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UNIVERSITY OF TECHNOLOGY

Industrial Processes -
New challenges for high temperature materials

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High Temperature Corrosion Centre

Temperature

1200

900

600

RT

Oxygen partial pressure (bar)

0,21

10^{-15}

10^{-23}

10^{-25}

10^{-39}

Corrosive gases: e.g. N_2, CO, CO_2, CH_4 (vol%)

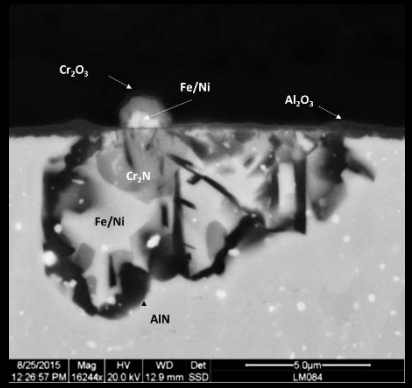
100

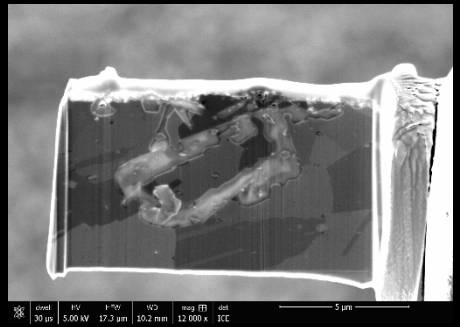
0

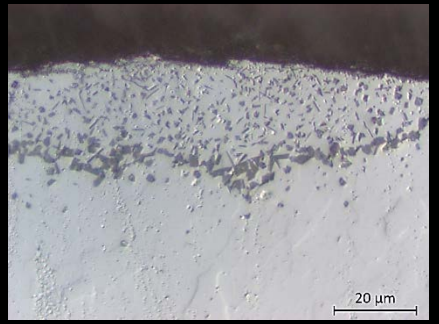
Two major topics:

Nitridation

The uncontrolled formation of internal nitride precipitates

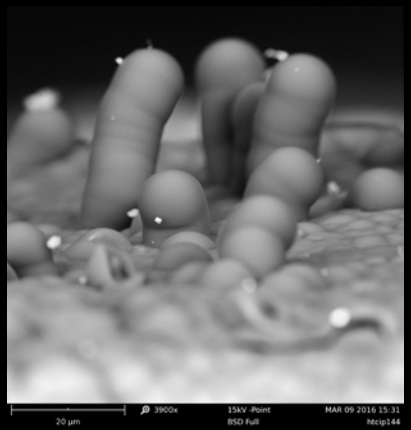


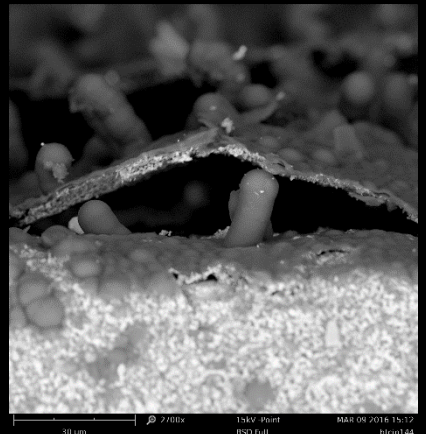


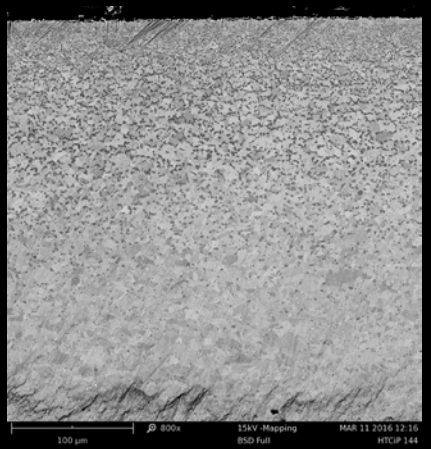


Carburization/Metal Dusting

The uncontrolled uptake of carbon into alloys and formation of graphite internally and externally.

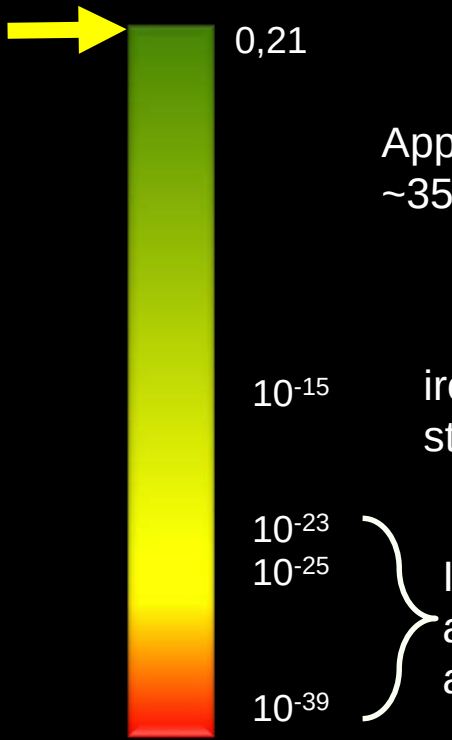






Corrosion by very controlled exposure experiments.

