

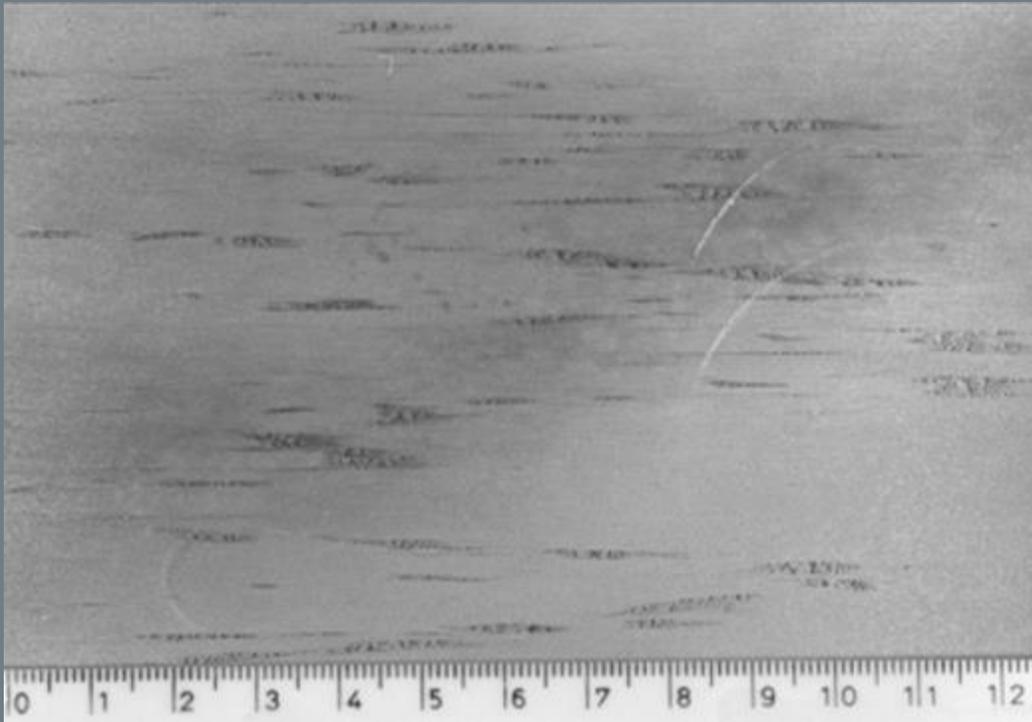


# Blistering Formation in High Strength Steels (HSS) During Hot Rolling

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Academic Supervisor: Dr. Mark<sup>1</sup> Coleman

Rolled in scale



## Project Background

- Blistering occurs when oxide scale is swollen during oxidation; generating a critical stress and gas release at the scale/ steel interface.
- Blistered scale causes surface defect problems when it is rolled, becoming embedded into the steel.
- It is important to understand the mechanism of blistering and control the blister formation in order to prevent surface defects.
- Severe blistering has been found to occur in temperatures between 950 and 1000°C.

Nucleation and growth modes were investigated in order to understand the mechanism of blister formation.

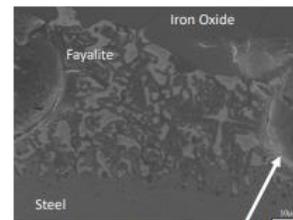


Fig 3 – Oxide morphology  
Stress incompatibility between phases

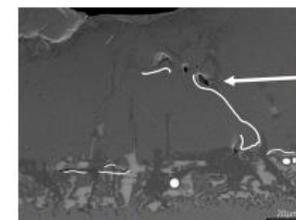


Fig 4 – Oxide stress paths

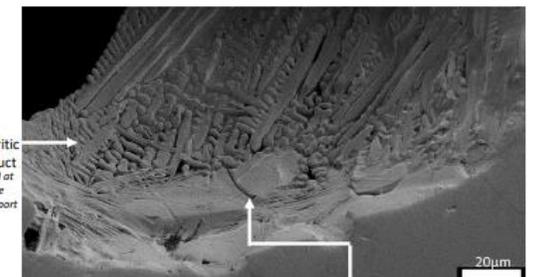


Fig 7 – Dendritic oxide growth  
Tensile stress exhibited during blister growth

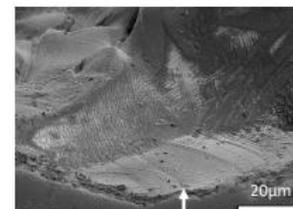


Fig 5 – Fracture plane  
Oxide scale lifted away

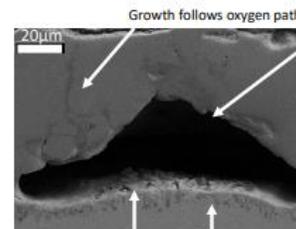
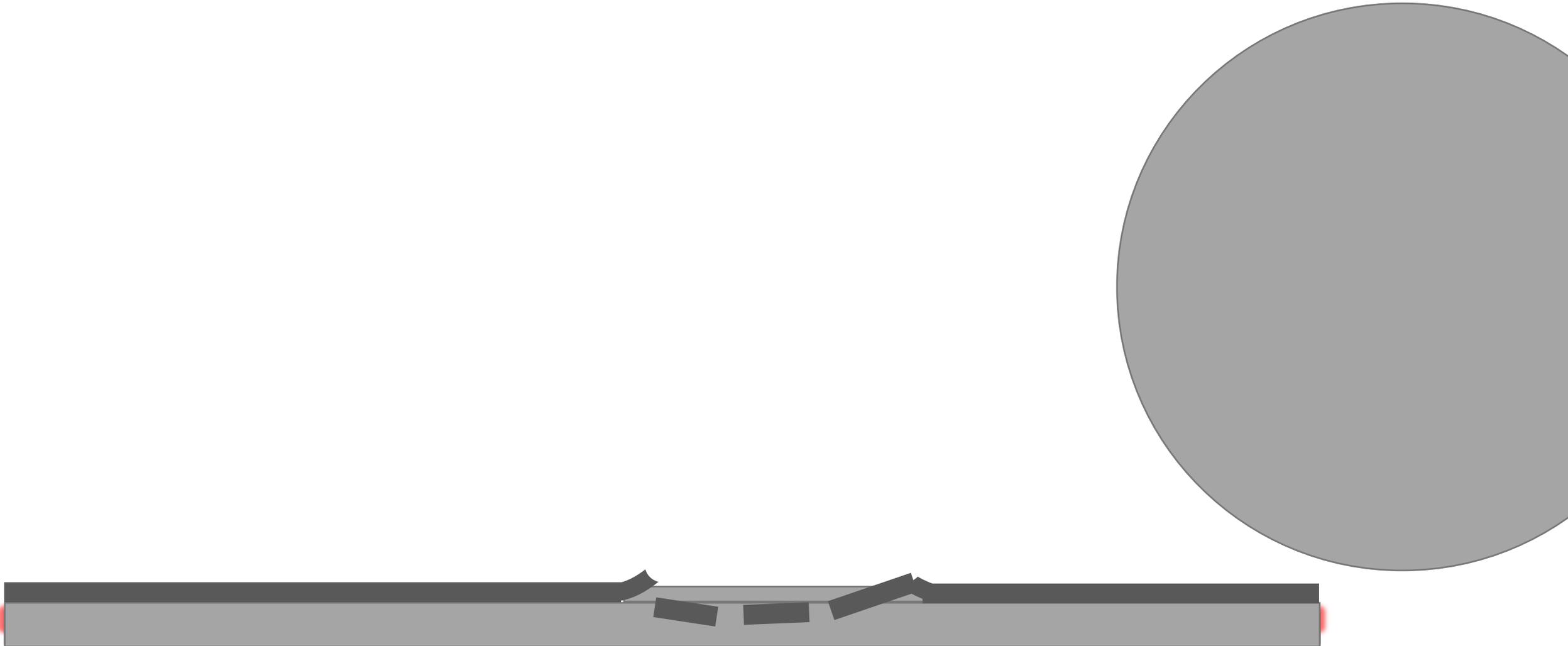


Fig 6 – Blister  
Oxidation decomposition



# Blister defect

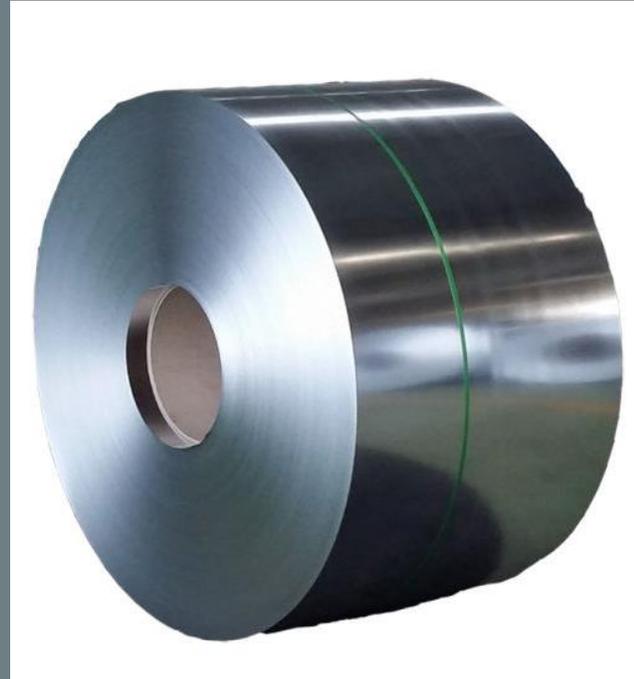
Blister in finishing strip mill



Construction Steel  
3812



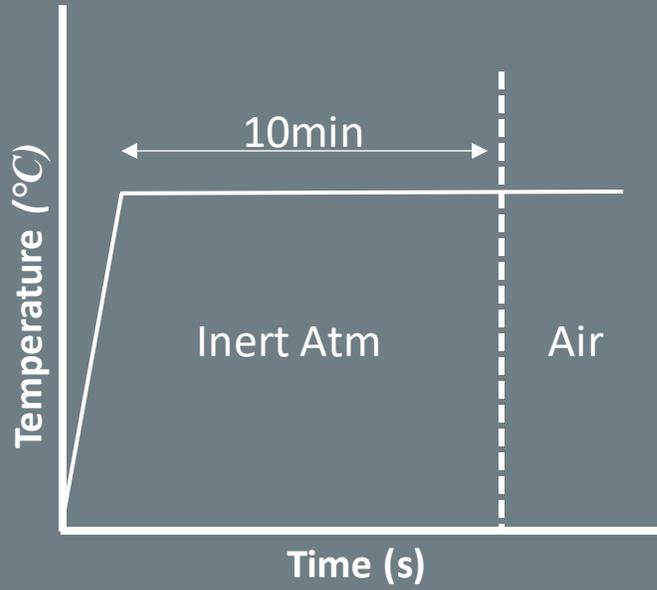
Electrical Steel  
B32



Steel	C	Si	Mn	Al	Cr
3812	0.15	0.1	0.86	0.036	0.028
B32	0.003	3.2	0.2	0.9	-



# 3812 Heat Treatment



800°C

900 °C

1000 °C

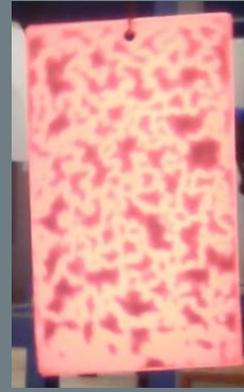
1100 °C

1200 °C

30(s)



