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Critical corrosion phenomena in combustion of biomass and waste in combined heat and power boilers

A. Persdotter, V. Ssenteza, H. Lindmark, I. Hanif, J-E. Svensson, J. Liske, J. Eklund, ***J. Phother,*** L-G. Johansson, L. Paz, R. Norling, S. Andersson, S. Bigdeli, ***T. Jonsson***, E. Börjesson, E. Caliskan

Project aim:

carry out research on high temperature corrosion during ***combustion*** *of* ***biomass and waste*** *in order to* ***help solve a number of corrosion problems*** *which restrict the development of* ***more energy efficient processes*** *and technologies.*

increasing the ***predictability*** *of corrosion attacks and* ***component life.***

Energy policy targets for Sweden

100 percent renewable electricity production by 2040	No emissions of greenhouse gases by 2045	50 percent more efficient use of energy in 2030, compared to 2005

Three pillars for Sweden's energy policy

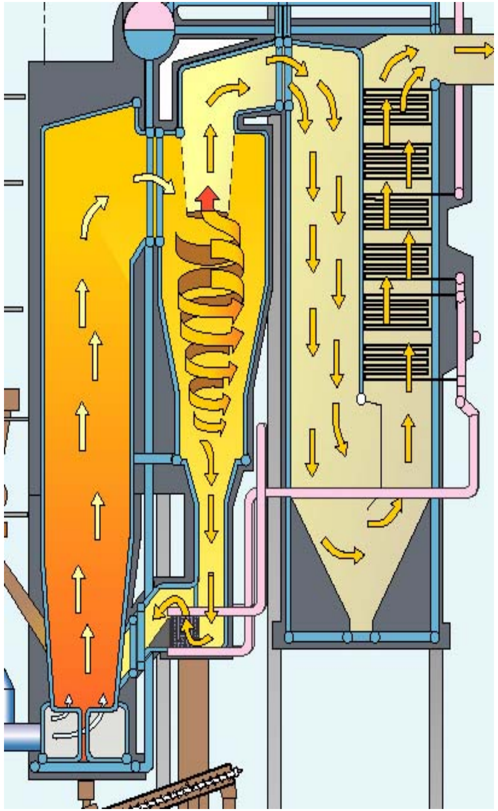
Swedish Energy Agency

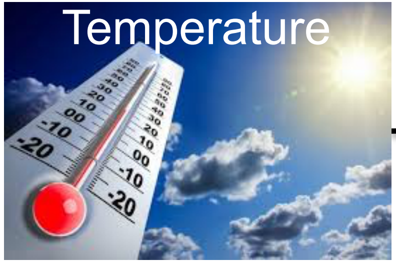
The future role of Bioenergy

More total Biomass utilization

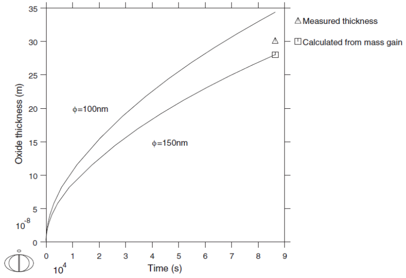
- Base load power
- Local small scale CHP
- Important complement to variable electricity sources