Oxygen partial pressure (bar)



Application of N_2-5%H_2 with ~35 ppm H_2O as impurity

iron and nickel oxide are not stable

In this regime chromia, alumina, yttria and zirconia are stable

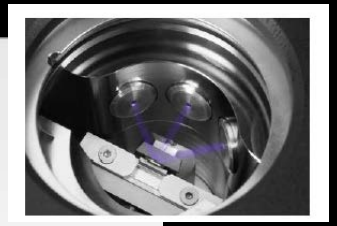
Materials investigated within this projects are:

FeCrAl(RE)
FeNiCrAl(RE)
NiCr
and stainless

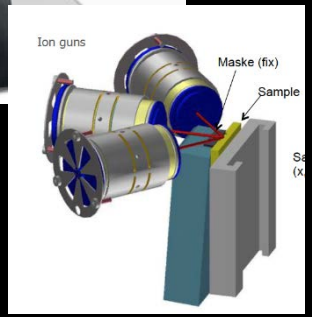
Analysis pre- and post mortem by state of the art microscopy

Cross sectional sample preparation

BIB (Broad Ion Beam)

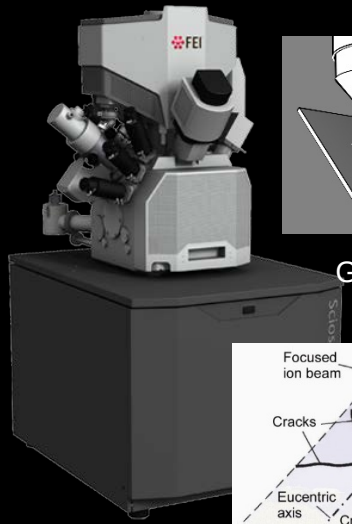


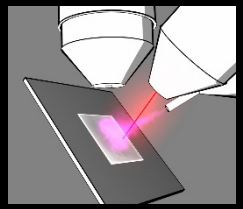
Argon Ion Beam



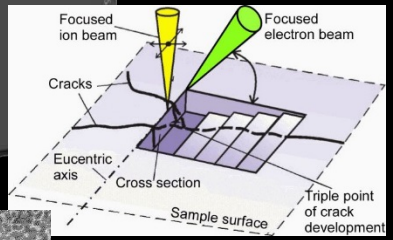
To produce large cross-sectioned surface (> 4×1 mm)

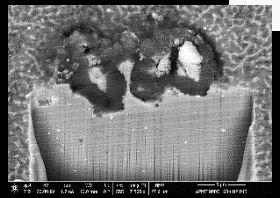
FIB (Focused Ion beam)





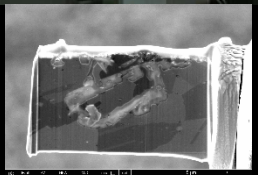
Gallium Ion Beam





For more selective and site-specific cross-section (around 30×50 µm)

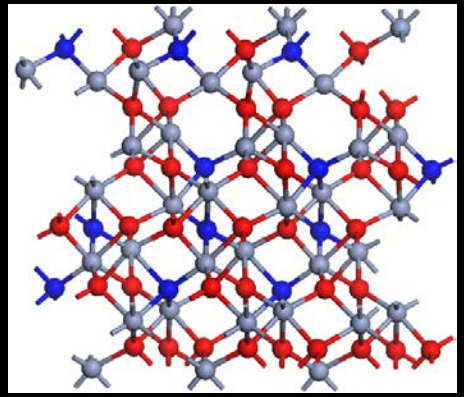
TEM (Transition Electron Microscope)