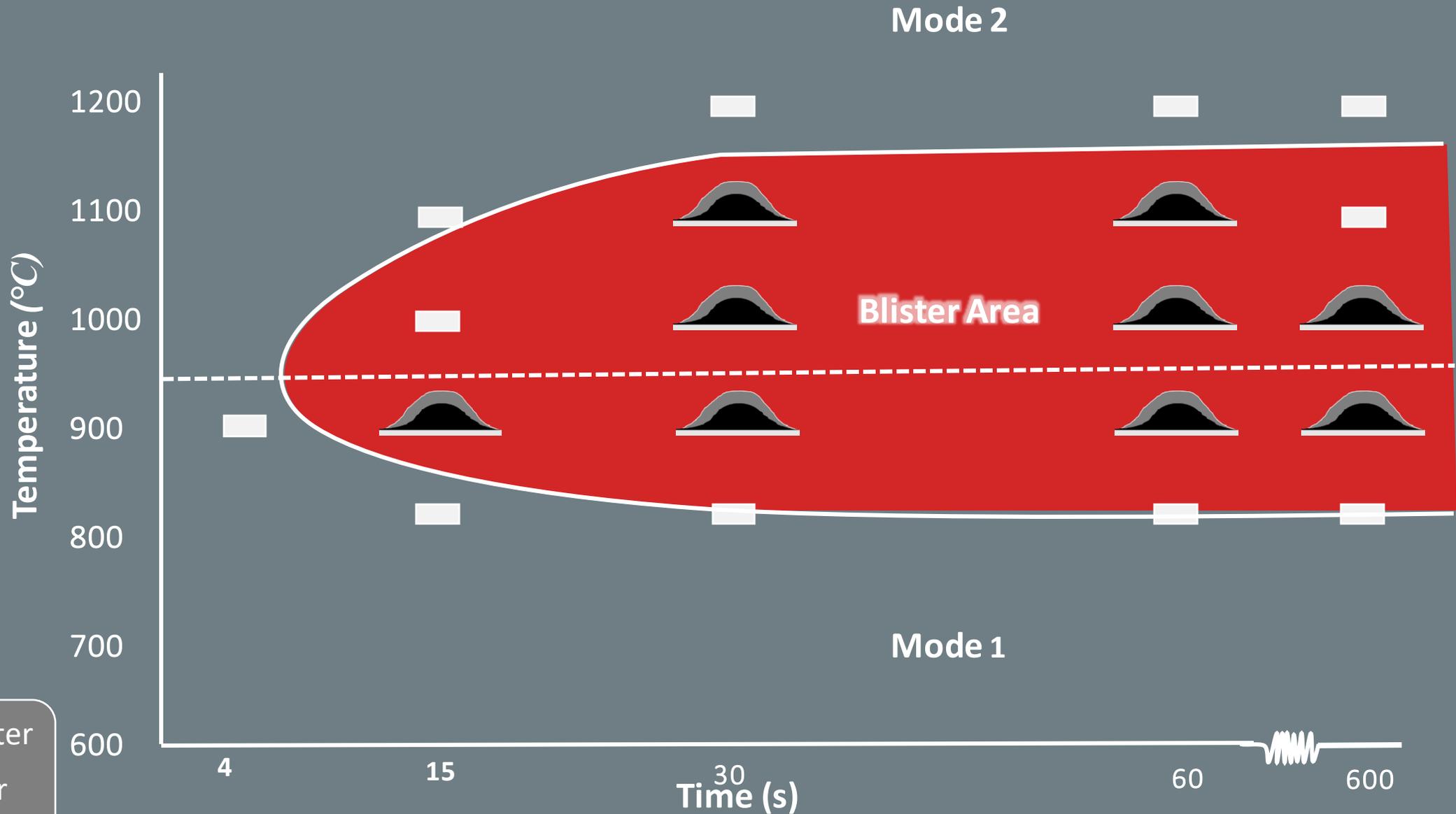
60(s)



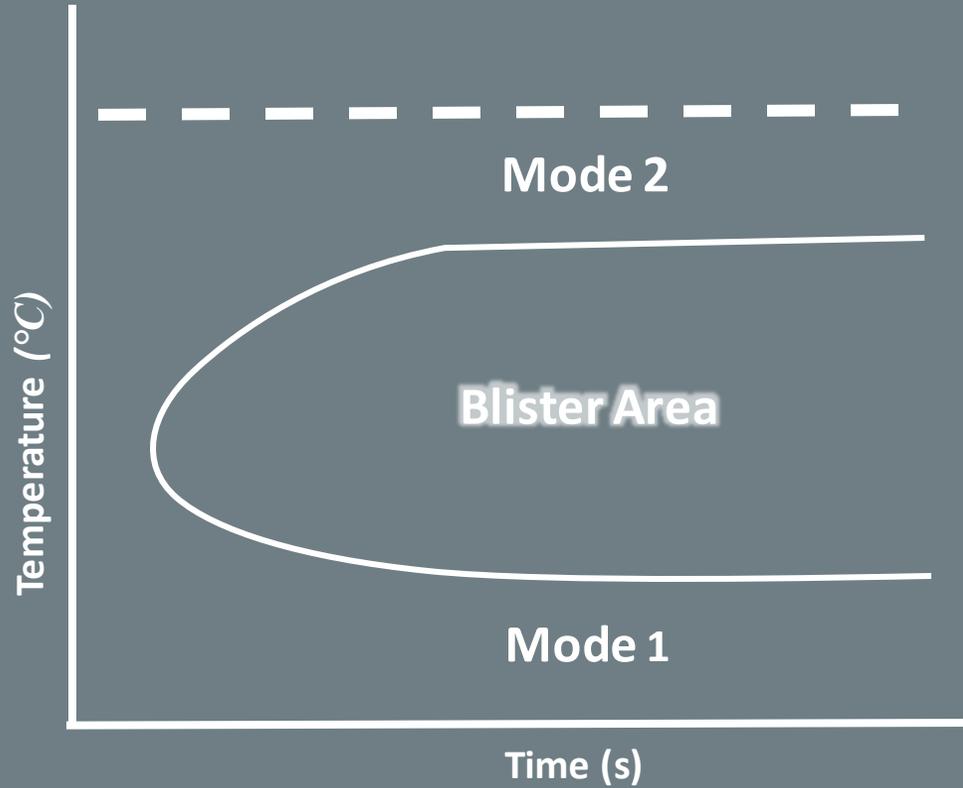
600(s)