Swedish Energy Agency

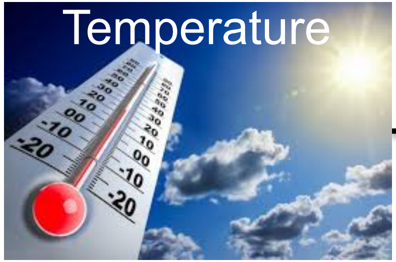




Life time of component

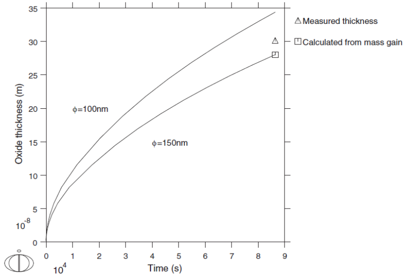


Corrosion rate



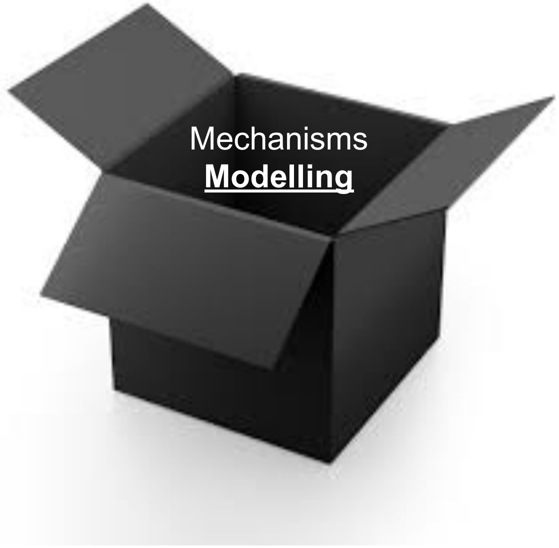
Kinetic modelling

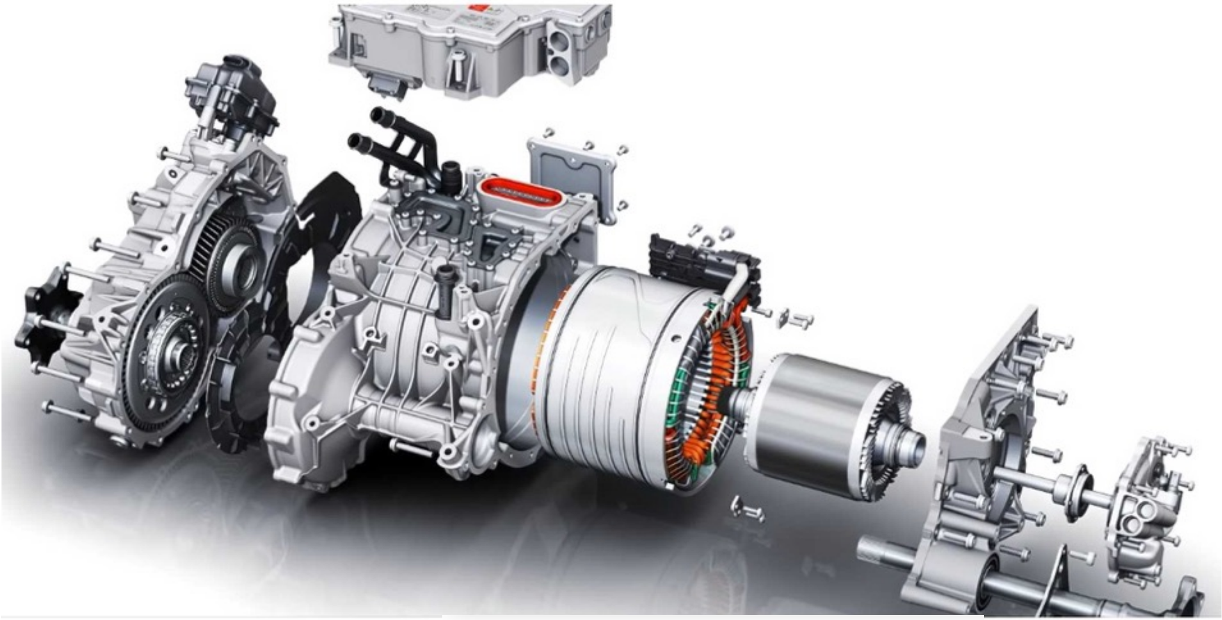
Life time of component



Corrosion rate

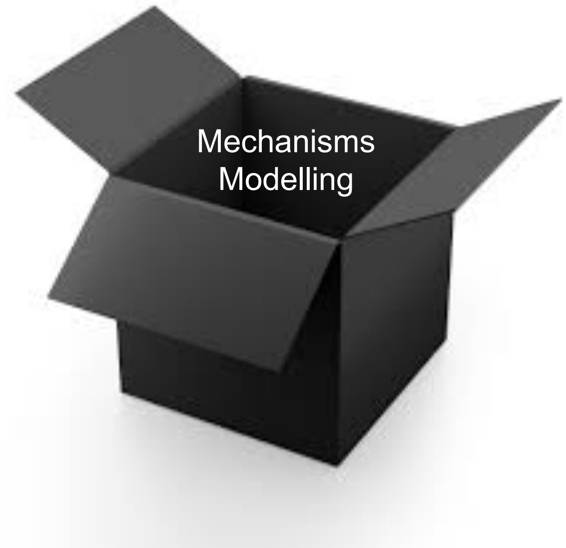
Kinetic modelling *– the engine*

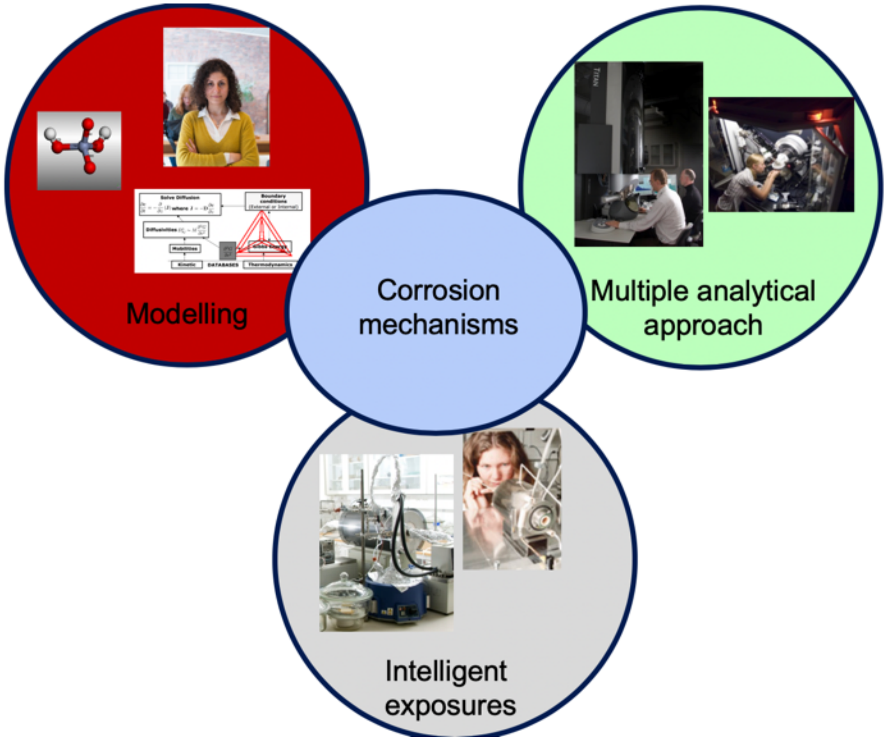




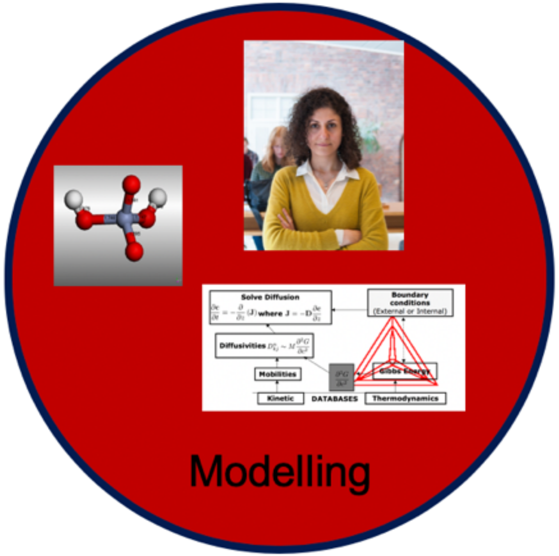
Audi e-tron Electric Motor Explored: Video
insideevs.com

Approach – corrosion prediction based on mechanisms

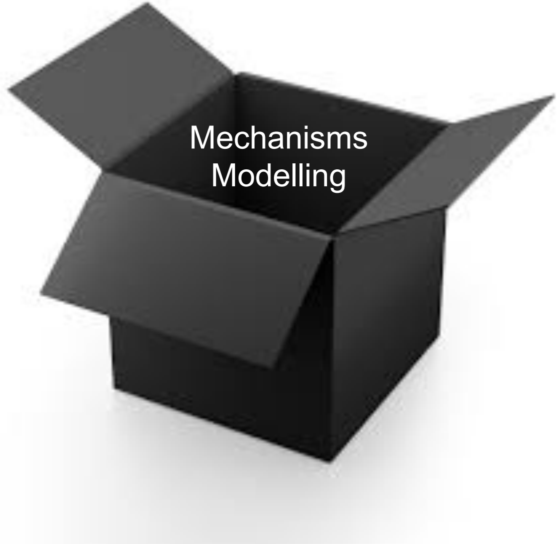




The engine – ***kinetic modelling***



- Thermodynamic ***kinetic*** modelling
- Model alloys – systematic studies of different oxidation modes
- Microscopy – mechanisms AND input to modelling



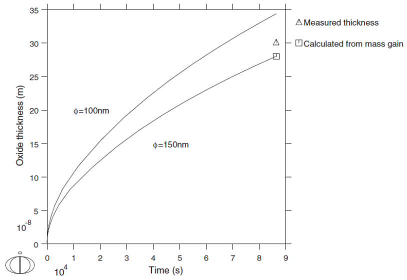
Temperature

Environment

Material

Oxidation mode

Corrosion rate



Life time of component

Primary regime

Primary protection

Protective

Break down

Self healing

Secondary regime

Secondary protection

Protective

Break down

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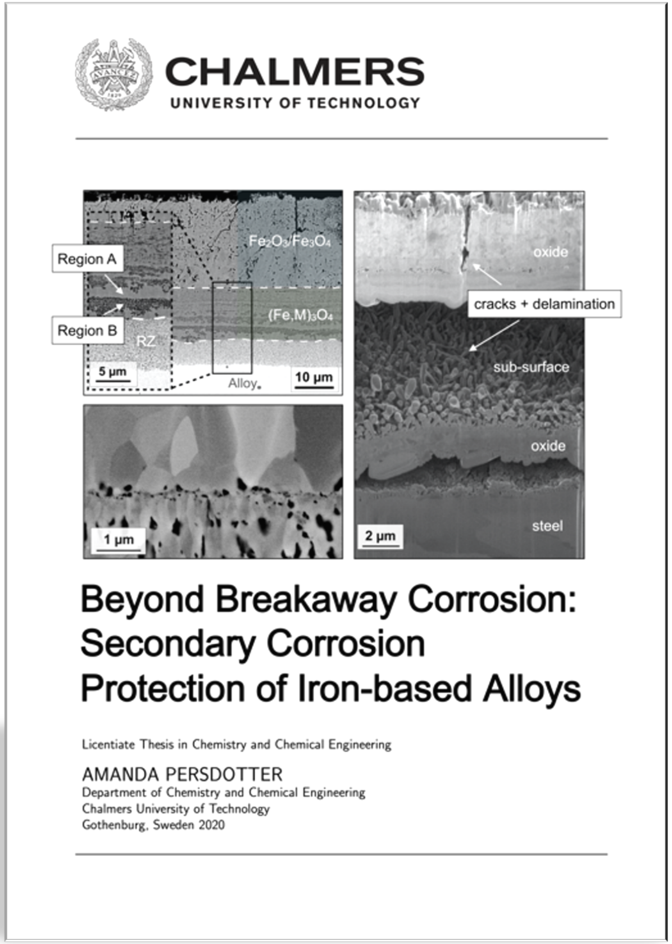
The High Temperature Corrosion Centre