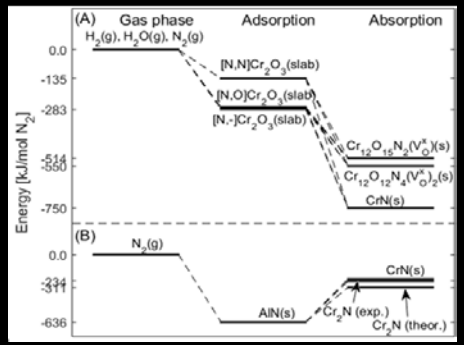


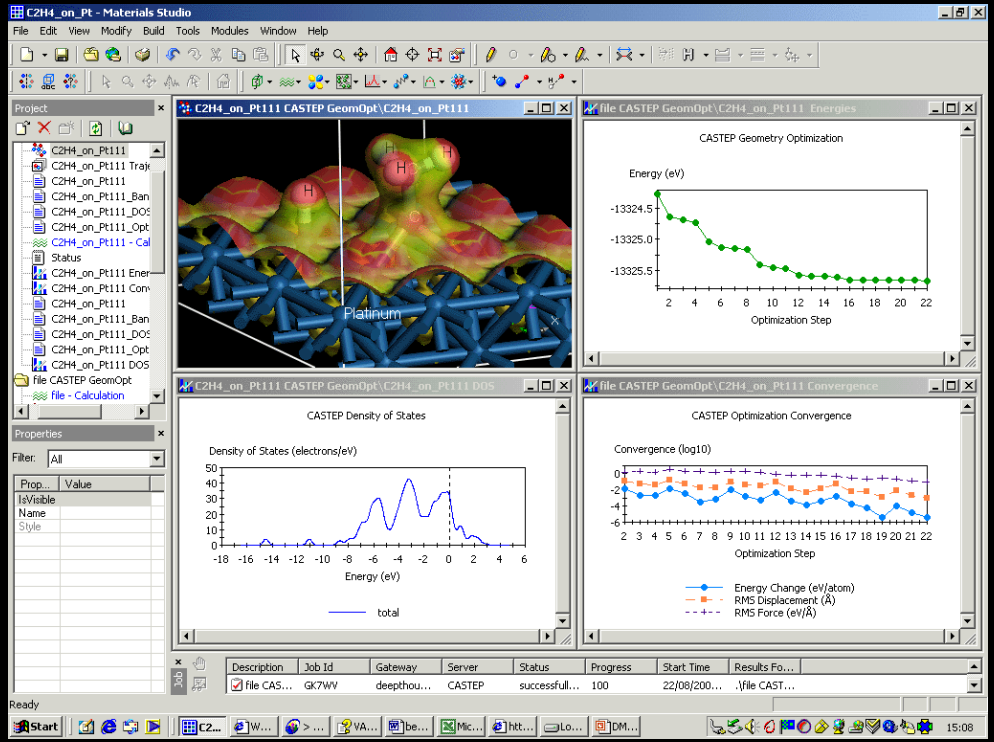
High resolution analysis

ple Ion Beam Milling System

Investigation of the energy landscape of corrosion processes by ab initio methods



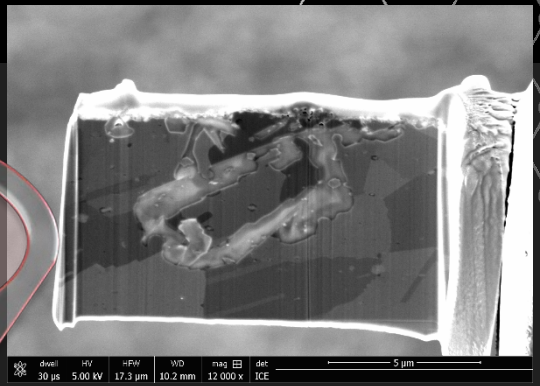


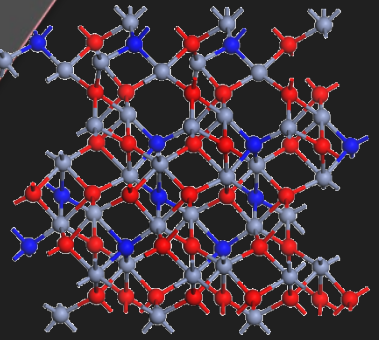


Controlled high temperature experiments

Careful analysis by state of the art microscopy

Identification of relevant surface and bulk processes





Conceptual understanding of the corrosion mechanism

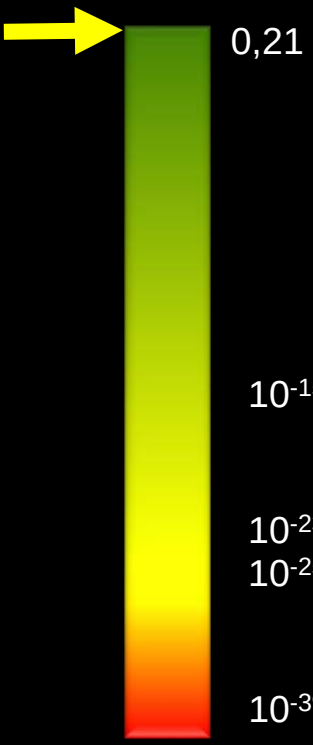
Hands-on People

High temperature exposures in low oxygen activity environments
Christine Geers

Microscopy Nooshin Mortazavi and Mohammad Sattari

Theoretical Chemistry – ab initio calculations by
Vedad Babic and Itai Panas

Oxygen partial pressure (bar)



Application of N_2-5%H_2 with ~35 ppm H_2O as impurity

iron oxide is not stable

In this regime chromia, alumina, yttria and zirconia are stable

?