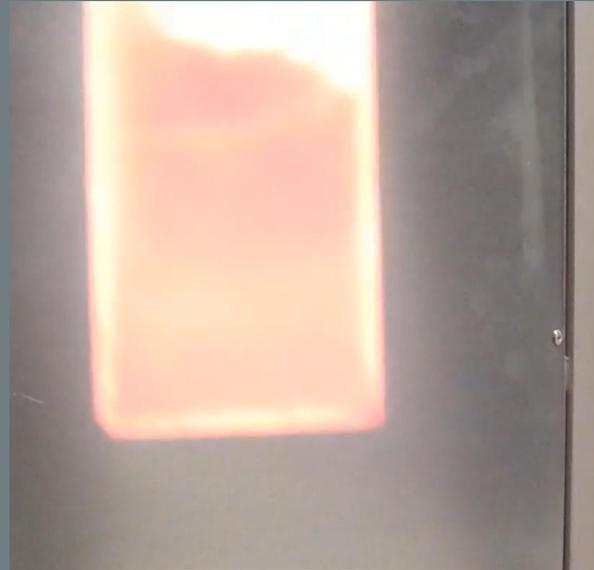
# 3812 Blister Heat Treatment



# 3812 Formation Mechanisms



Mode 2



Blister



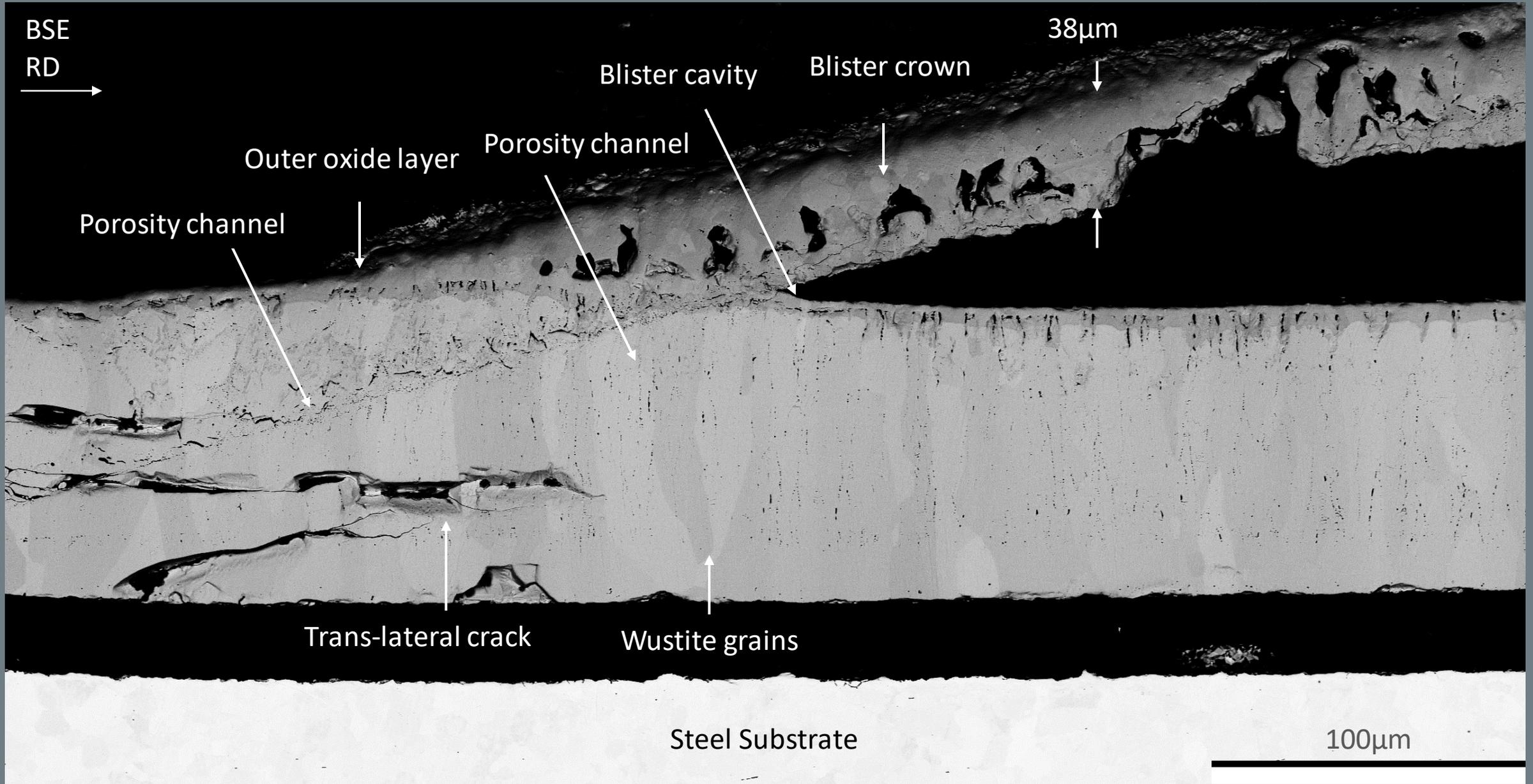
Mode 1



New phenomena



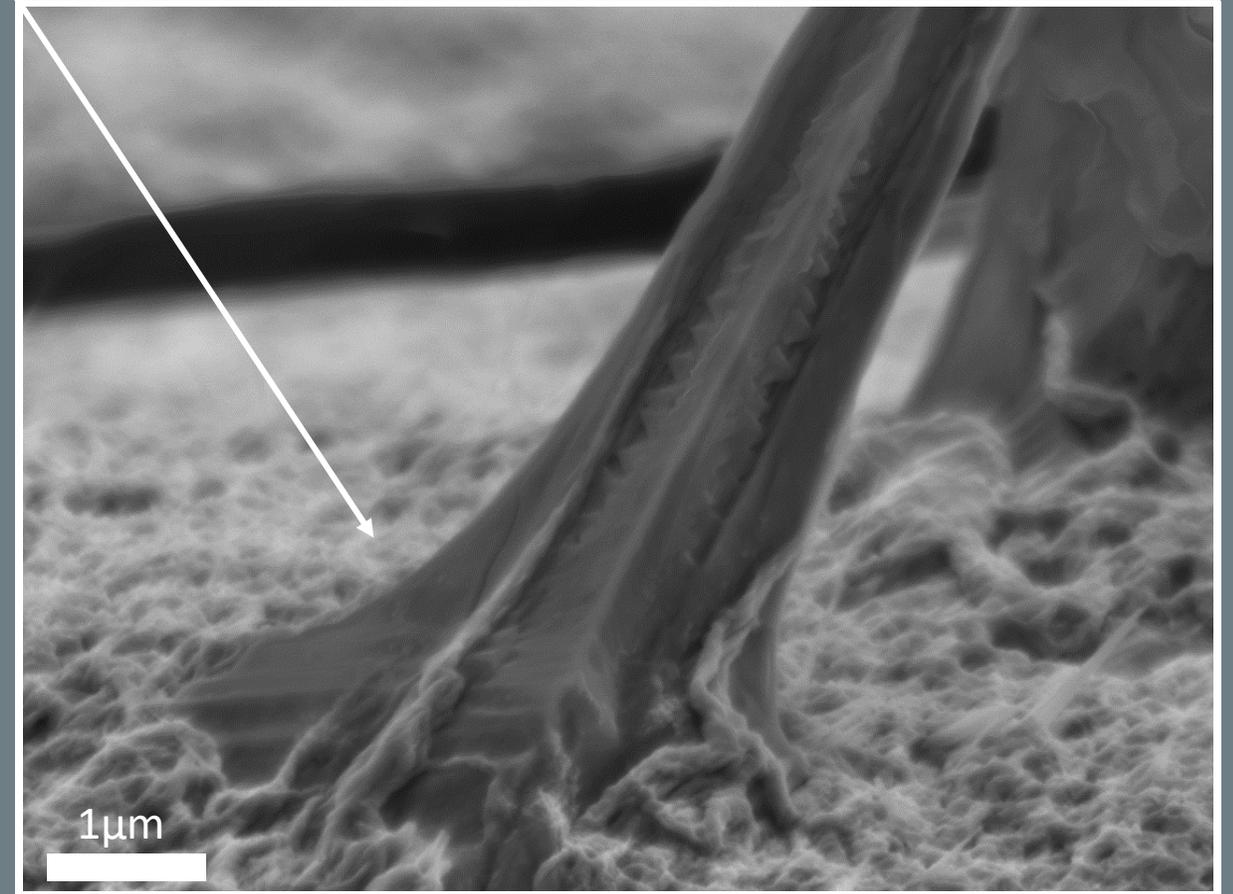
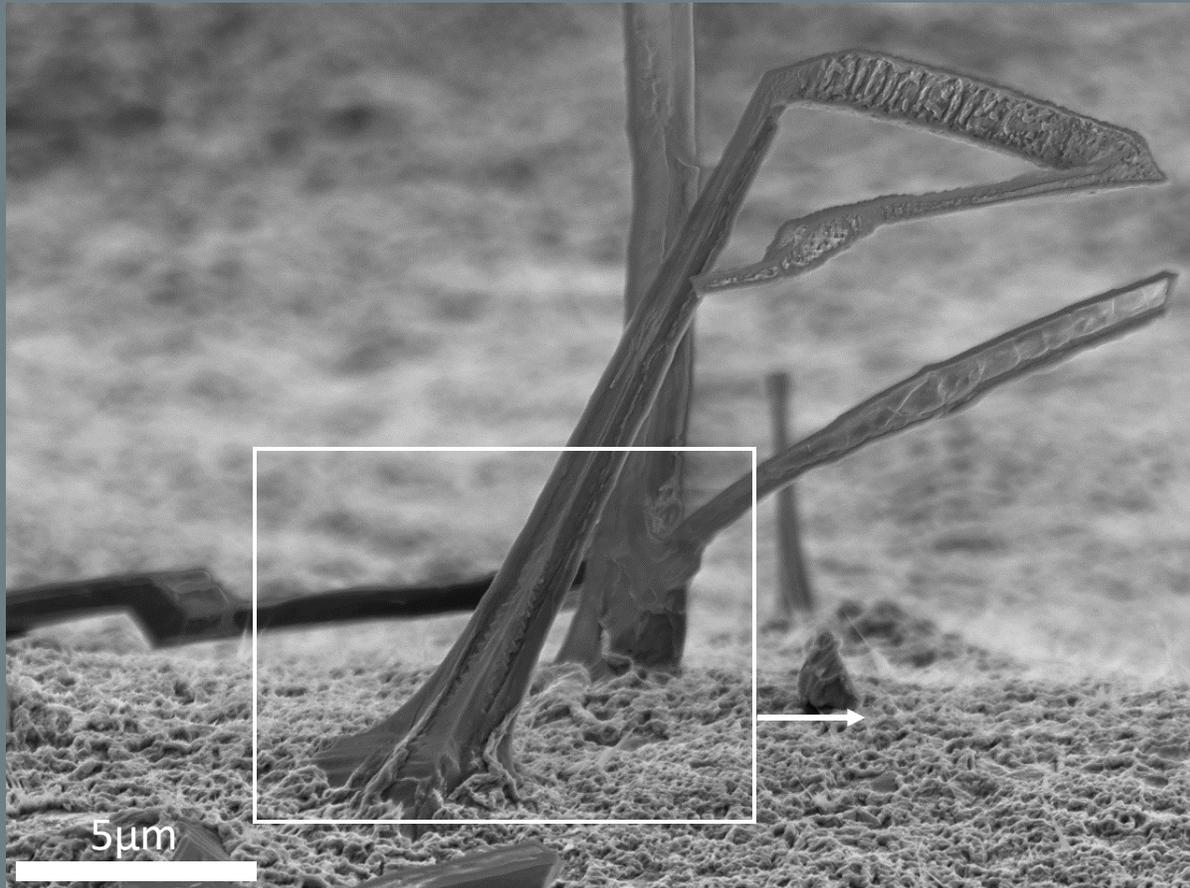
# 3812 Blister



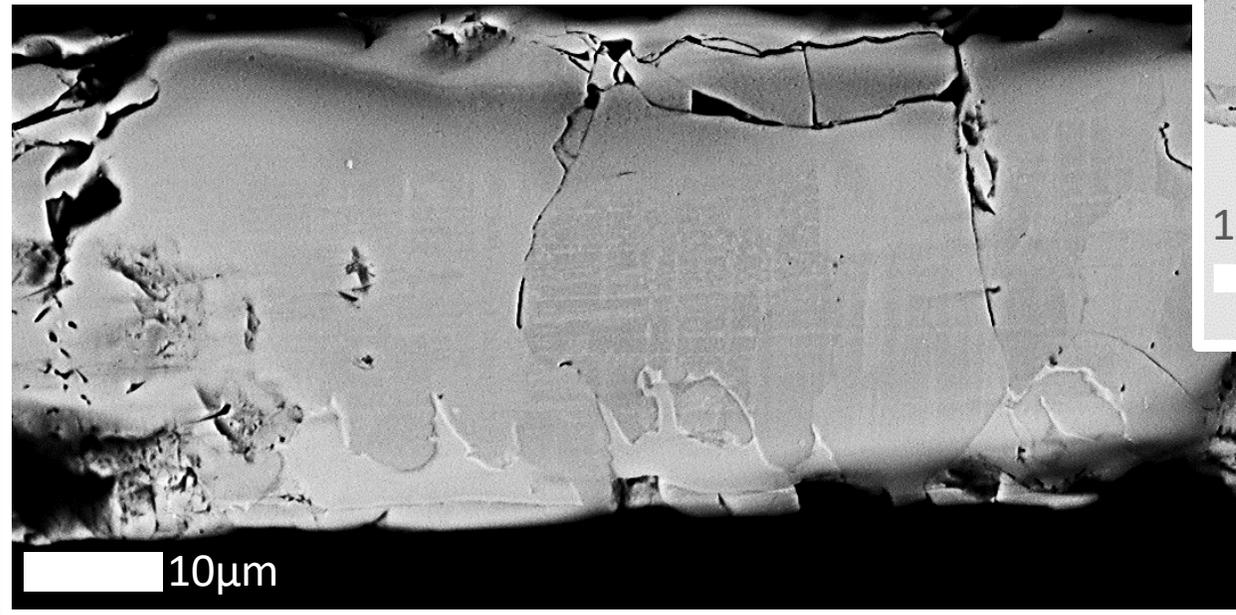
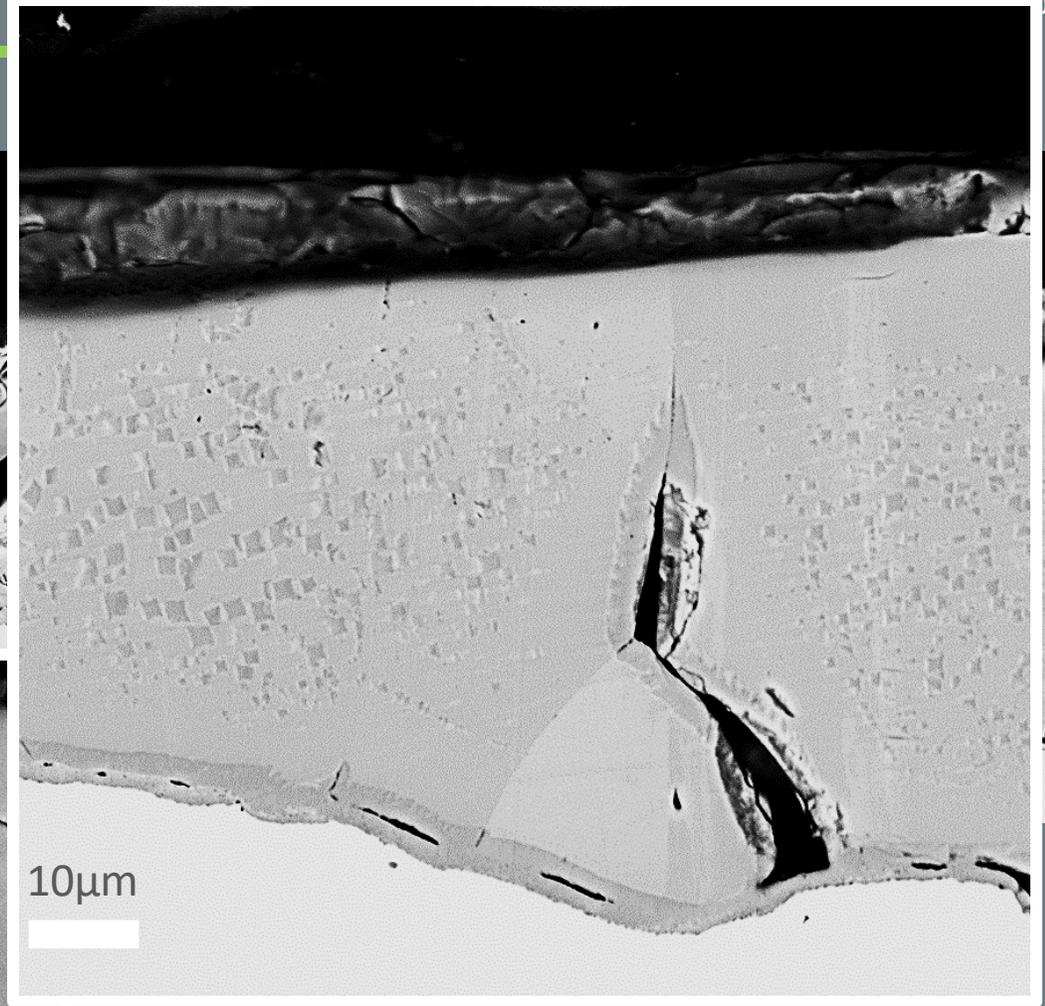
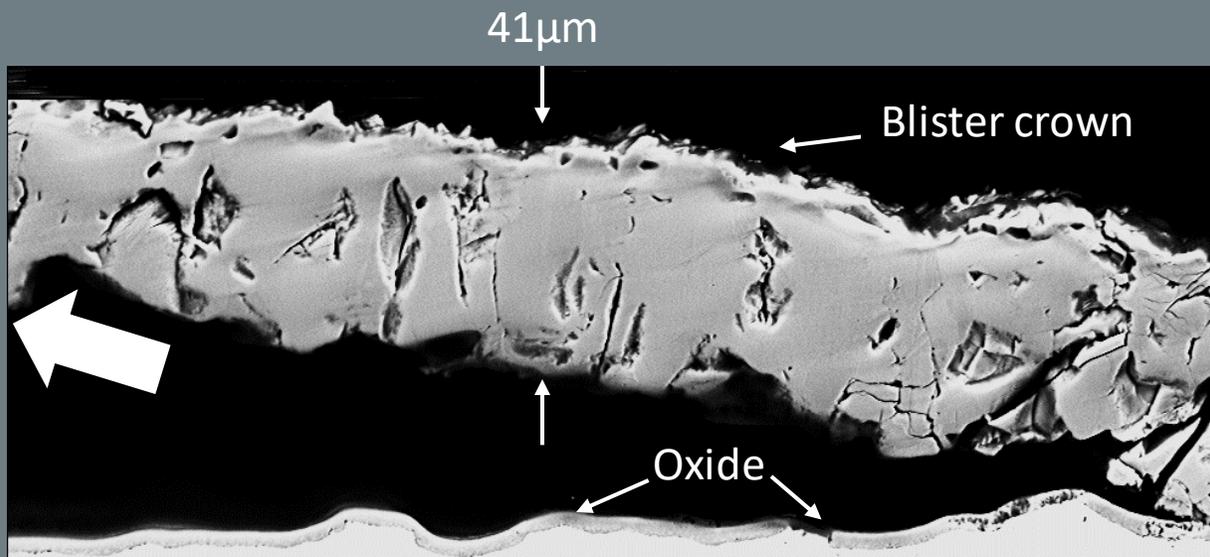
# 3812 Whisker formation