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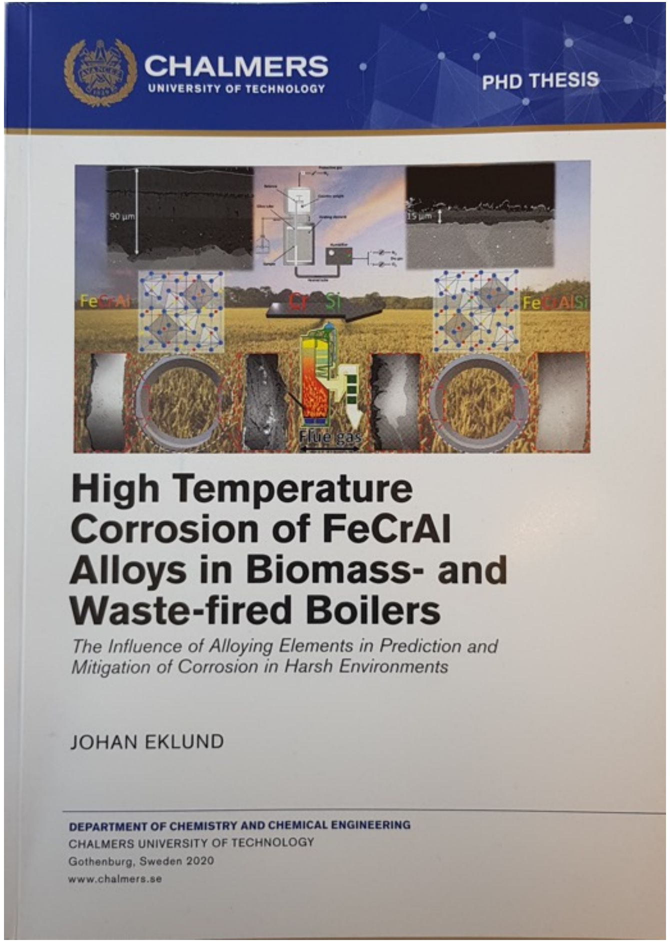
Beyond Breakaway Corrosion: Secondary Corrosion Protection of Iron-based Alloys

Licentiate Thesis in Chemistry and Chemical Engineering

AMANDA PERSDOTTER
Department of Chemistry and Chemical Engineering
Chalmers University of Technology
Gothenburg, Sweden 2020



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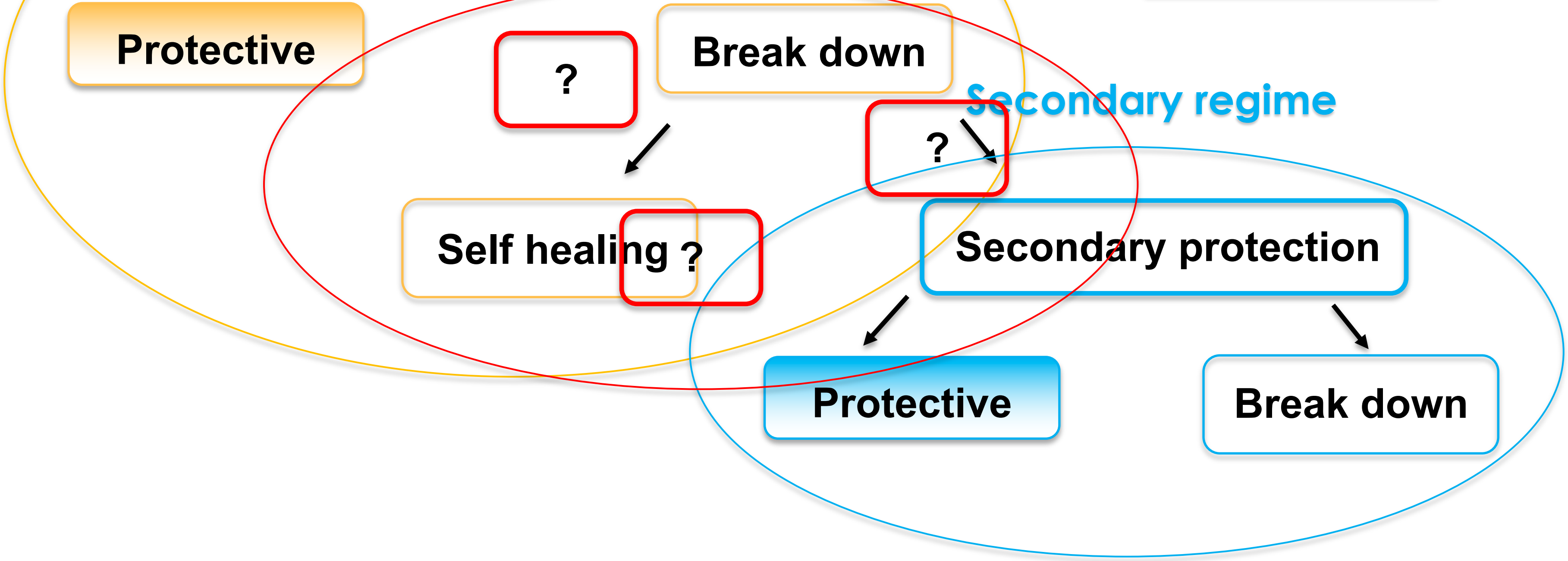
PHD THESIS

High Temperature Corrosion of FeCrAl Alloys in Biomass- and Waste-fired Boilers

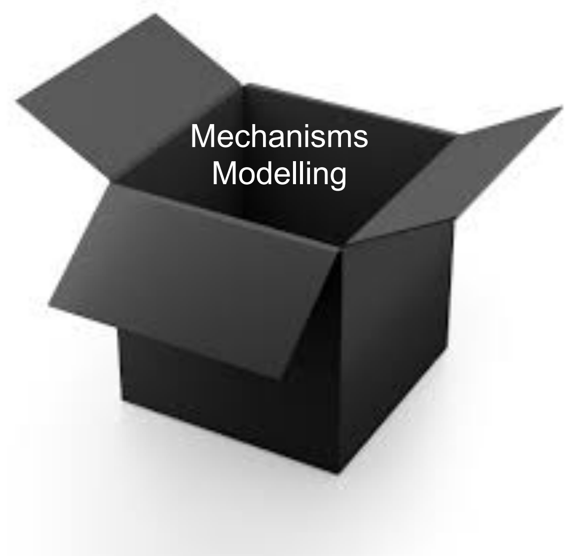
The Influence of Alloying Elements in Prediction and Mitigation of Corrosion in Harsh Environments

JOHAN EKLUND

DEPARTMENT OF CHEMISTRY AND CHEMICAL ENGINEERING
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020
www.chalmers.se


Primary regime
Primary protection
« Tertiary » regime
Protective
?
Break down
Secondary regime
?
Self healing ?
Secondary protection
Protective
Break down


?



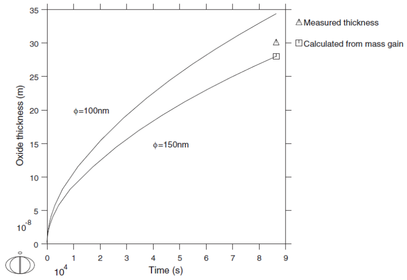
Temperature

Environment

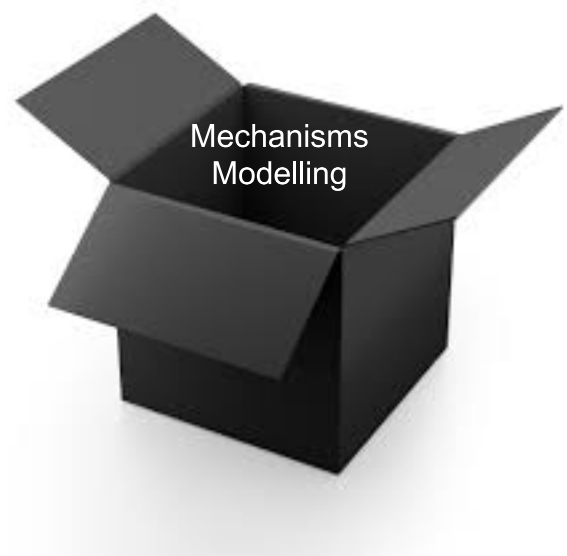
Material

Oxidation mode

Corrosion rate



Life time of component



Temperature

Environment

Material

✓
Primary

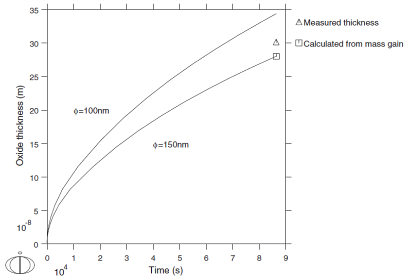
✓?
Secondary

✓?
Tertiary

?