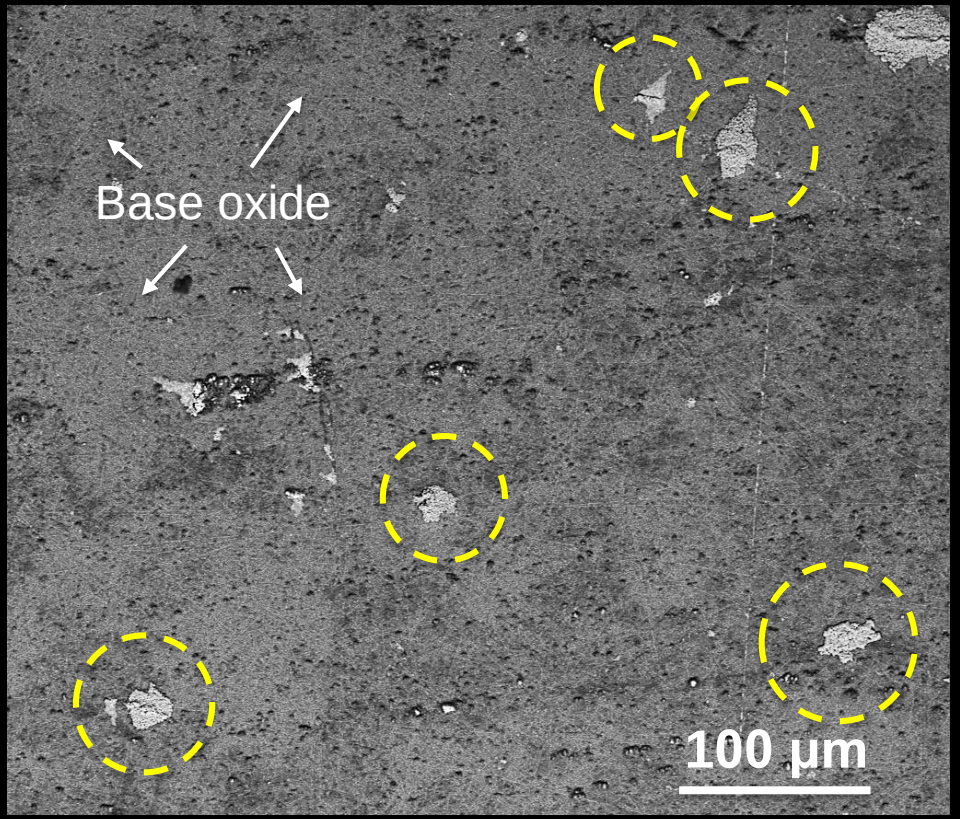
Questions we have addressed:

- stability of oxides under nitriding conditions, synergetic effects — HTC/KME 2015
- possible nucleation sites for chromia on an alumina forming alloy – identification by marker experiments — HTC/KME 2016
- the impact of surface texture on the onset of nitridation — HTC/KME today
- the effect of yttria and zirconia on alumina growth (ongoing) — HTC/KME upcoming