Oxide growth preferential plane

Idiomorphic growth

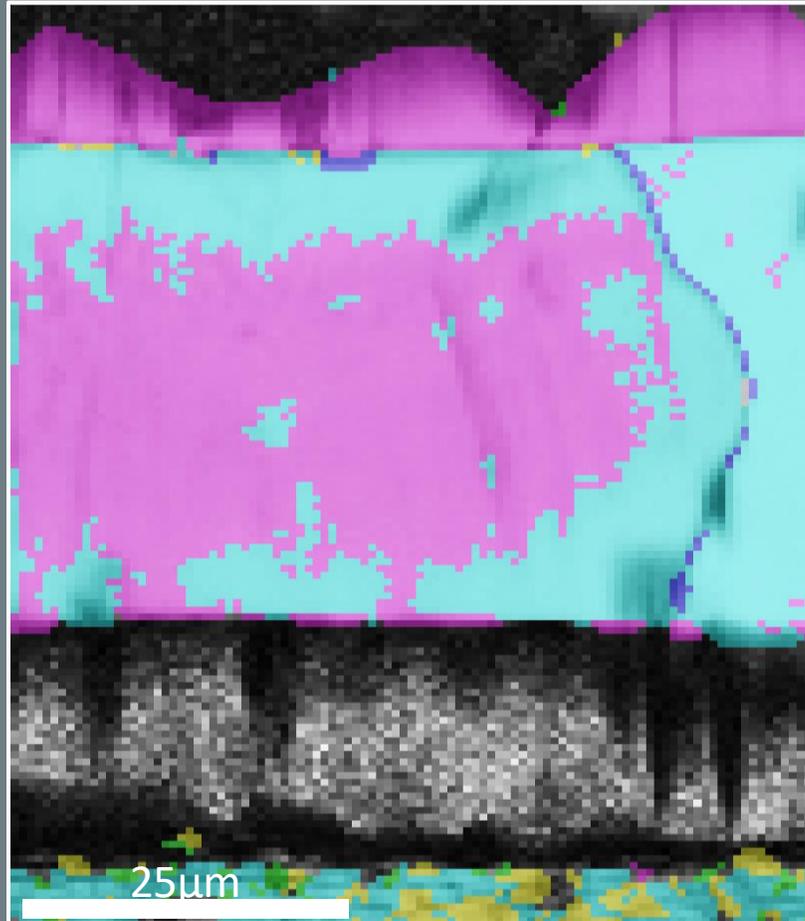


# 3812 Blister



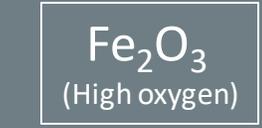
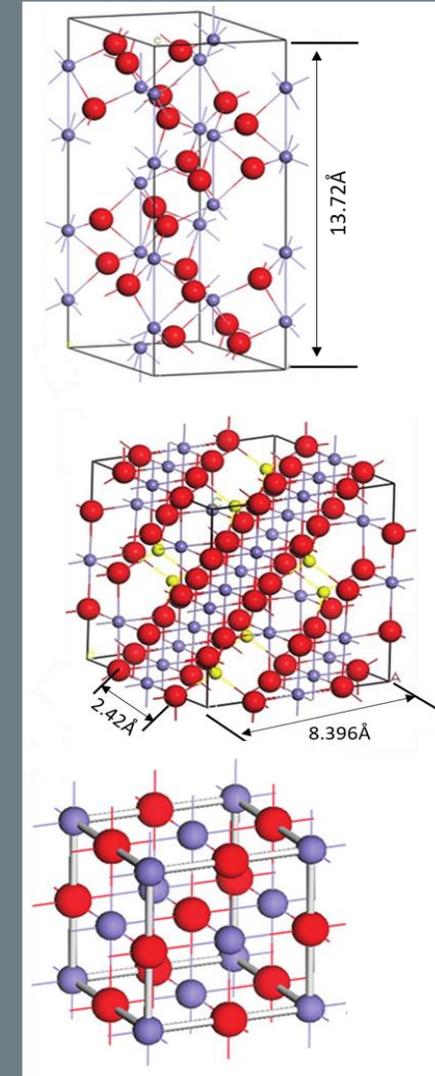
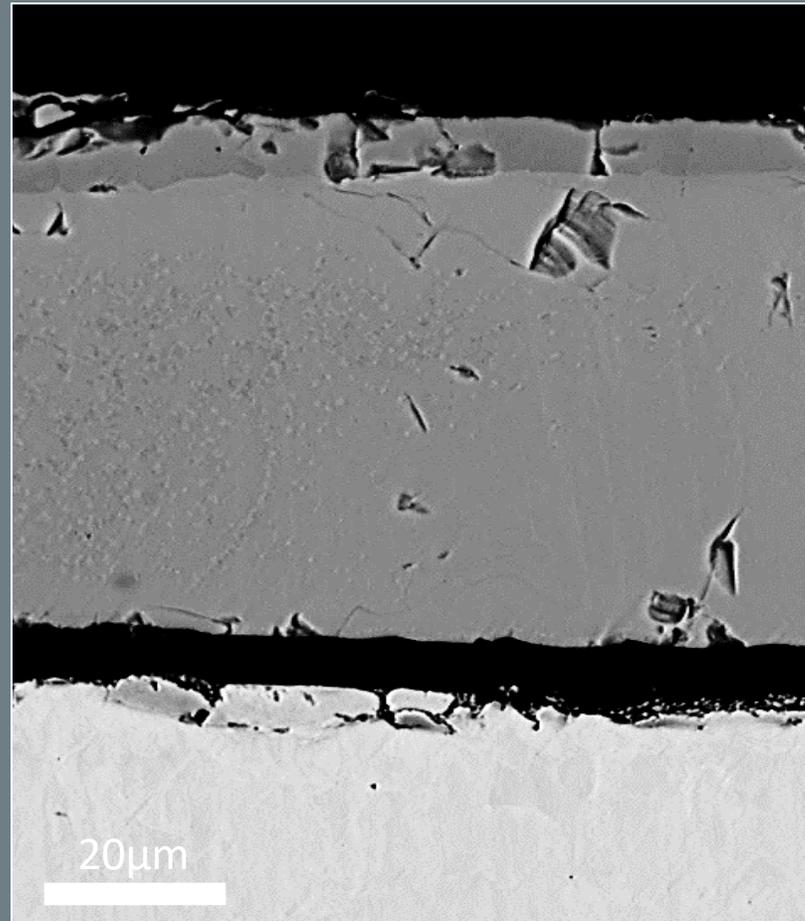
# 3812 EBSD Phase identification