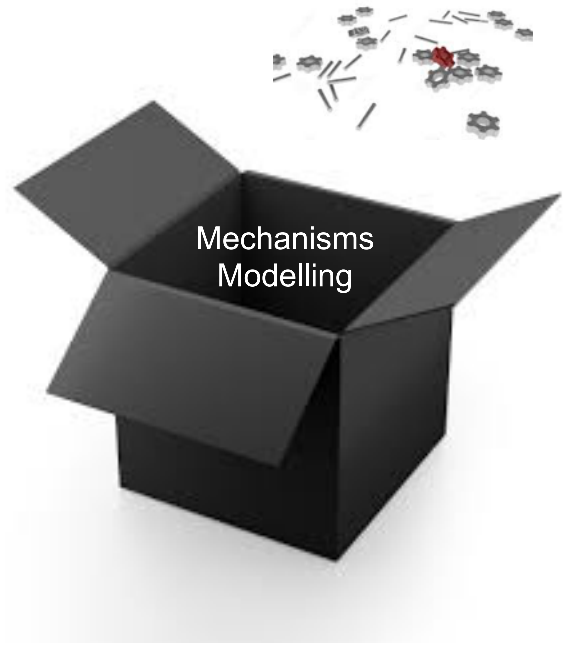
?

Corrosion rate



Life time of component

*Utilizing 3DFIB and TEM in order to investigate the mechanism behind steel grain boundary corrosion attack – **Julien Phother***



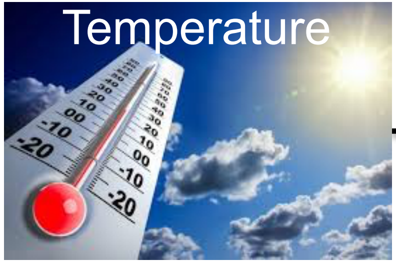
√ Primary

√? Secondary

√? Tertiary

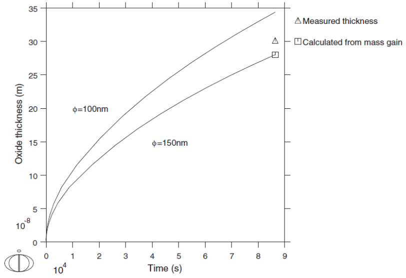
?

?



Generic approach

Life time of component



Corrosion rate

Energy policy targets for Sweden

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Three pillars for Sweden's energy policy

Swedish Energy Agency

*...sion during **combustion** of*

...number of corrosion problems

...es.

*increasing the **predictability** of corr...*

SANDVIK

Sumitomo SHI FW

KANTHAL Part of Sandvik Group

Valmet

The future role of Bioenergy

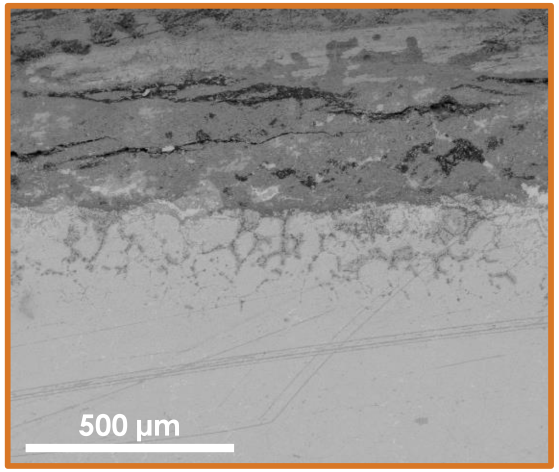
More total Biomass utilization

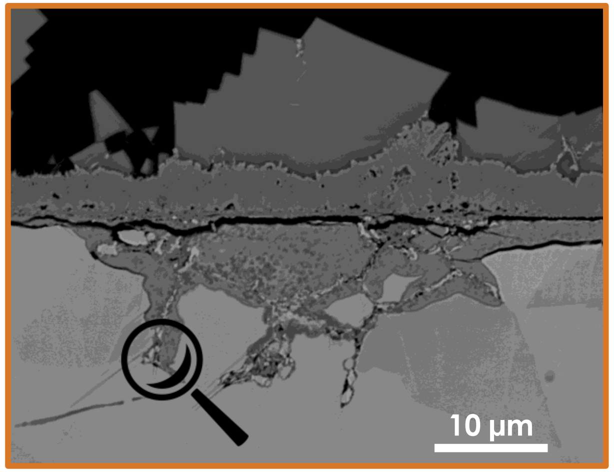
- Base load power
- Local small scale CHP
- Important complement to variable electricity sources

Swedish Energy Agency

Utilizing 3D/FIB and TEM in order to investigate the mechanism behind steel grain boundary corrosion attack

PhD Dissertation – 25th September





3D tomography

Morphology
(Pores, widths, etc etc.)