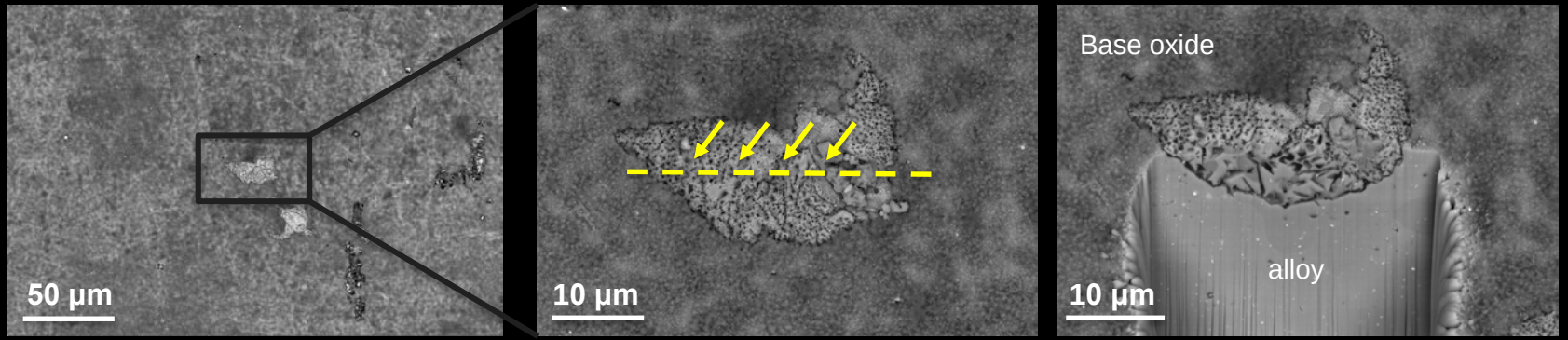
-An overview

Alloy: Kanthal APMT

Temperature: 900°C
Environment: 95%N_2 + 5%H_2
Exposure time: 1 week



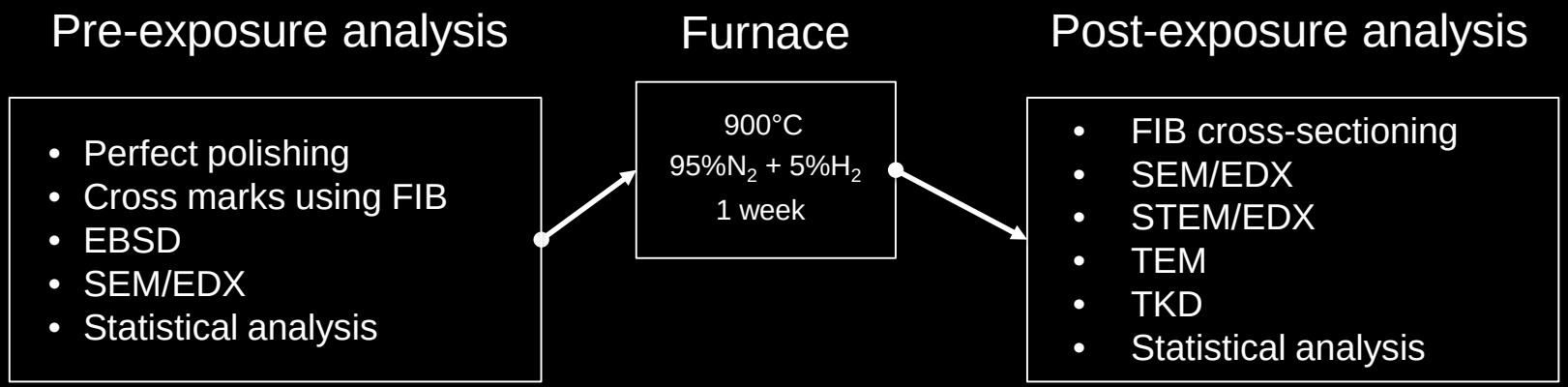