Phase Map

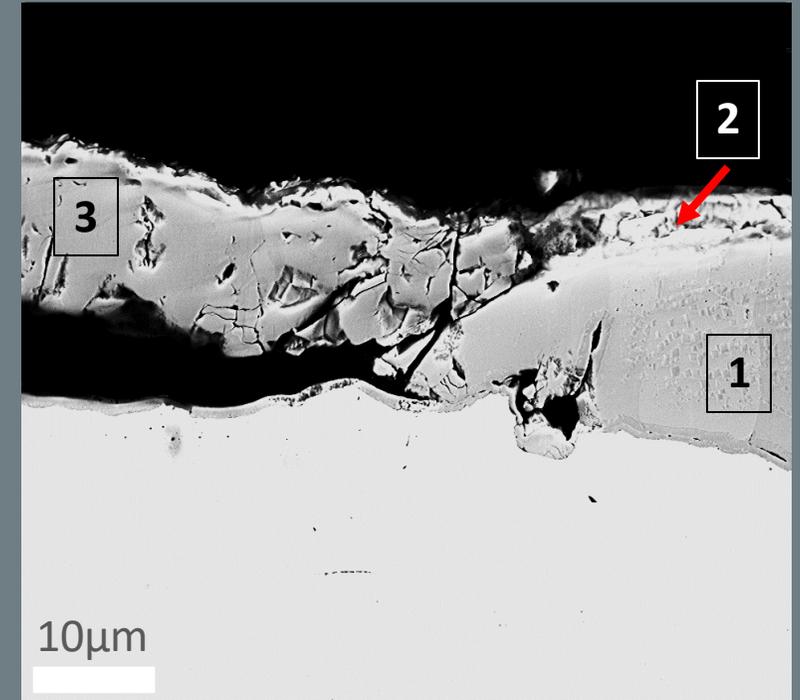
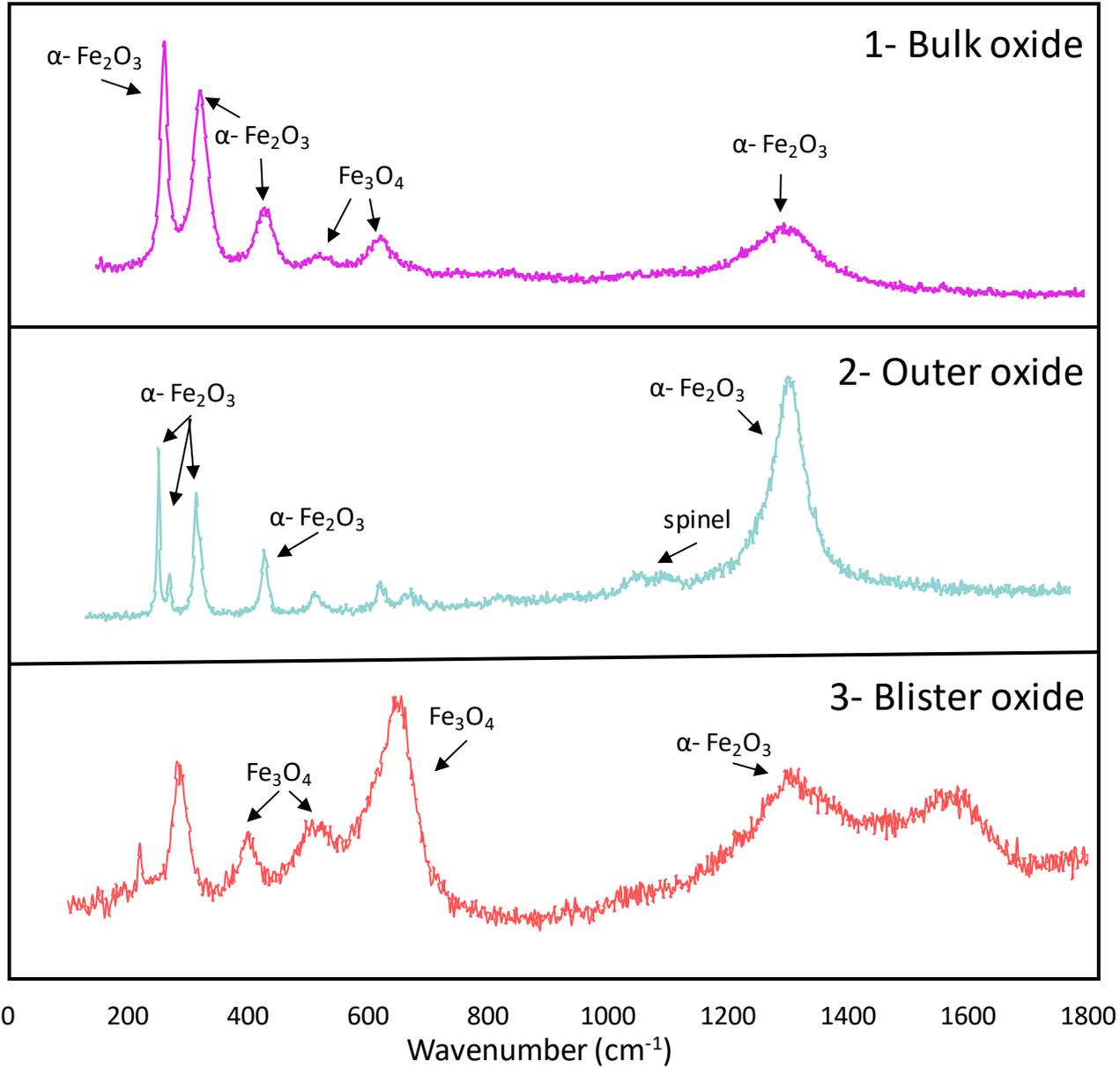


Iron bcc	Silicon	Fe <sub>2</sub> O <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub>	FeO
1.9%	0.5%	0.5%	36.6%	22.4%

BSE Image

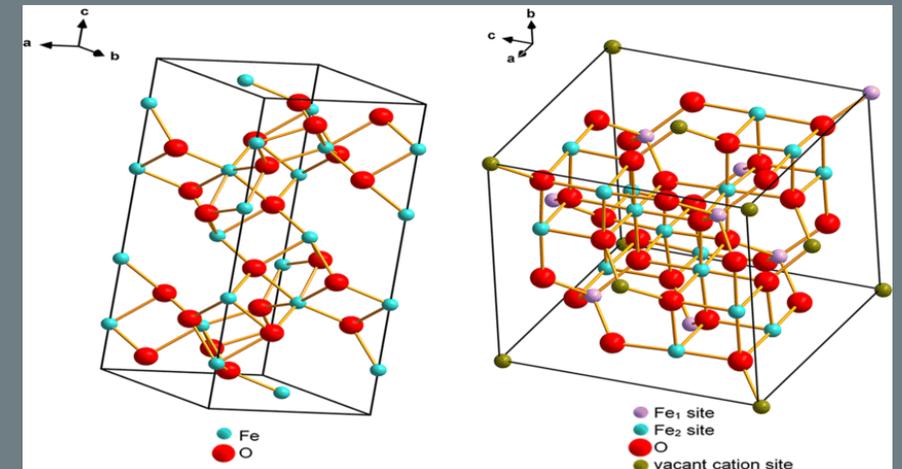


# 3812 Raman Spectroscopy



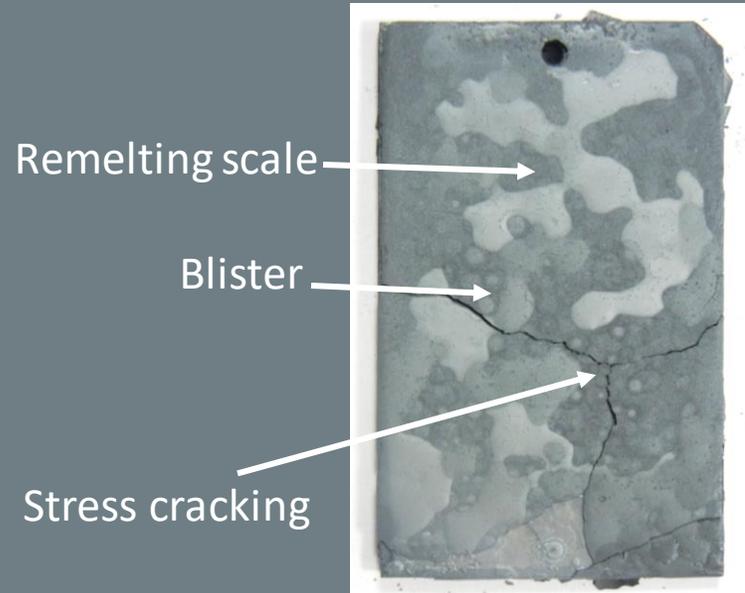
$\alpha\text{-Fe}_2\text{O}_3$

$\gamma\text{-Fe}_2\text{O}_3$



# 3812 New phenomena (blister during cooling)

Blister during heating

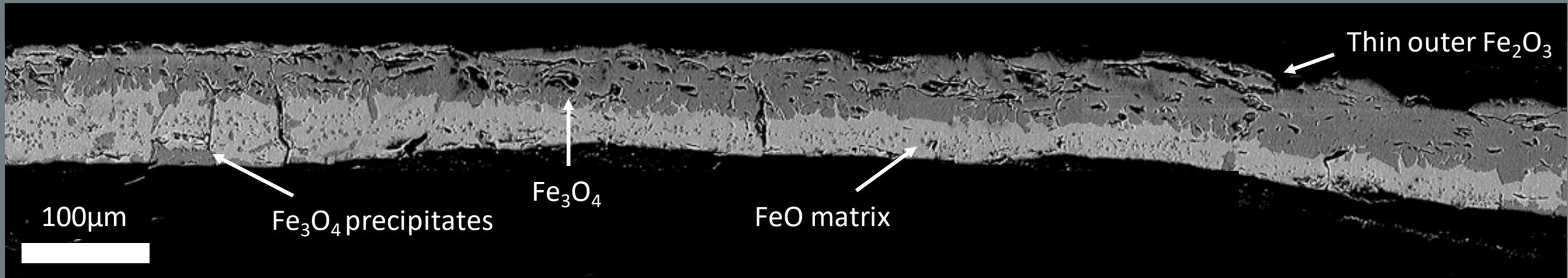
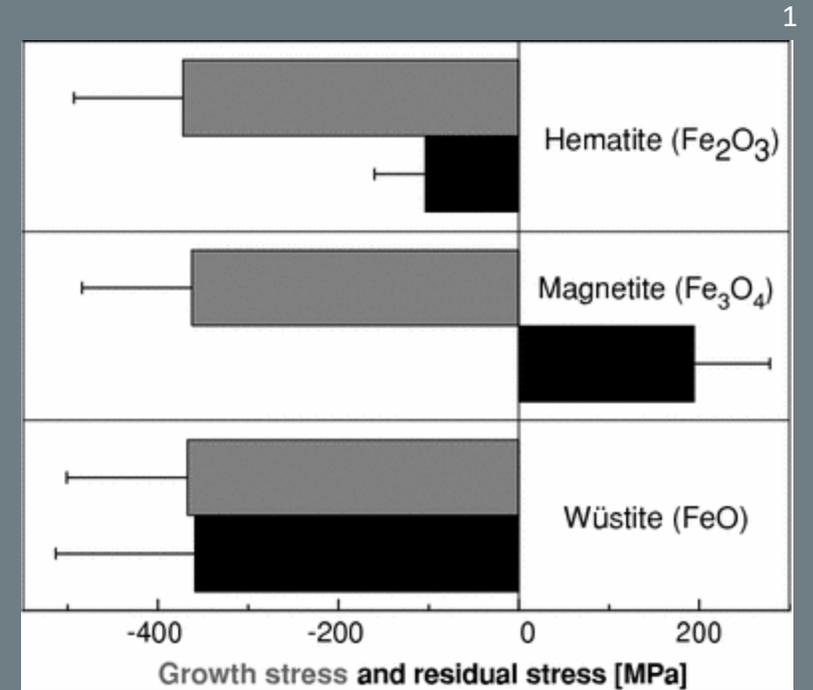


