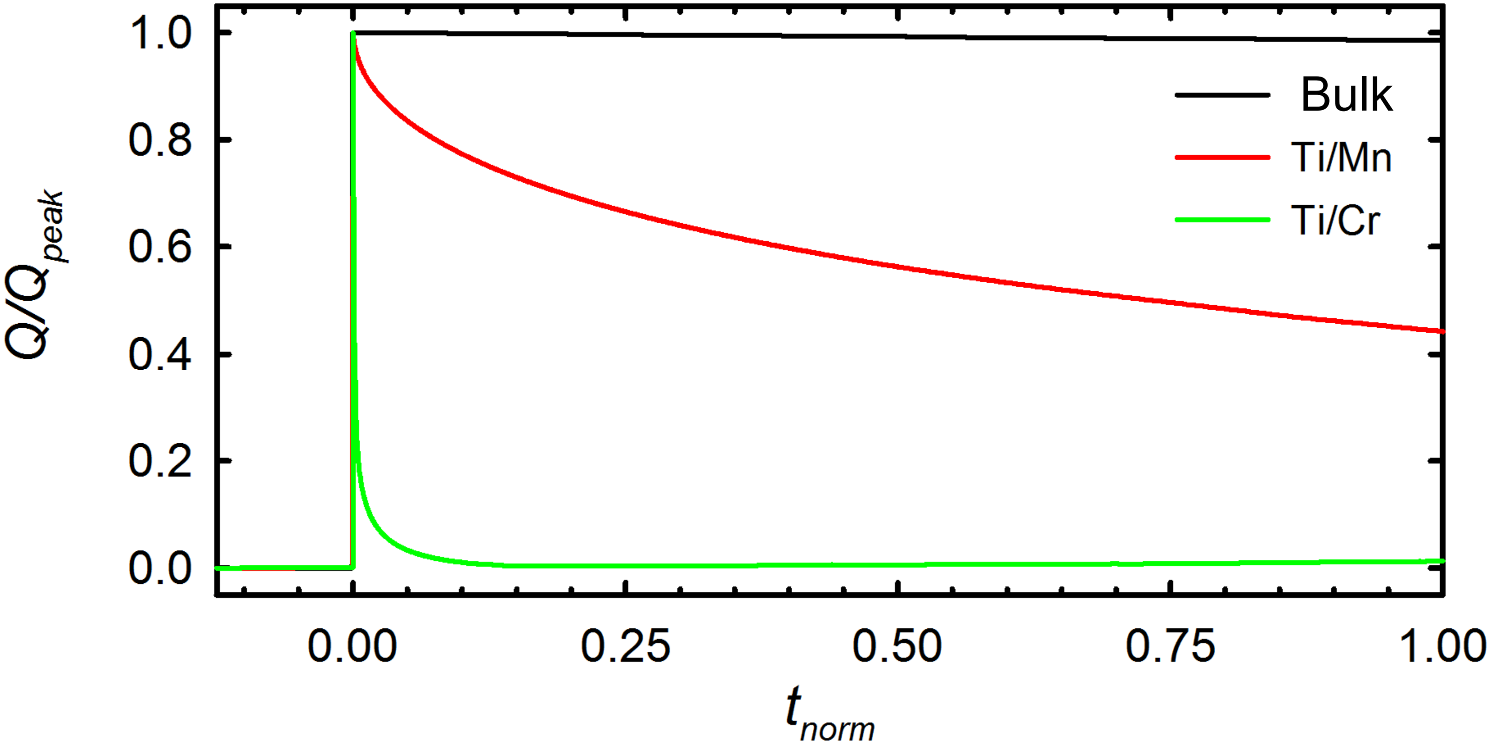
Ti/Mn



Ti/Cr



Charge bleed off comparison



- SEE measurements in progress with a collaboration with Princeton Plasma Physics Labs
- Goal to correlate resistivity, charge bleed off, and SEE with microstructure to optimize high voltage insulating performance