-A closer look



Marker Experiment

Kanthal APMT

95%N_2+5%H_2, 900°C – *1 week*

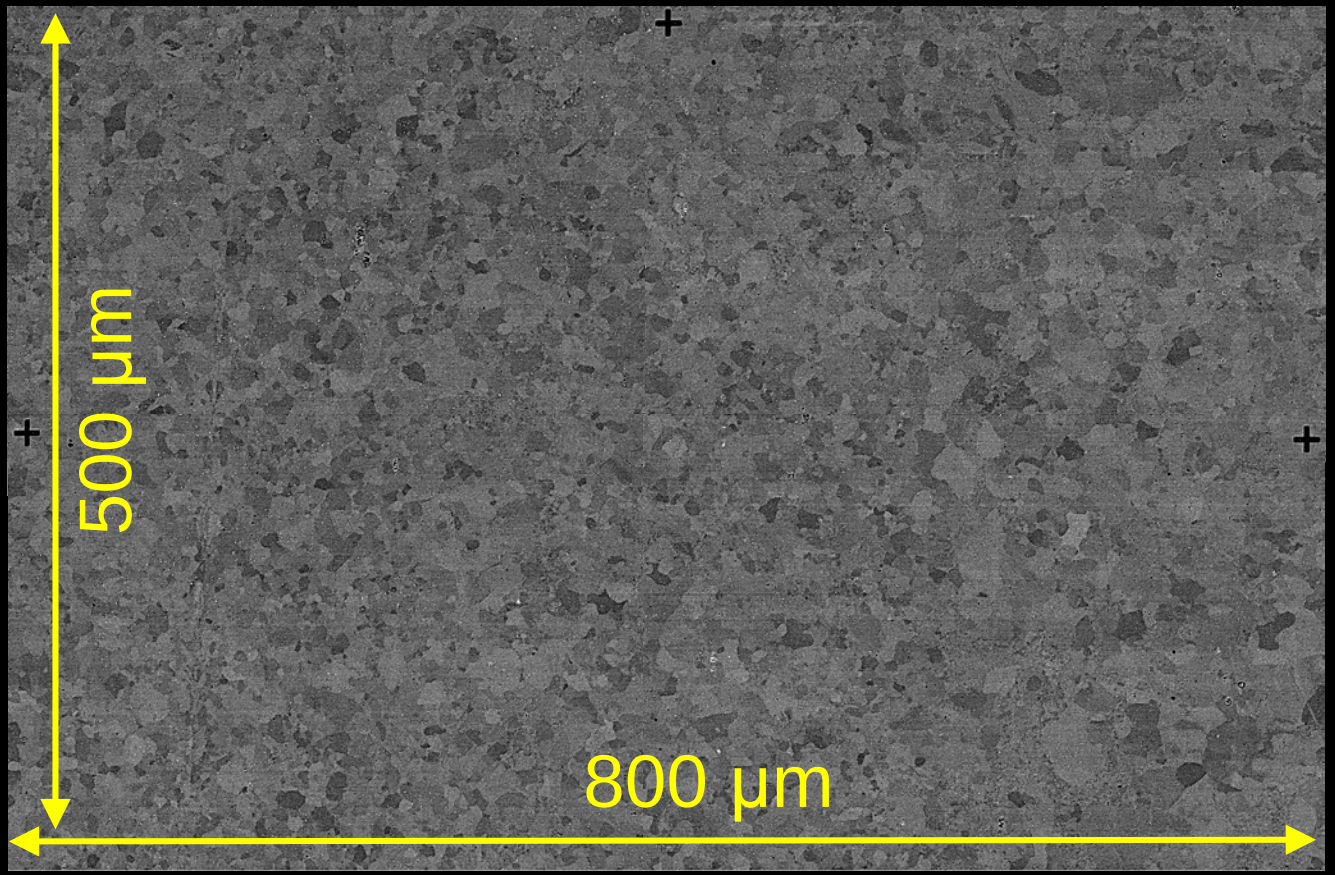


Marker Experiment – The goal

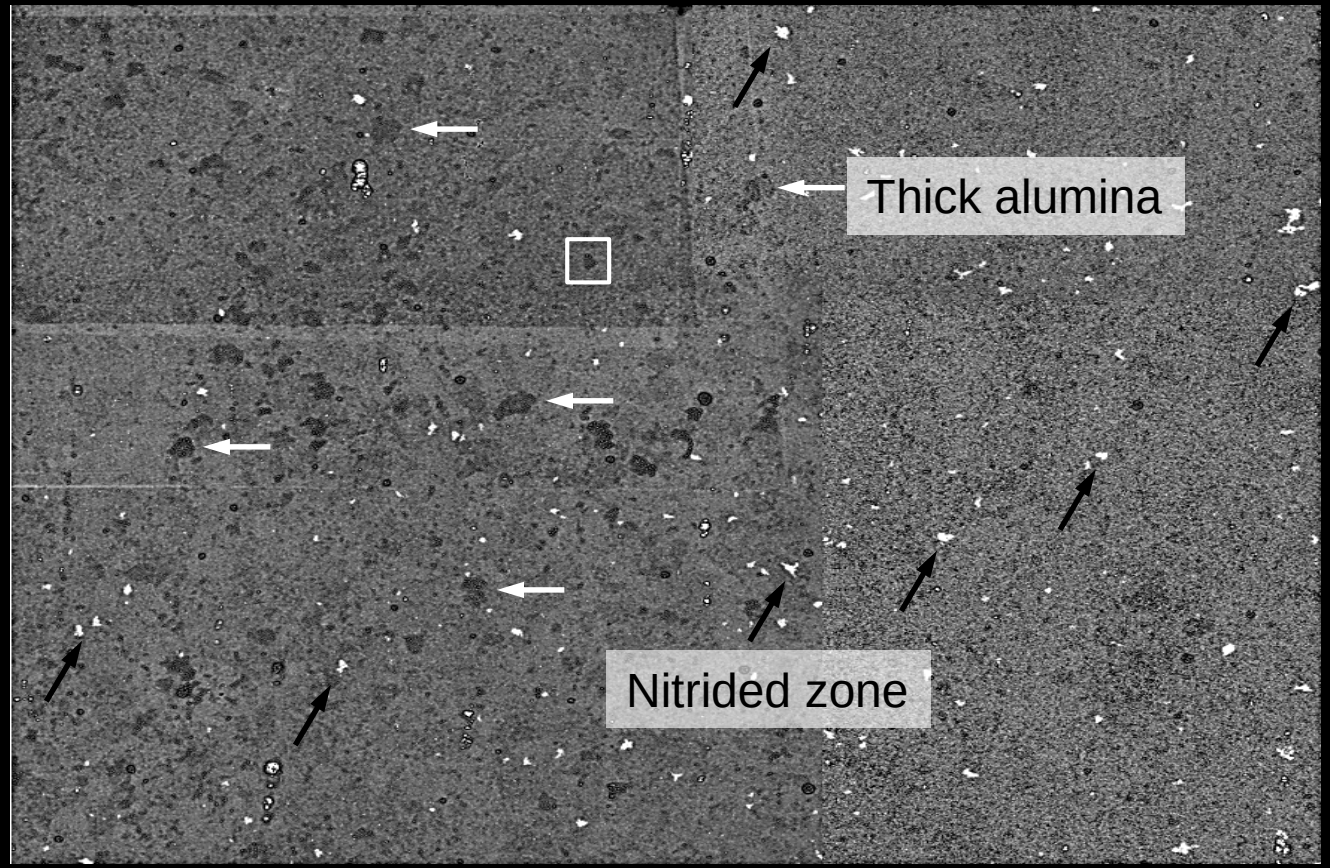