1000°C 600s

Blister on cooling

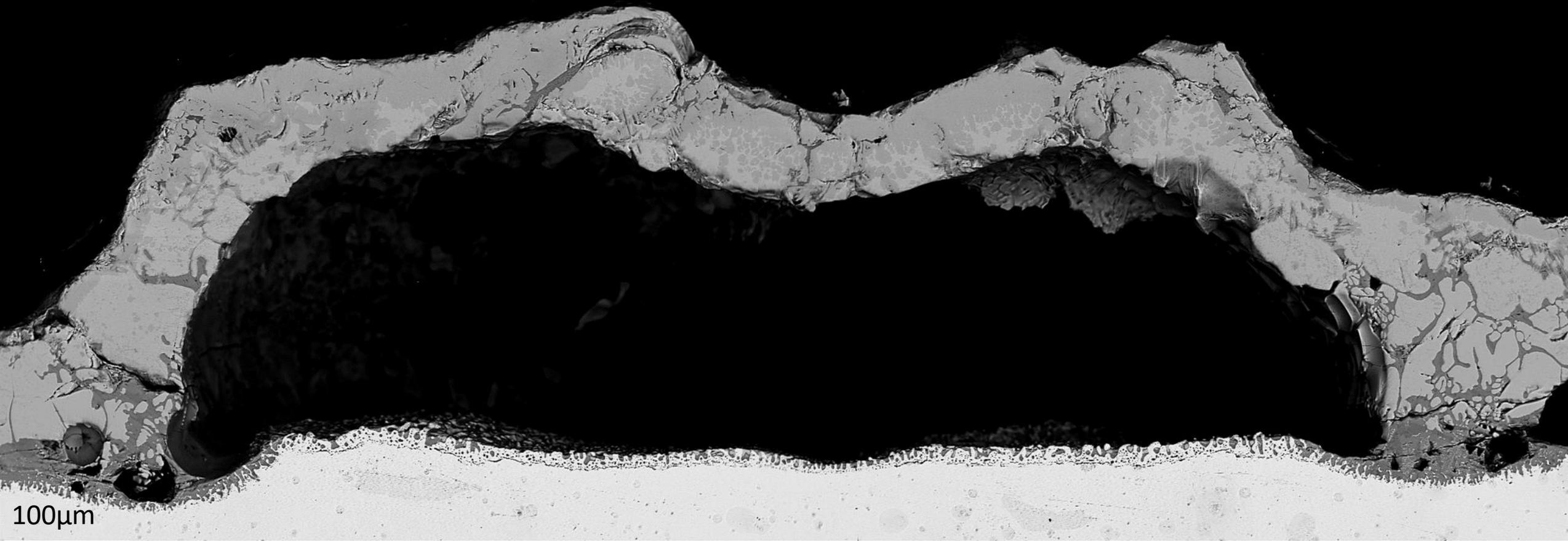


1200°C 60s

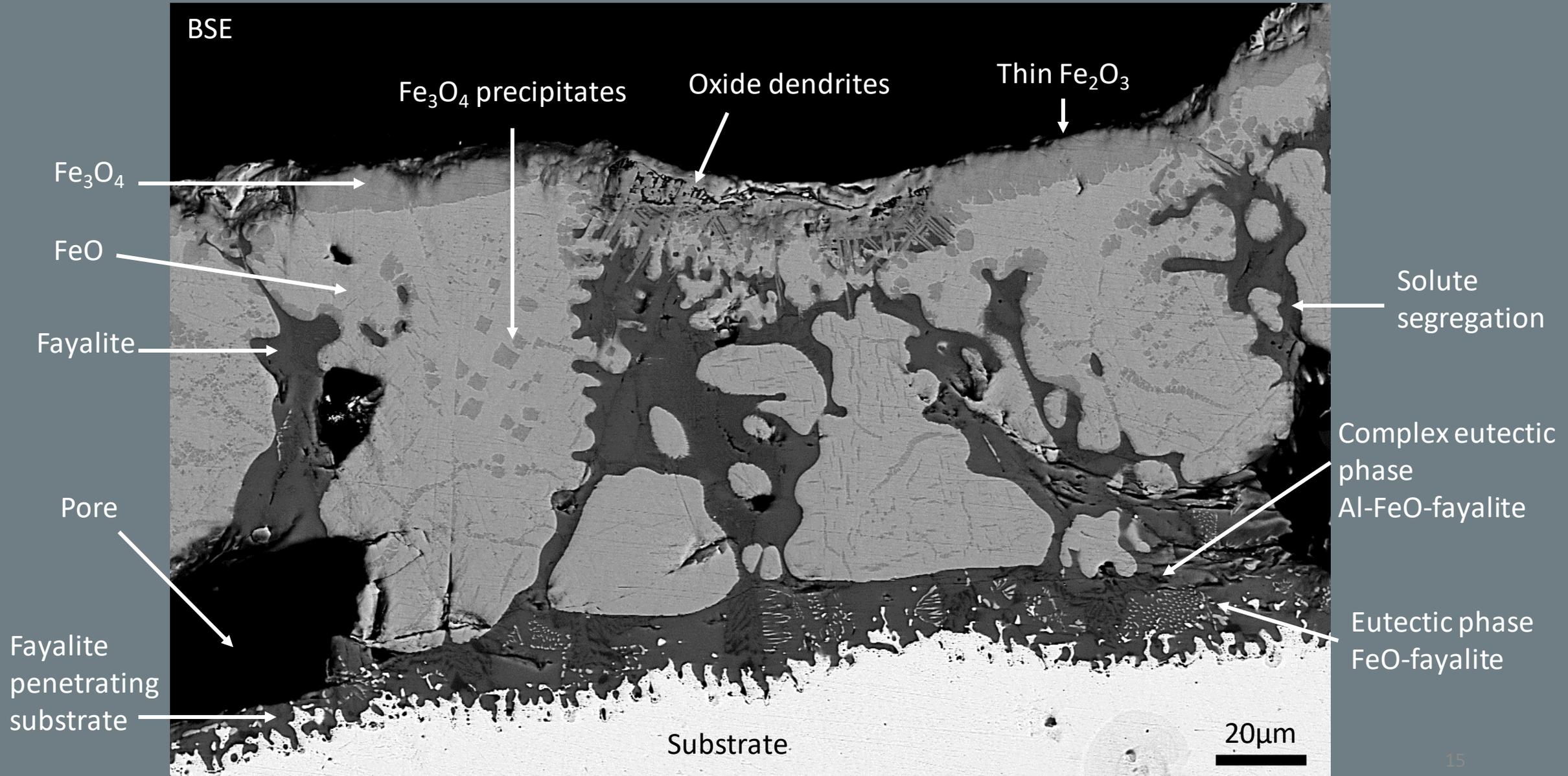


# B32 Blister

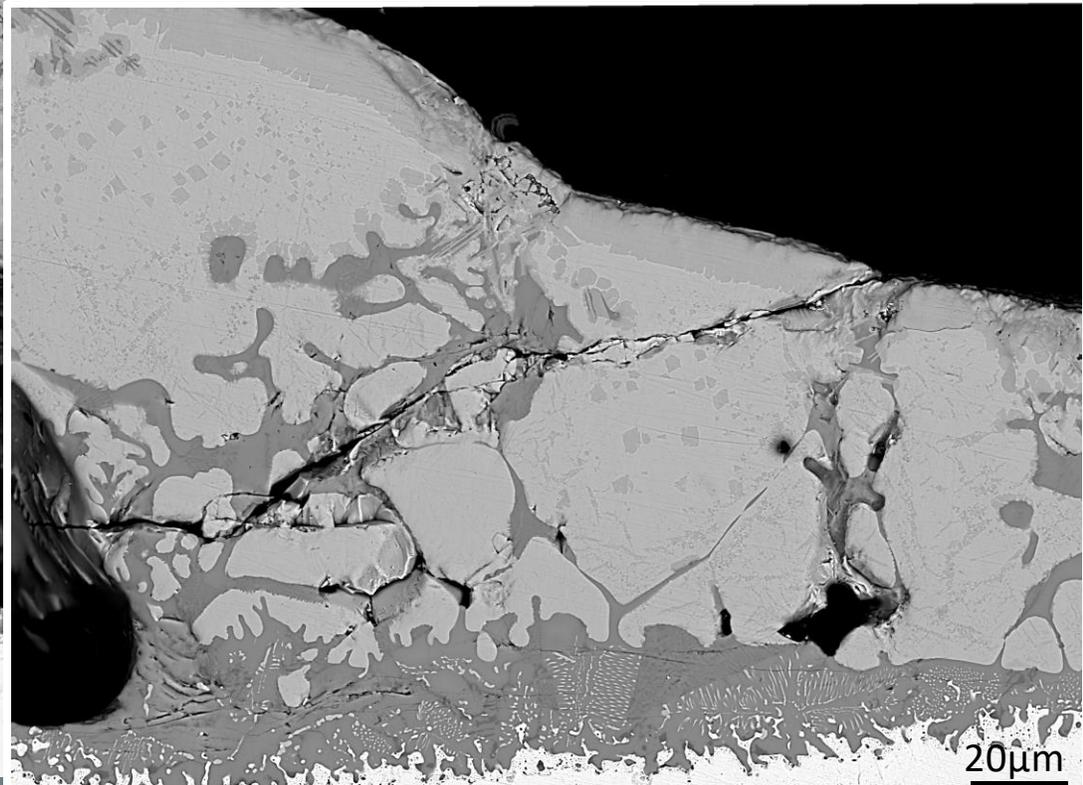
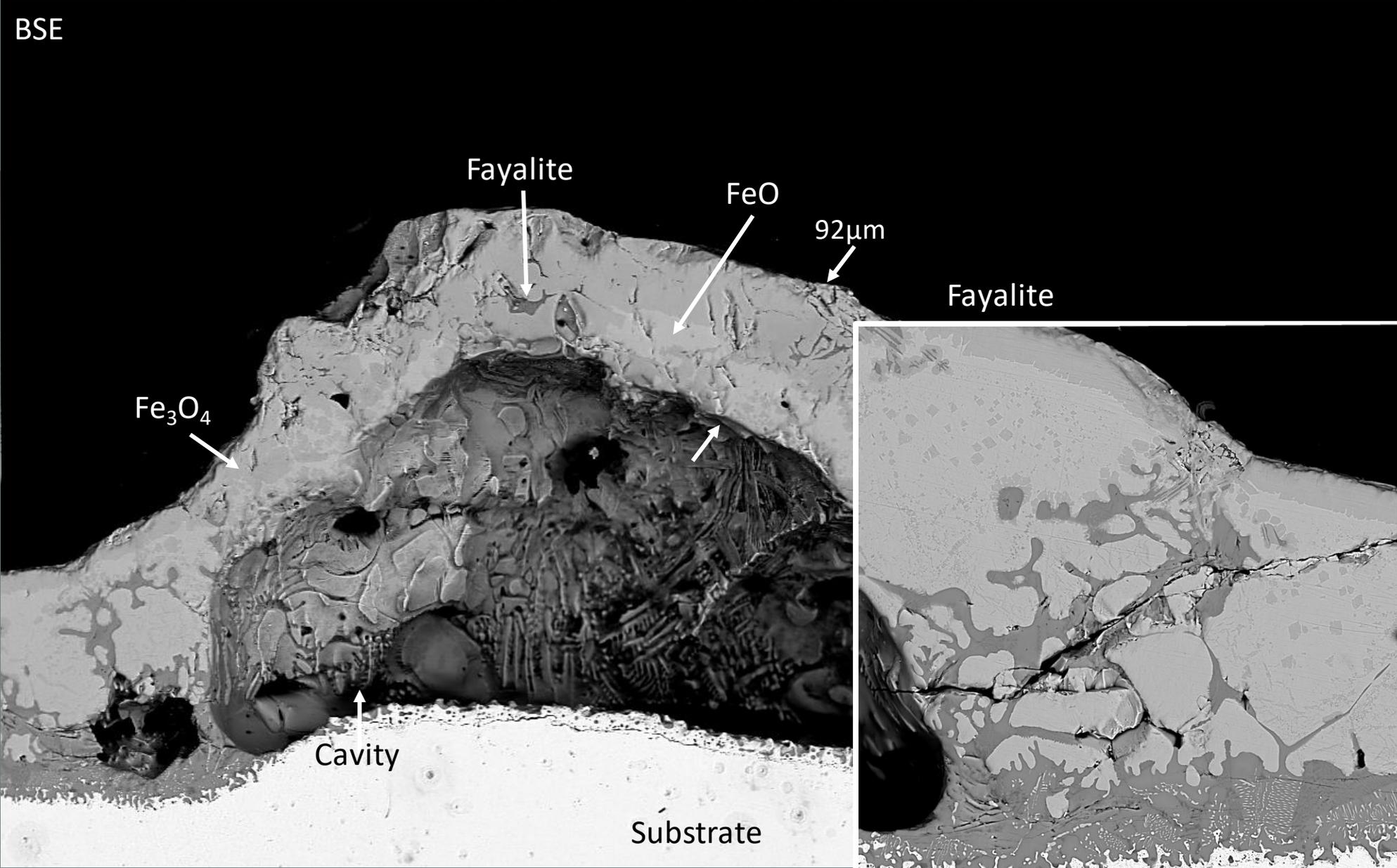
BSE