TEM

Oxides composition
Depletion zones
Chlorine detection

New insights into intergranular corrosion in stainless steels

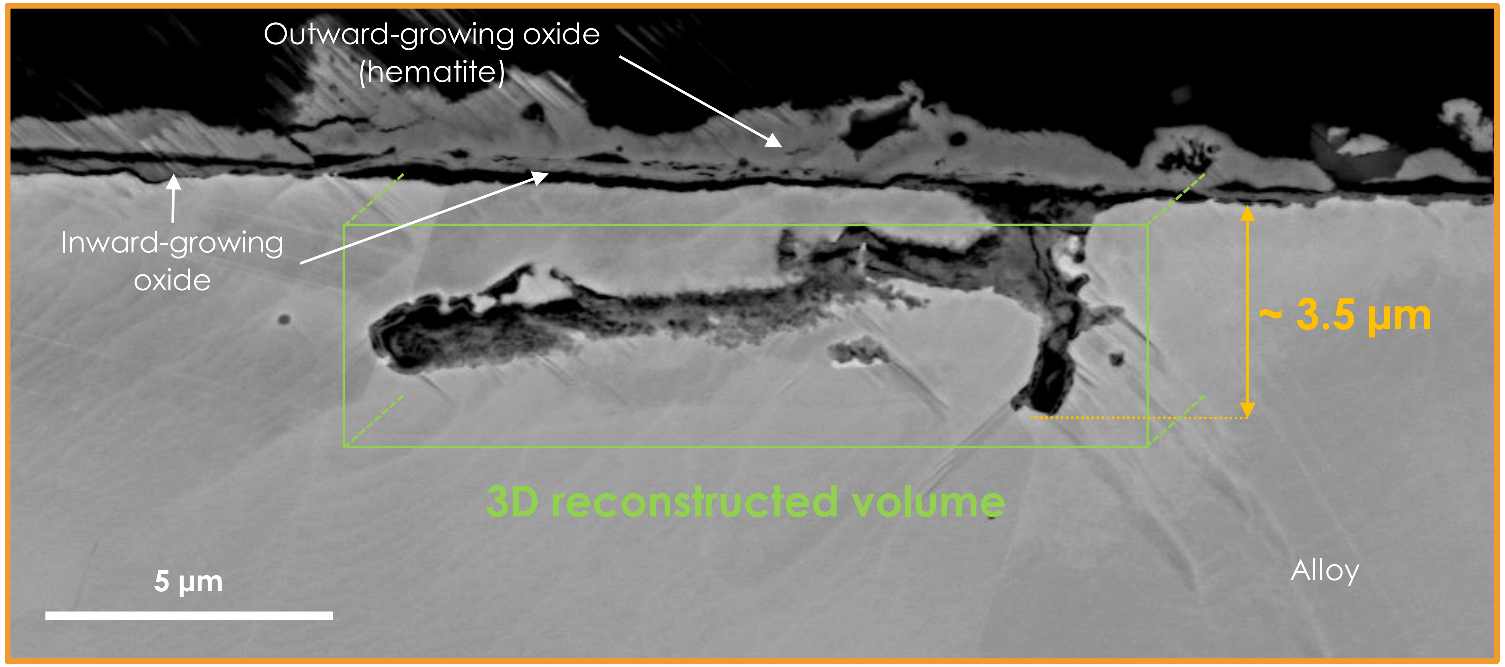
304L

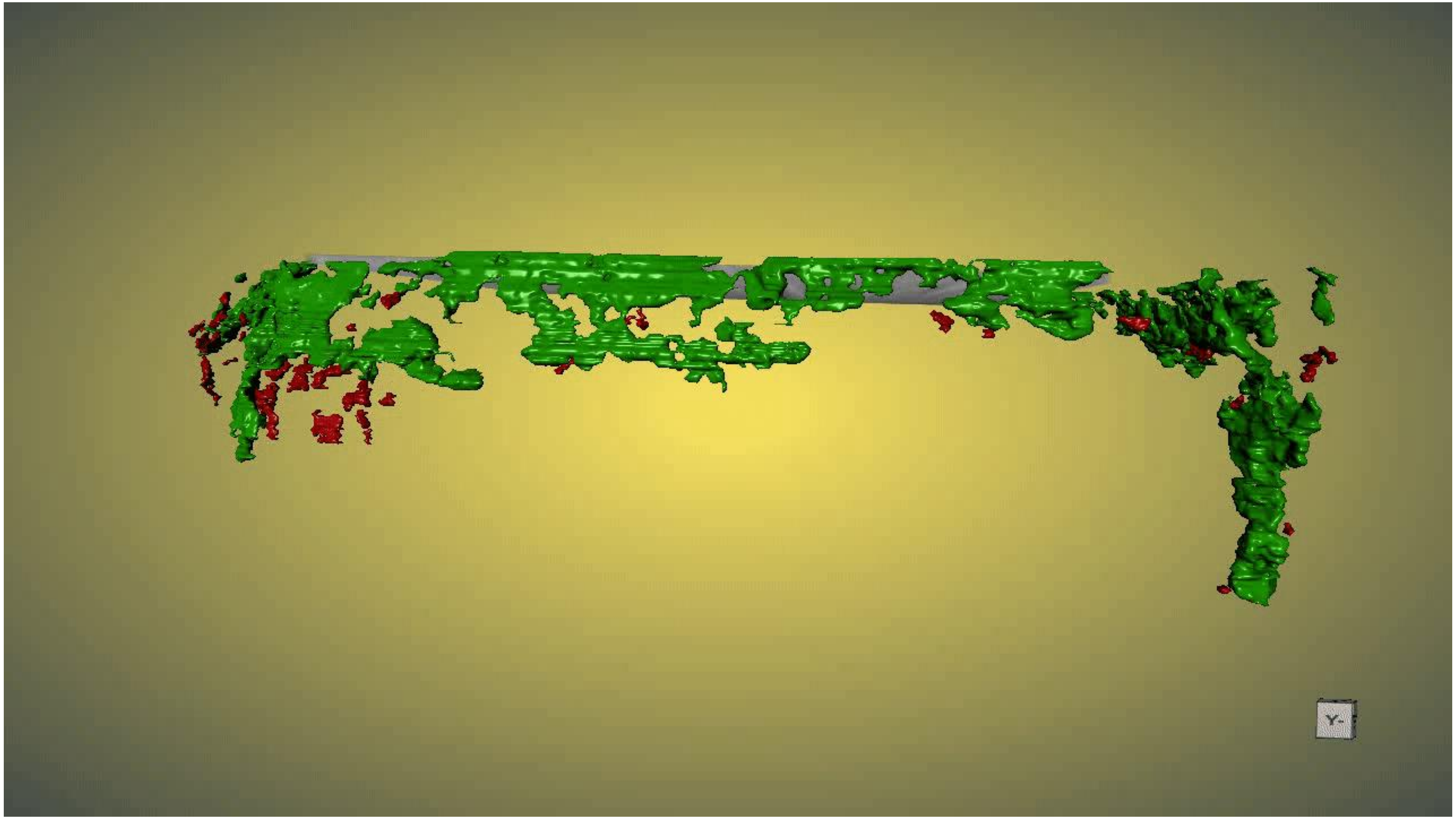
10 wt.% Ni
19.9 wt.% Cr

1 & 24 hours at 600 °C

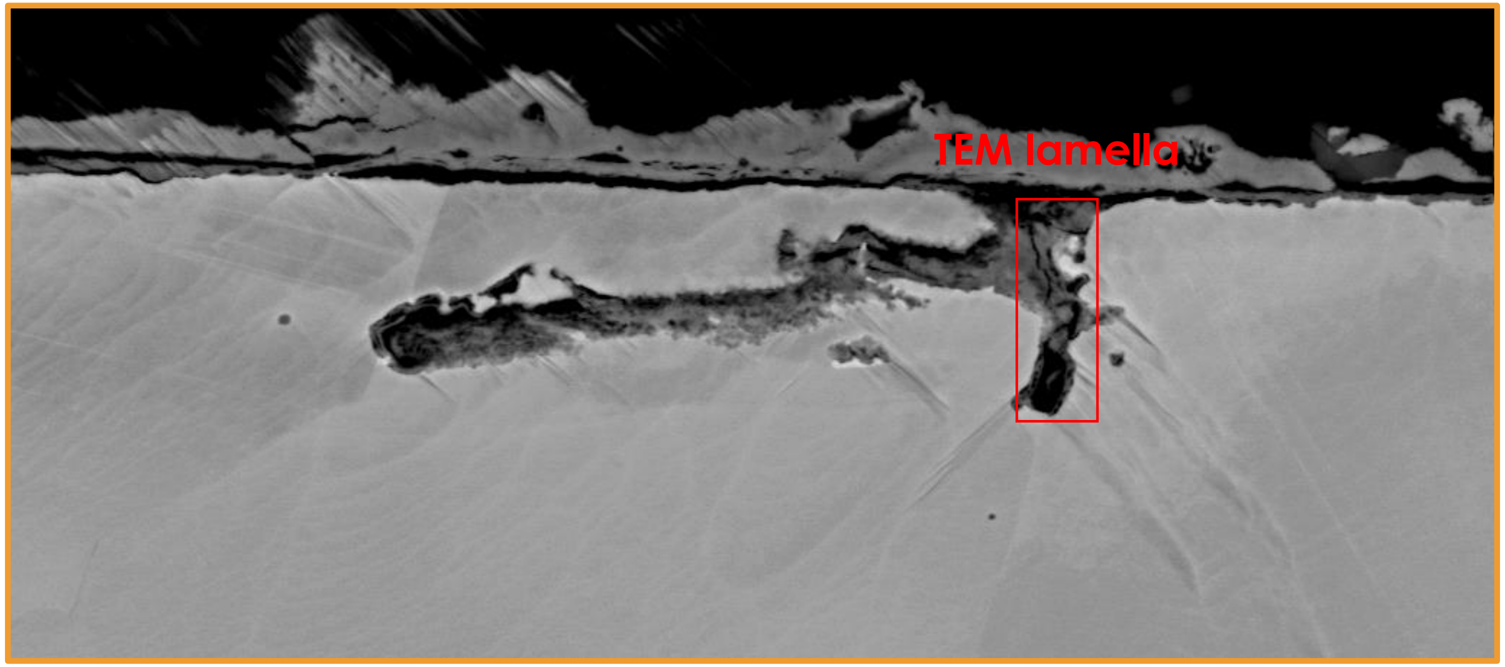
5% O_2 + 20% H_2O + N_2 (bal) + continuous KCl deposition