The influence of metallurgical factors on nitridation/scale failure:

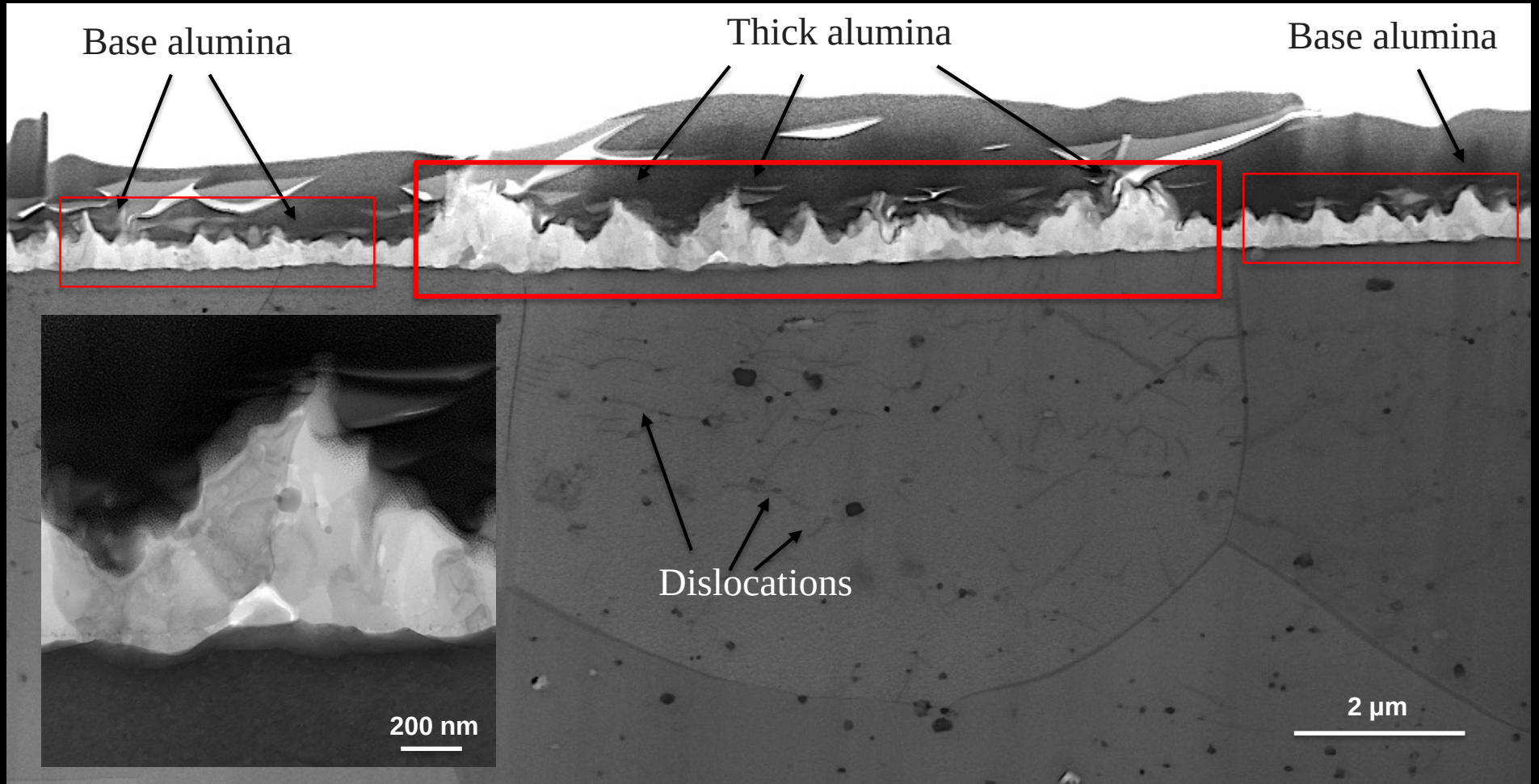
1. **Grain size**
2. **Second phase particles**
3. **Crystallographic Orientation**