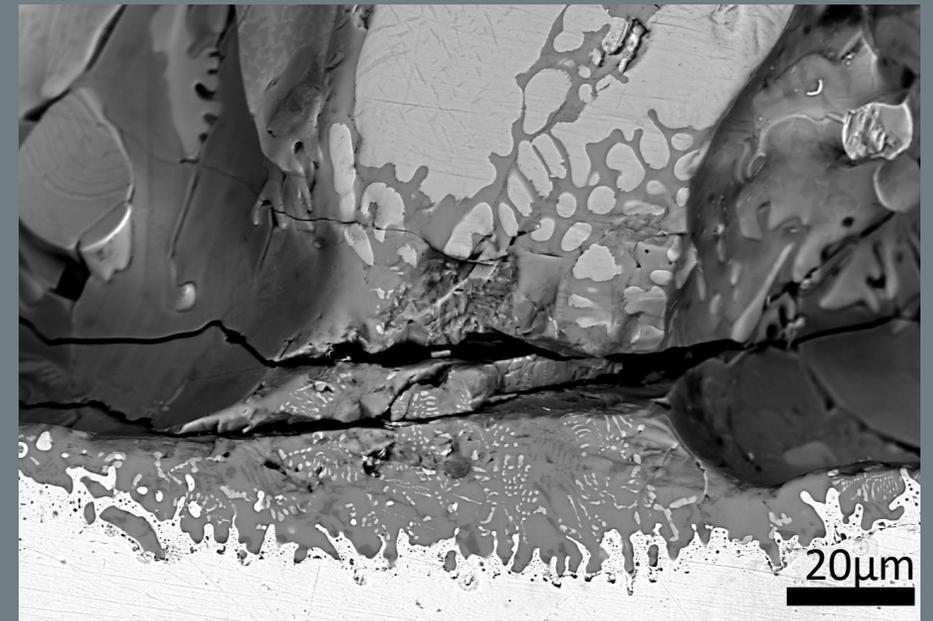
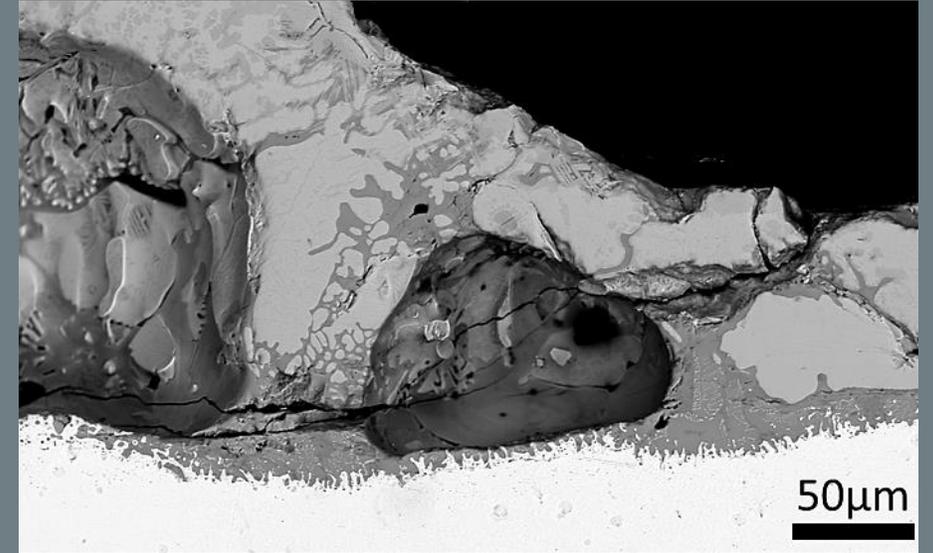
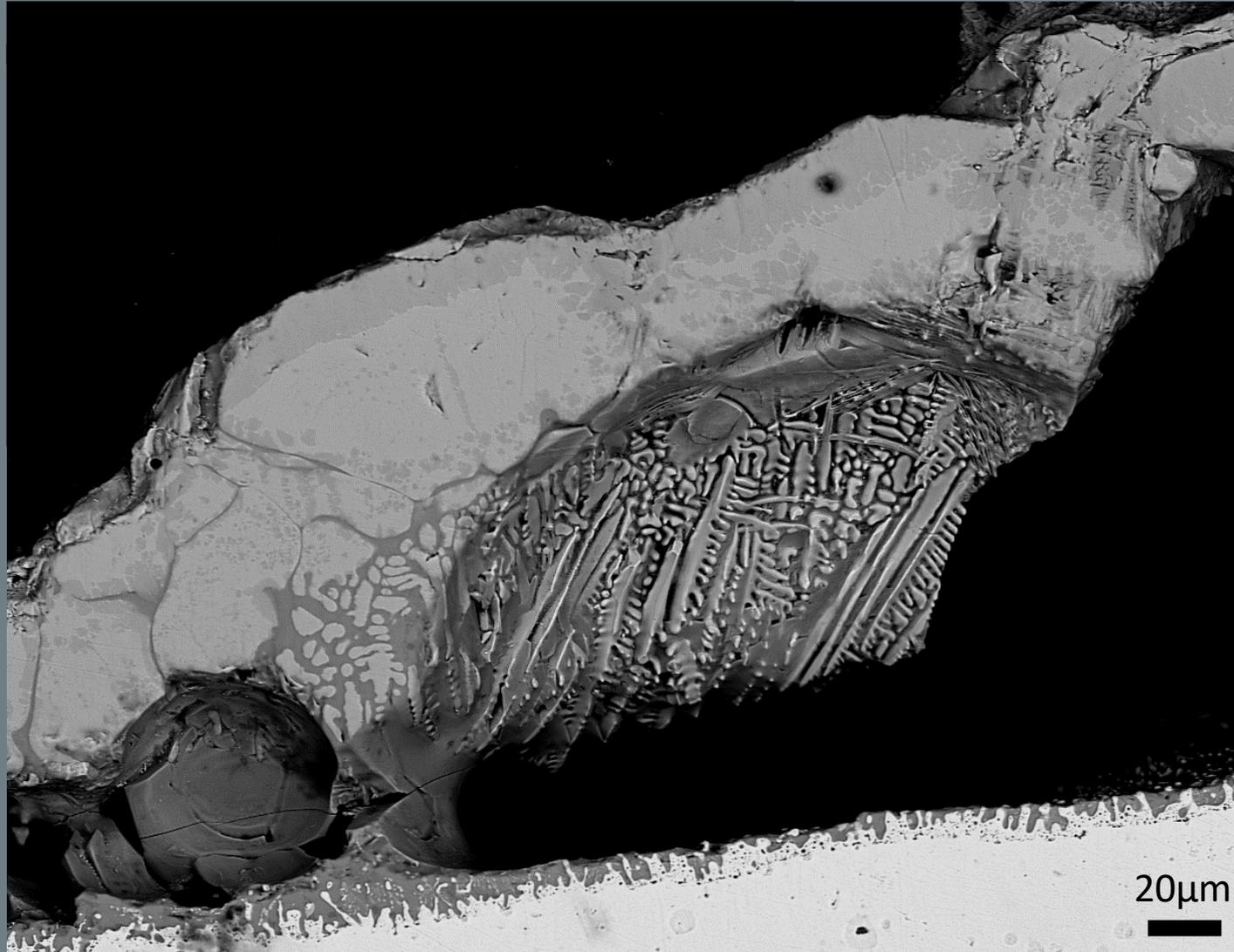
# B32 Oxide morphology