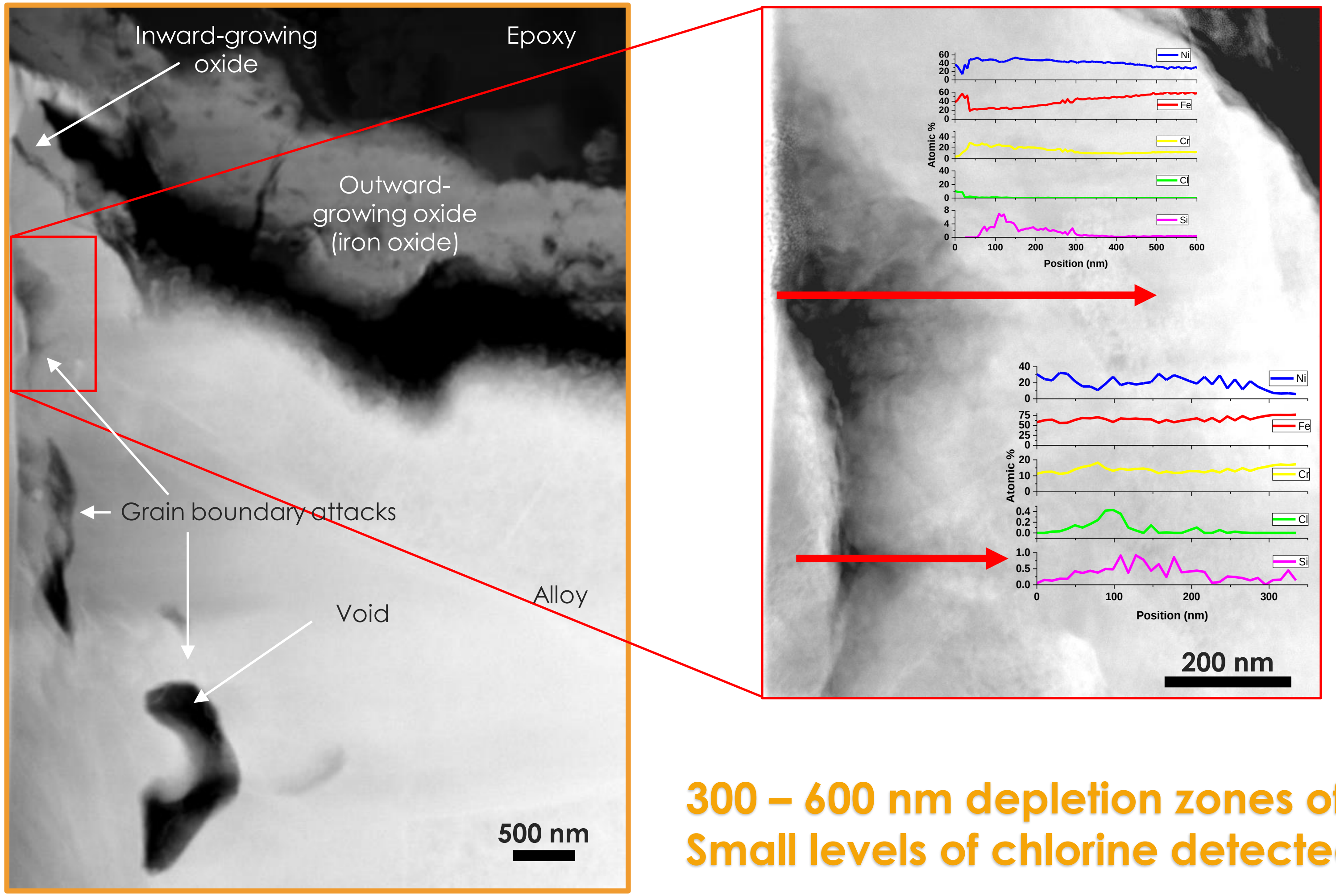
Initiation of a grain boundary attack (1-hour exposure)



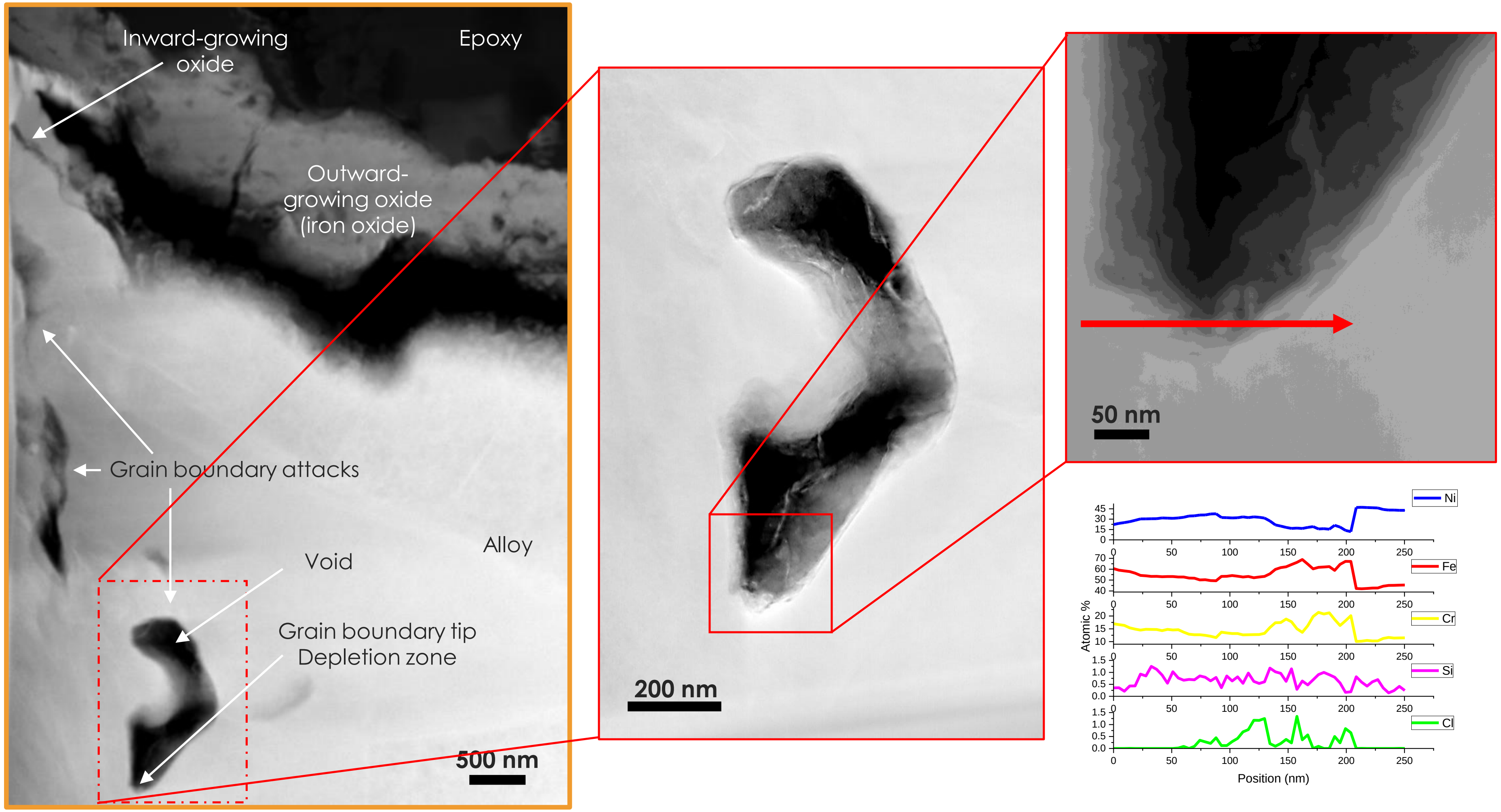

Y-

Initiation of a grain boundary attack (1-hour exposure)