BSE images – Before exposure

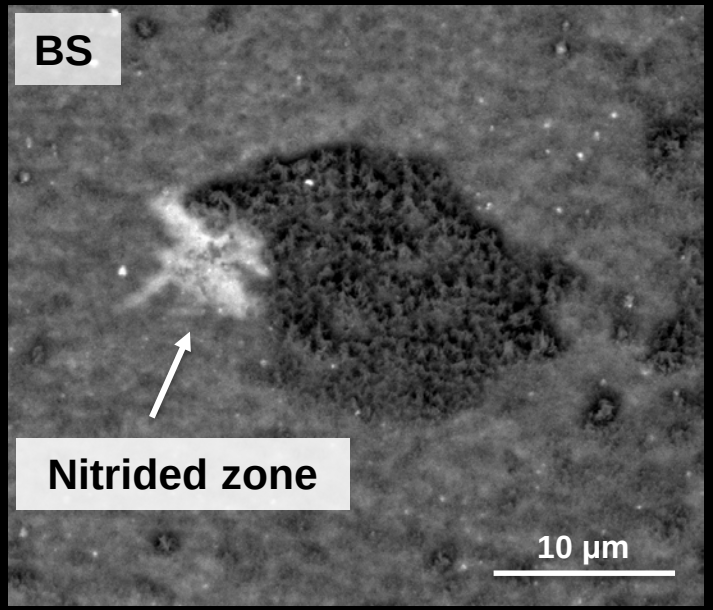


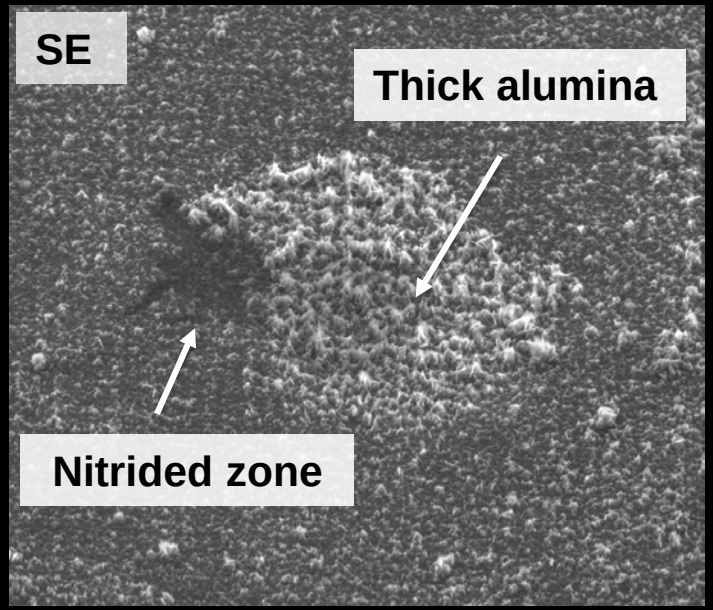
BSE images – After exposure




Base alumina
Thick alumina
Base alumina
Dislocations
200 nm
2 µm

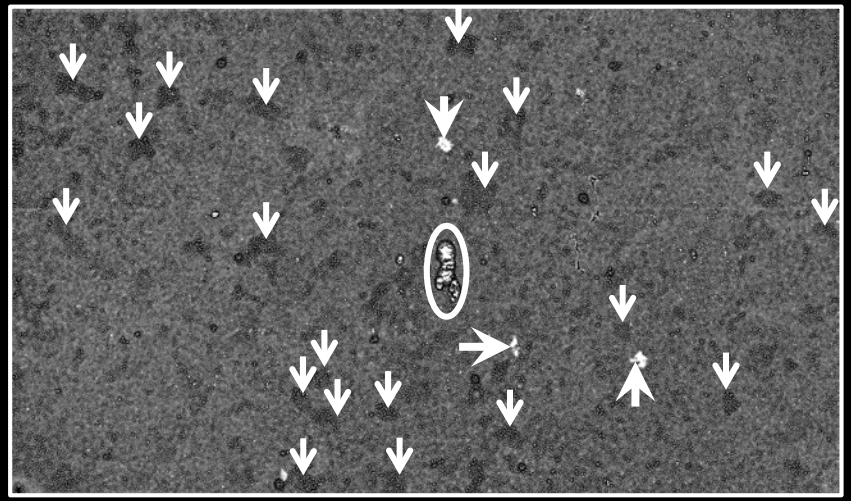
Tilt angle: 45°



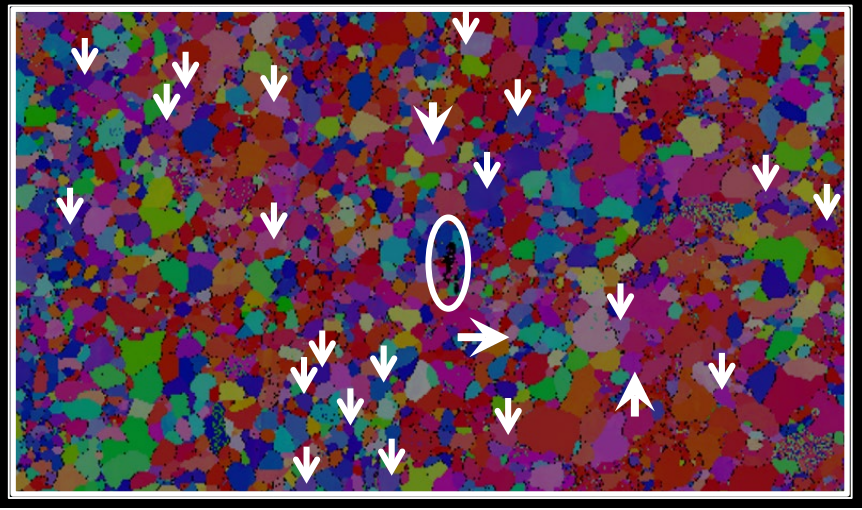


Occurrence of thick alumina and nitrided zone at the same place.

Exposed



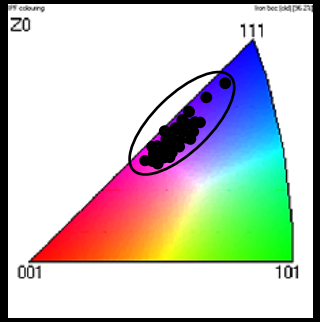
Before exposure

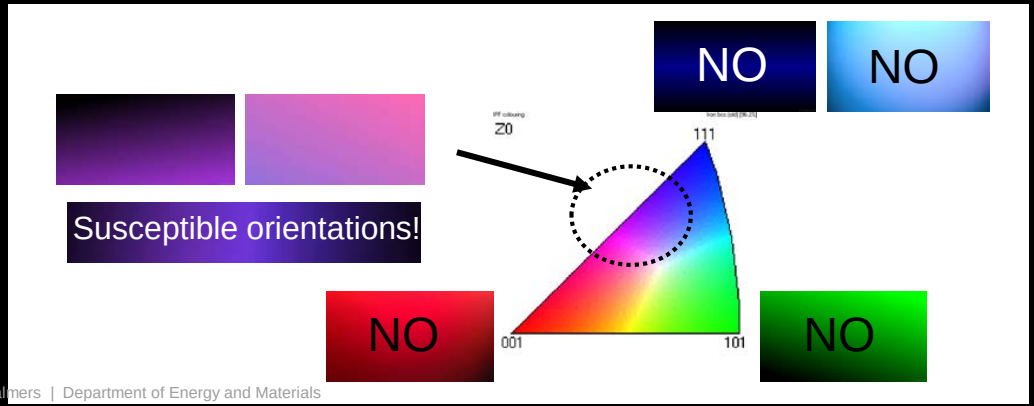


$PD_{100} = 0{,}19/R^2$

$PD_{110} = 0.27/R^2$

$PD_{111} = 0.11/R^2$





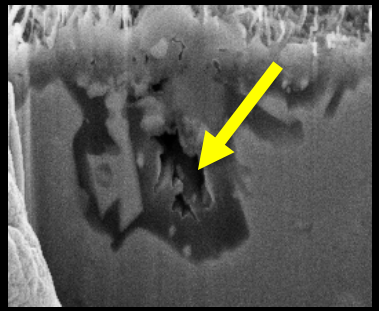
- Texture engineering in future design (avoid specific orientations)

Outlook – a high amount of fundamental questions are still in the process to be answered.

- Defining material chances and limitations by thorough mechanistic understanding.
- Identification of transport paths through oxides, grain boundaries and corrosion products active under conditions with very low oxygen partial pressures.
- Synergies between oxide species and corrosion products.
- Transfer of results gained from nitridation experiments to carburization mechanisms.
- Investigation of kinetic aspects during nitridation and carburization, possible modelling.
- Evaluating void formation during the corrosion process.

analysis of one missing feature is currently in progress

We just started to look at the origin and impact of porosity



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Thank you for your kind attention.

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