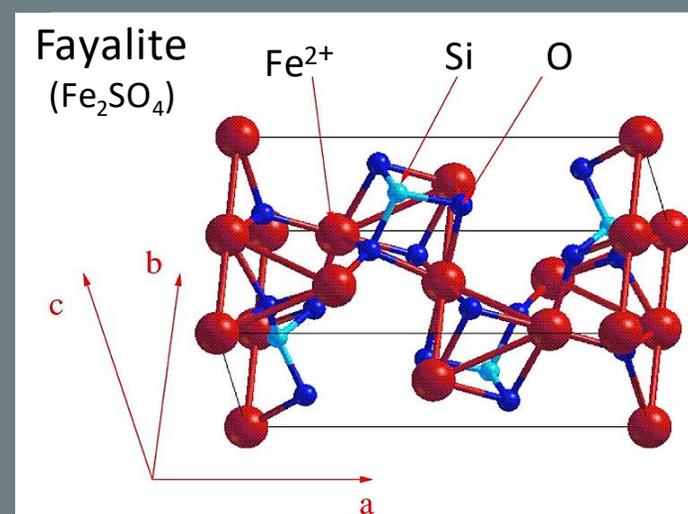
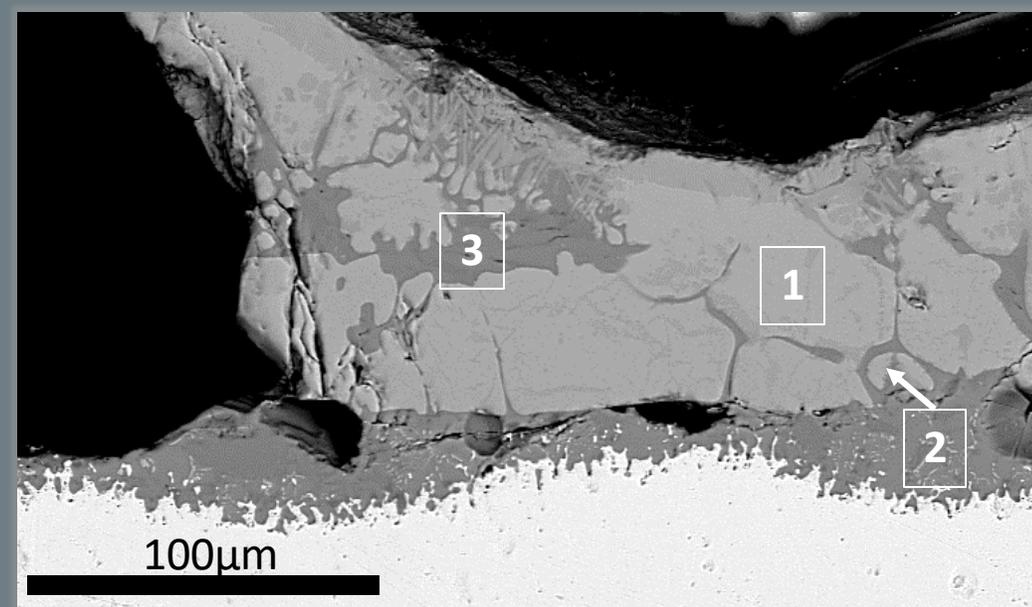
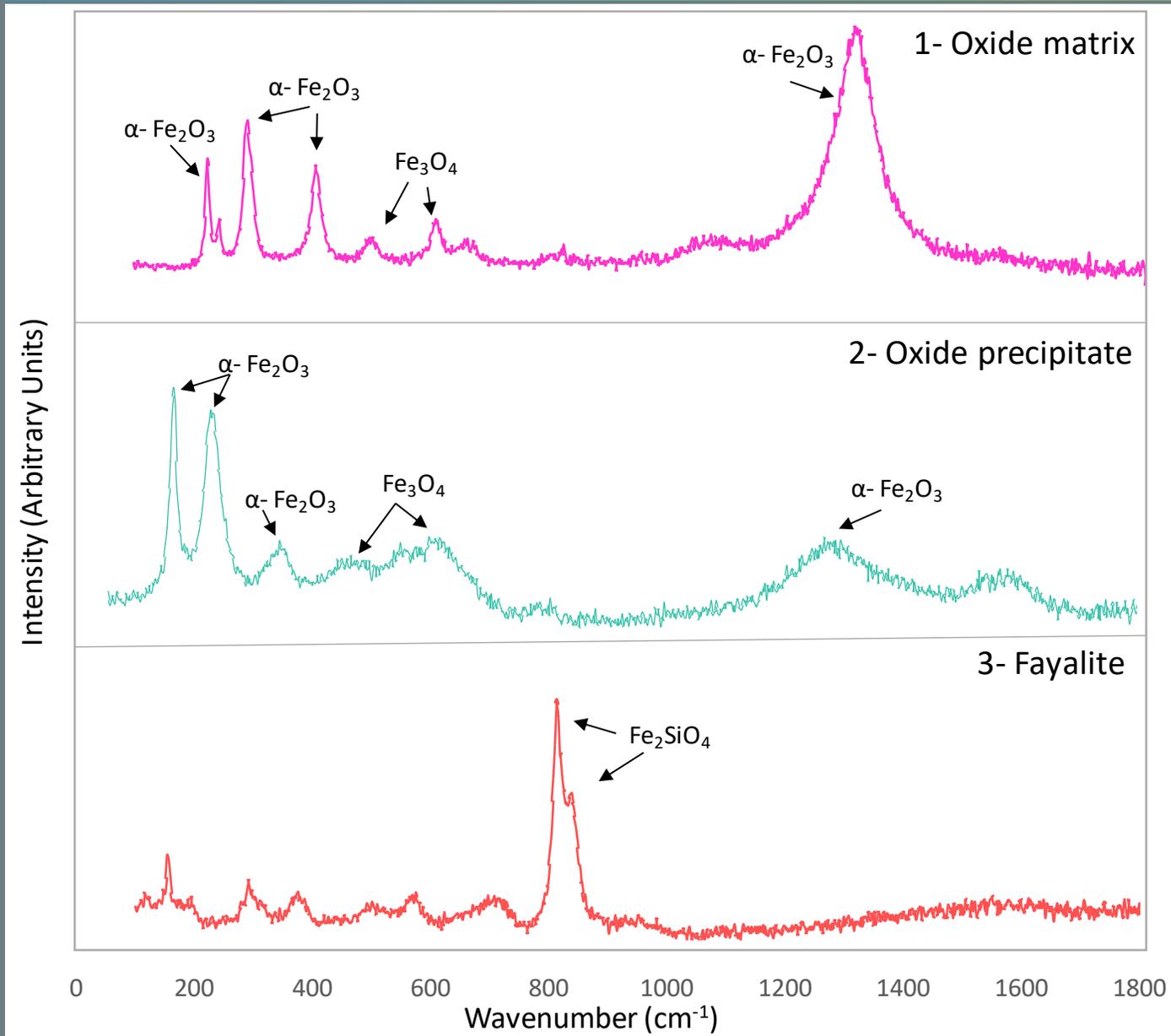
# B32 Oxide morphology



# B32 Oxide morphology

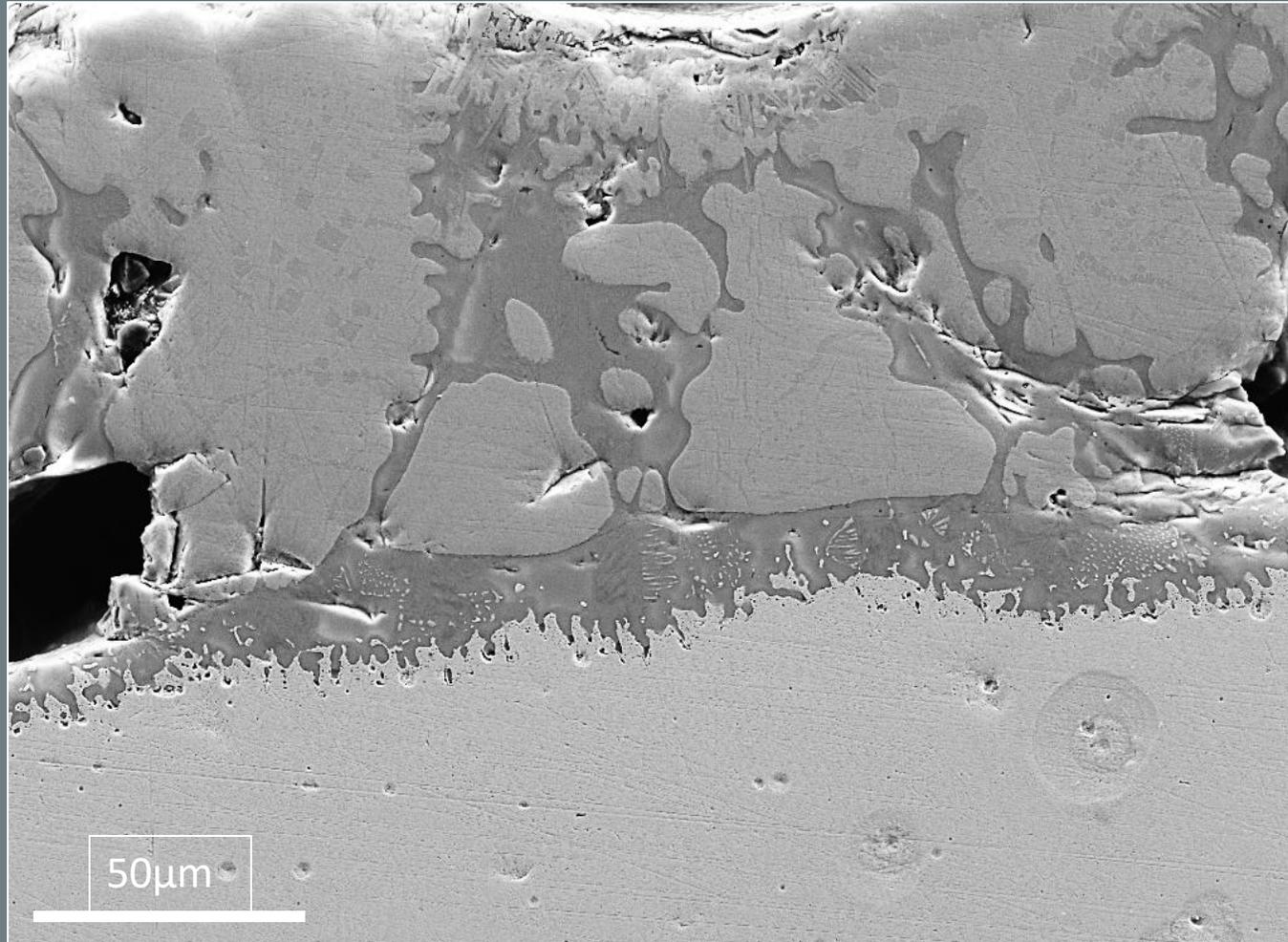


# B32 Raman spectroscopy

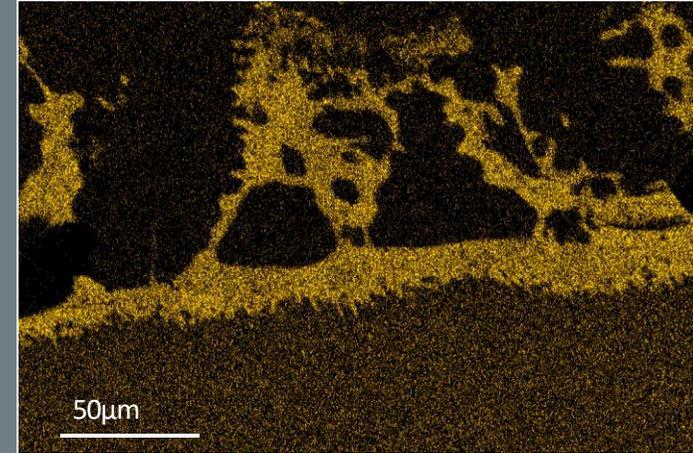


1- Comparison of LDA and GGA results. Phys. Rev. B. 67.10.1103/PhysRevB.67.094106.

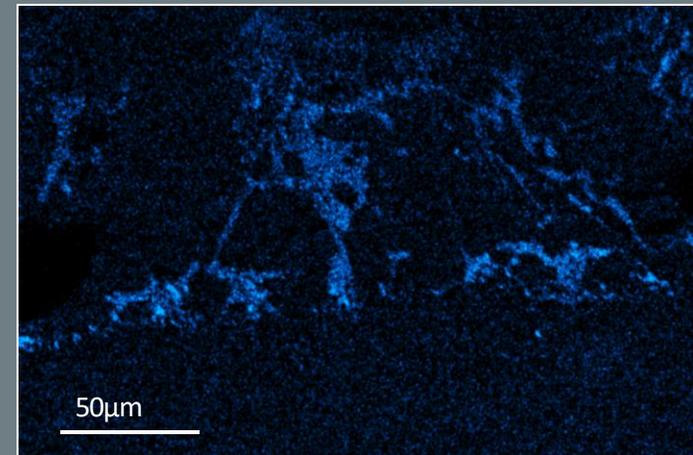
Electron Image



Si



Al



1. Blister formation on B32 and 3812 steel grades were characterized; key differences were found in the oxide morphologies
2. New phenomena discovered within 3812 steel grade; blister on cooling
3. B32 contains a complex  $\text{Al-Fe}_2\text{SiO}_4\text{-FeO}$  eutectic in the bulk of the oxide which is not present within blistered regions

## Future Work

- Nanoindentation on oxide to assess stress within oxide layers
- Insitu investigation of early stages of oxidation
- FIB inside of blister region to produce TEM lamella to investigate oxidation within the blister
- X-ray CT to investigate porosity

*Thank you for listening*

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