300 – 600 nm depletion zones of Fe and Cr
Small levels of chlorine detected

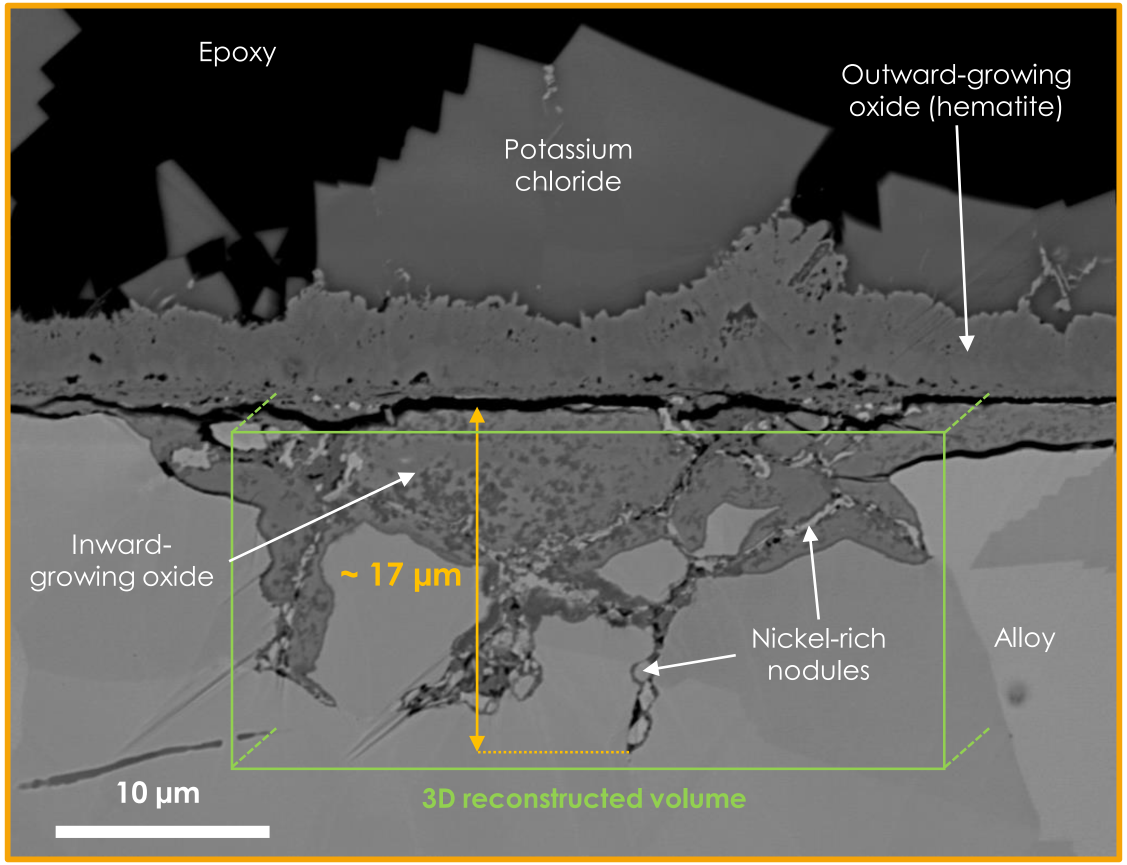

Inward-growing oxide
Epoxy
Outward-growing oxide (iron oxide)
Grain boundary attacks
Void
Alloy
Grain boundary tip Depletion zone
500 nm
200 nm
50 nm
Ni
Fe
Cr
Si
Cl
Atomic %
Position (nm)

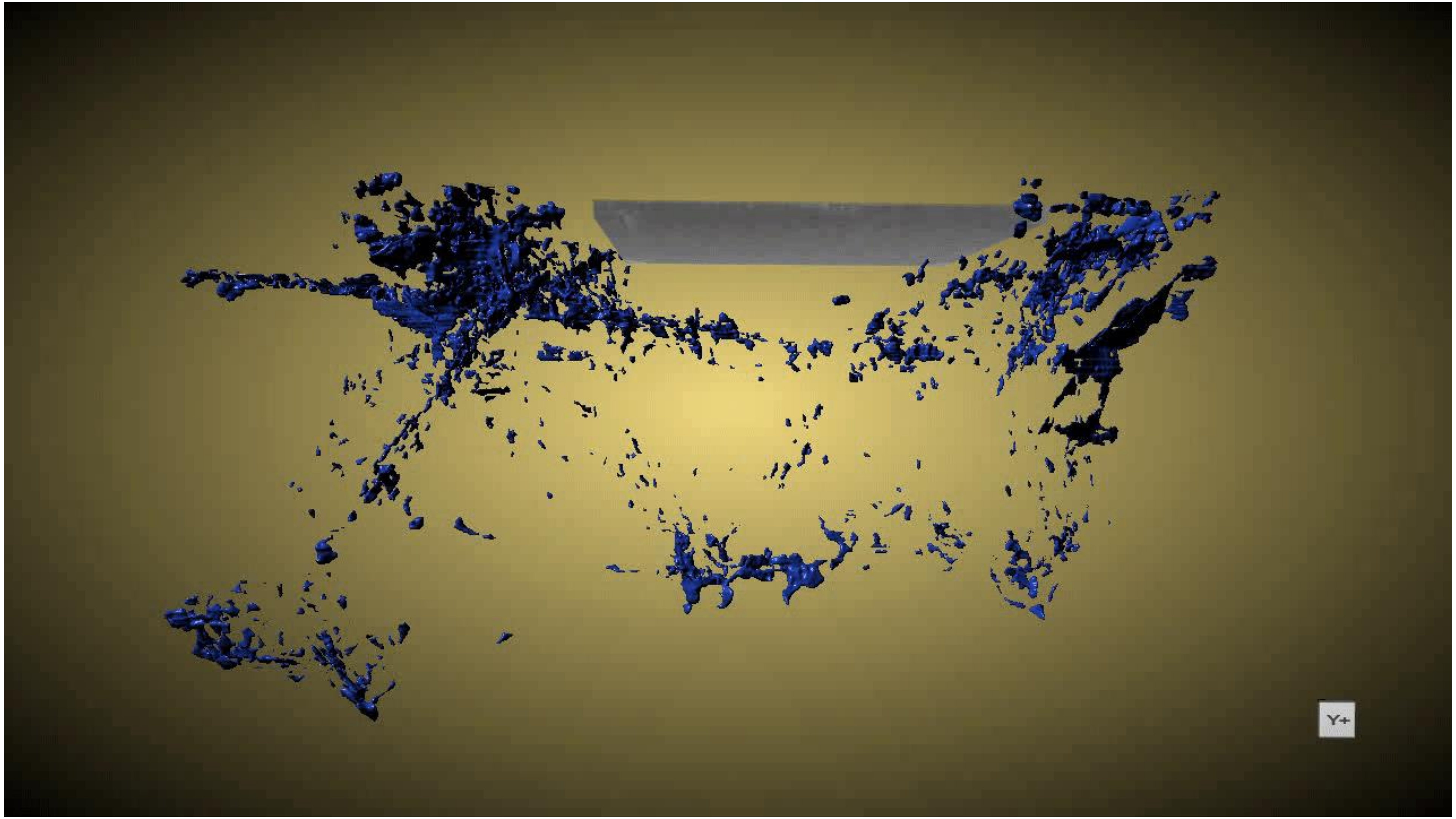
Suggestion of interpretation of results

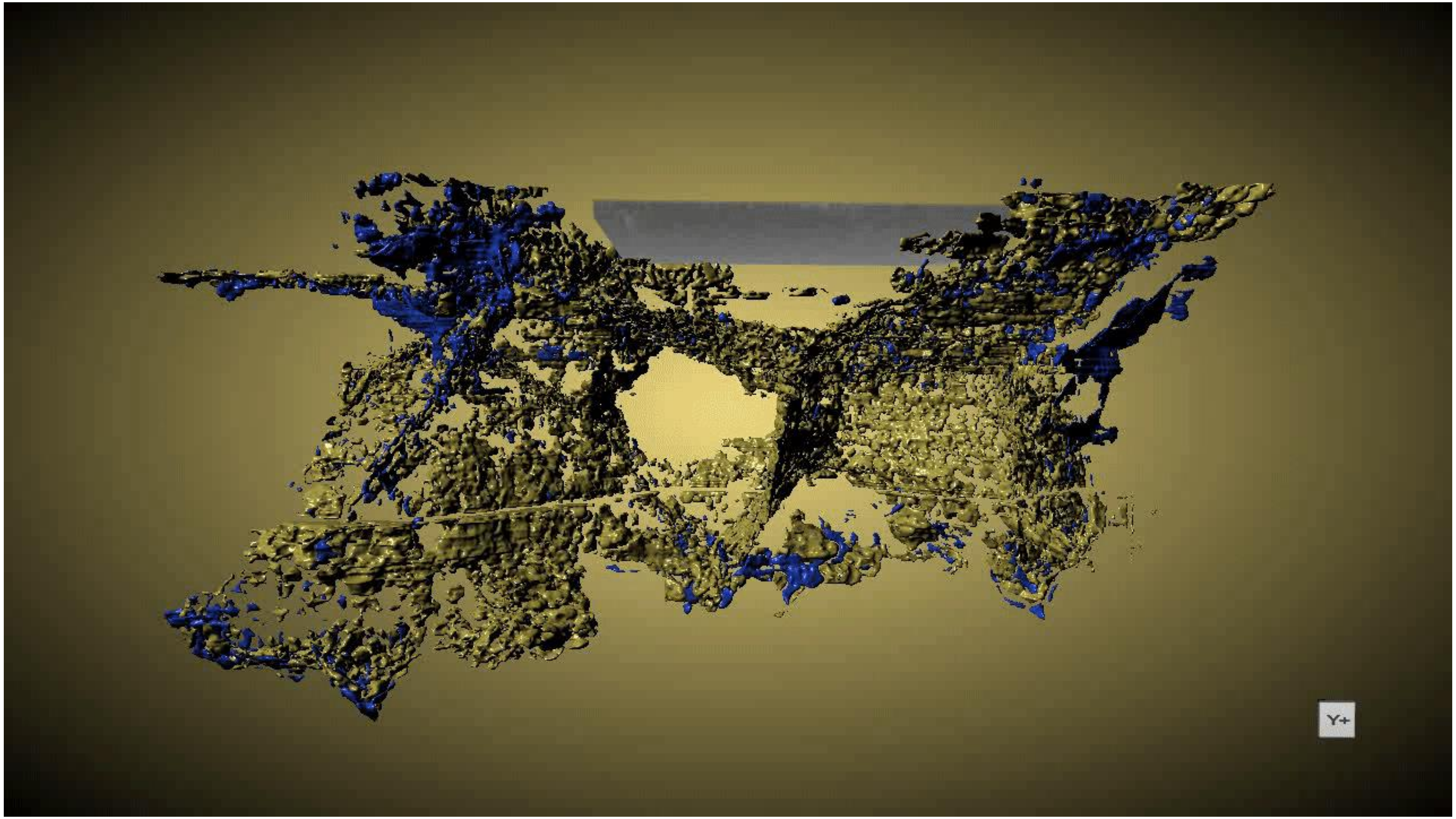
- Connected pores: fast pathways.
- Bulk diffusivity of Cr in 304L at 600 °C predicted to be ~ nm after 1 hour.
- Depletion zones of 100 – 600 nm.
- Small levels of chlorine detected on the surface of voids.

Local enrichment of Cl at the grain boundary regions may increase the diffusivity of alloying elements

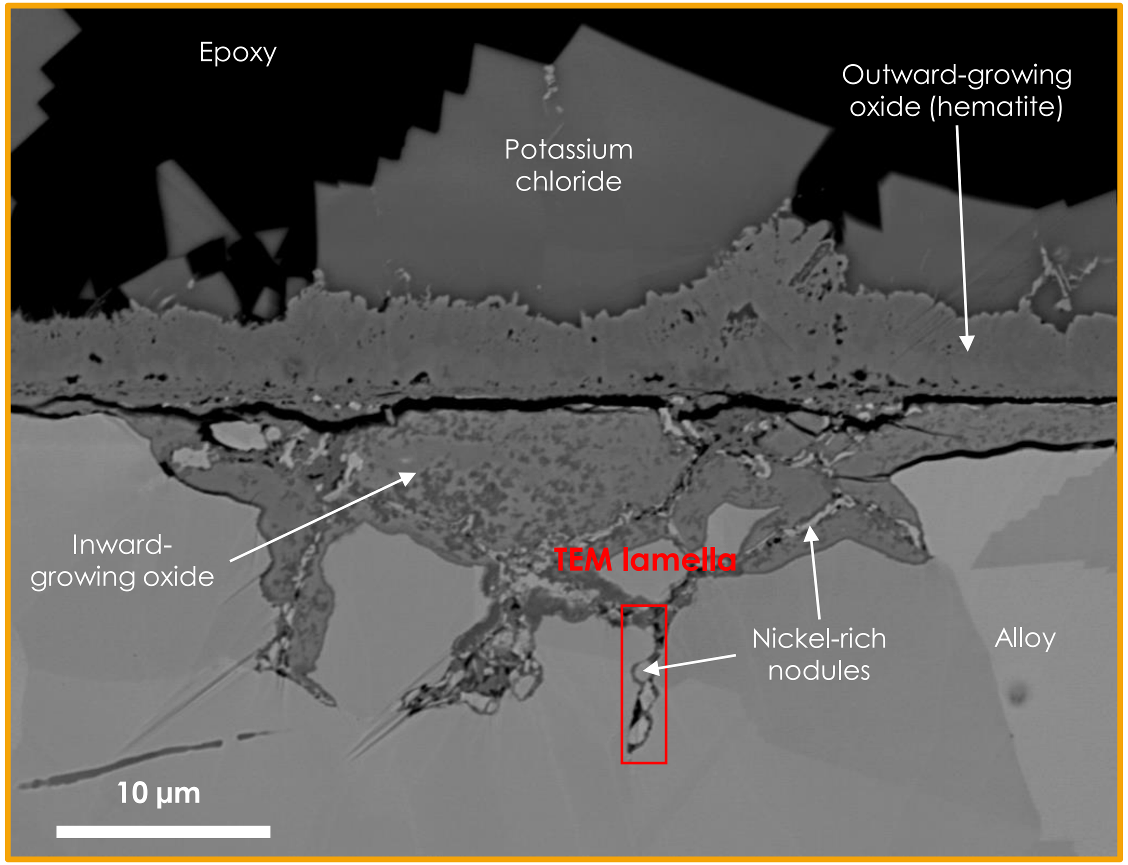
Propagation of a grain boundary attack (24-hour exposure)

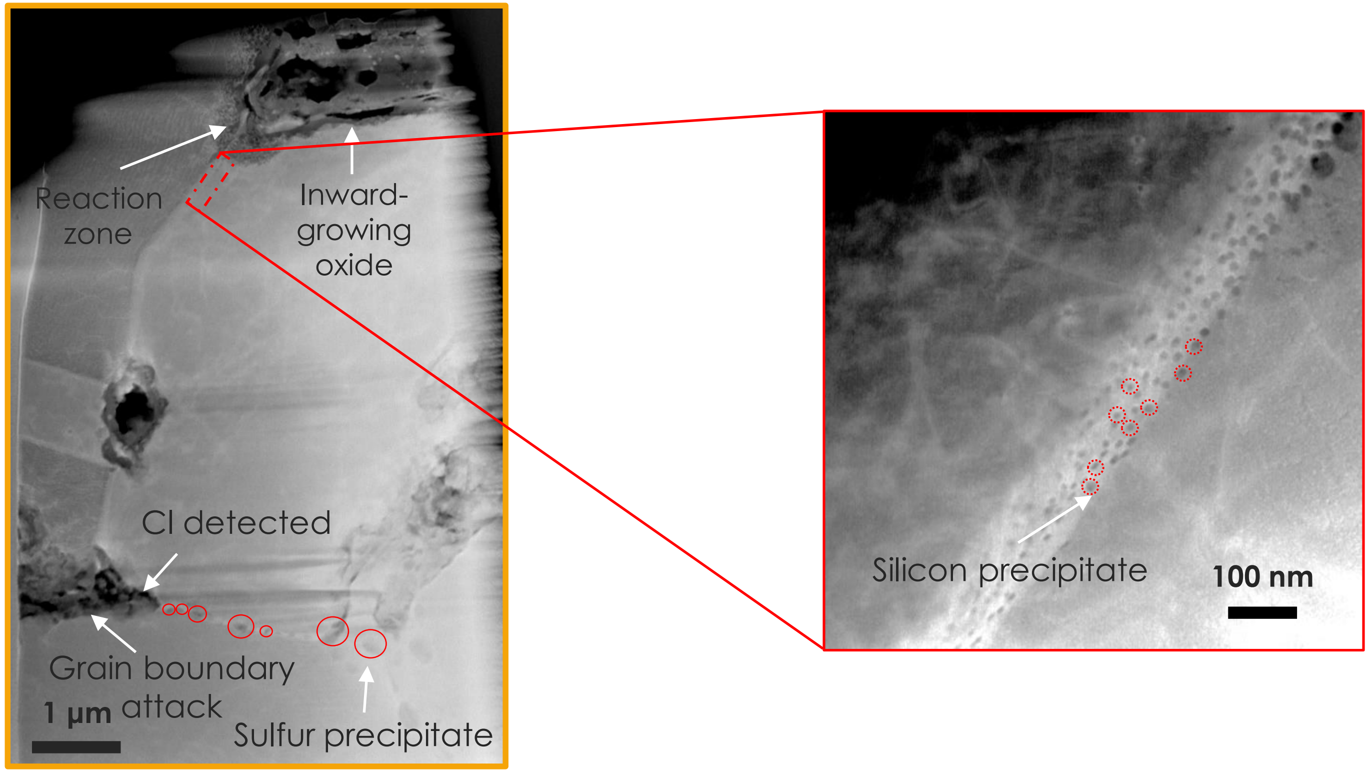



Y+


Y+

Propagation of a grain boundary attack (24-hour exposure)




Reaction zone
Inward-growing oxide
Cl detected
Grain boundary attack
1 μm
Sulfur precipitate
Silicon precipitate
100 nm

Suggestion of interpretation of results

- Unconnected pores: similar fast pathways as 1-hour exposure not possible.
- Large amount of interfaces at the grain boundaries.
- Lingering presence of chlorine at the grain boundaries.
- Trace elements segregation might increase the diffusivity at the grain boundaries.

Increased diffusivity of alloying elements

AVANCEZ

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