

Oxidation assisted crack growth in gas turbine materials

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OXIDATION ASSISTED CRACK GROWTH IN GAS TURBINE MATERIALS

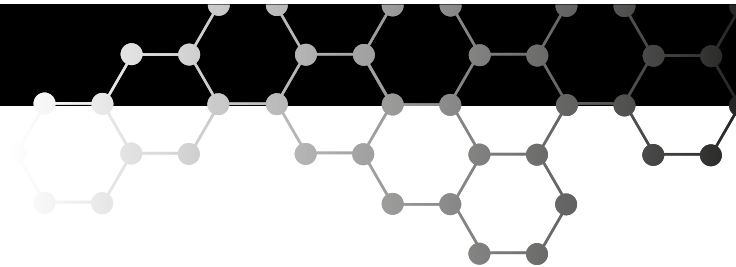
Project manager: Krystyna Stiller (Chalmers, Physics)

Participating company: GKN Aerospace Sweden AB

Ph.D. student: Anand H. S. Iyer (Chalmers, Physics)

Project group:
Krystyna Stiller (Chalmers , Physics)
Magnus Colliander (Chalmers, Physics)
Thomas Hansson (GKN)
Tomas Månsson (GKN)

Cooperation:
Prof. Ulrich Krupp, Osnabrück University (*affiliated professor Chalmers*)
Prof. Magnus Ekh, Applied Mechanics, Chalmers



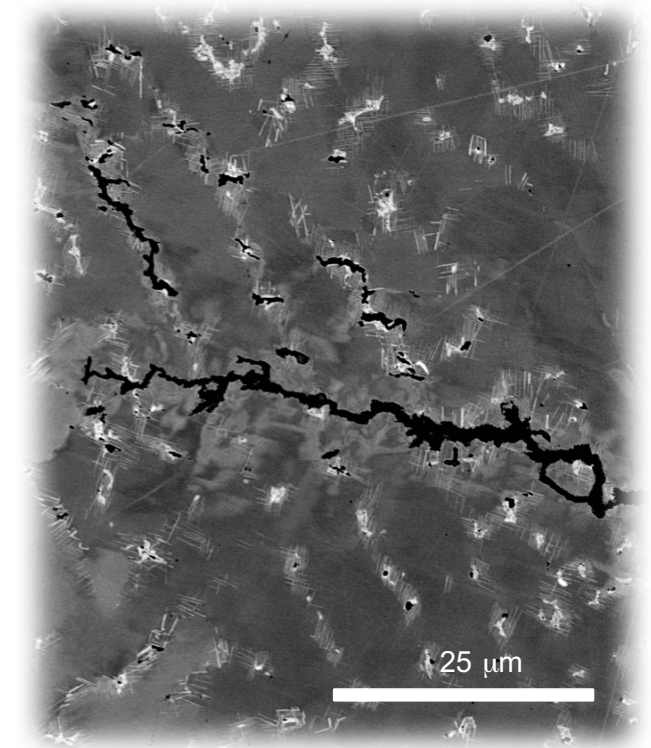
SUMMARY

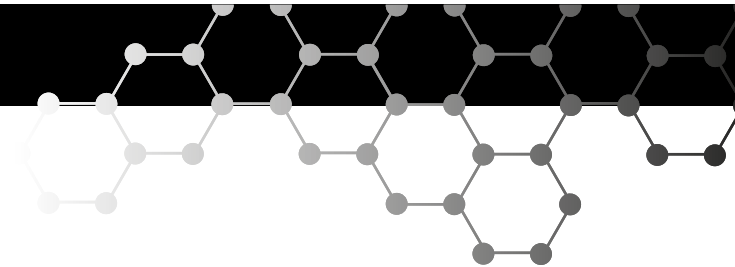
Aims of the project

- To increase the understanding of the crack tip oxidation under combined mechanical loading and high-temperature oxidation.
- To develop micro-mechanical testing methods to allow in-situ testing of grain boundaries with and without oxides inside the microscope.
- To develop predictive methods, based on the micromechanical testing, to assess the effect of oxidation on the local fracture resistance of the material.
- To link experiments and modeling on multiple scales.

Long term goal

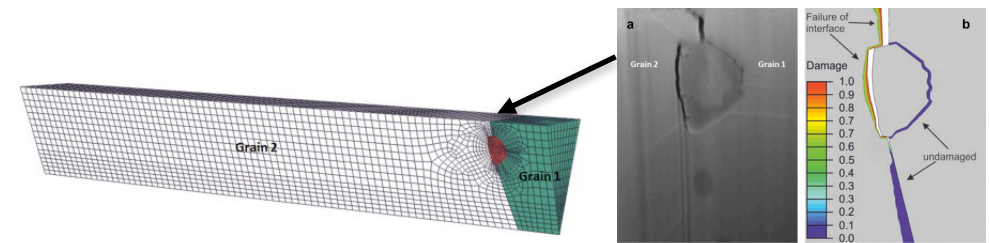
To facilitate the development of new materials, processes or computational methods to handle oxidation assisted crack growth in Ni-based high-temperature materials





STATUS

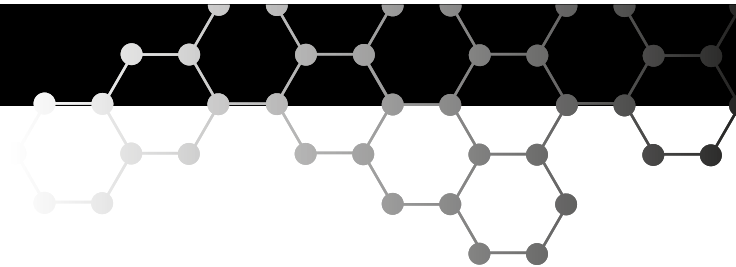
- PhD student recruited (Anand), started June 2015
- Main work so far:
 - Studies of cracking in welded superalloy
 - **Method development for microscopy**
 - Started development of crystal plasticity FE model (together with AM)
- Order has been placed for in-situ micro-mechanical testing equipment, delivery in ~1 month



H. Dudgale et al. Acta Mater. 61 (2013) 4707-4713.



Kleindiek Nanotechnik



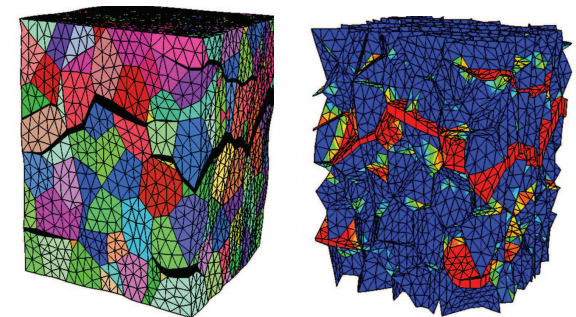
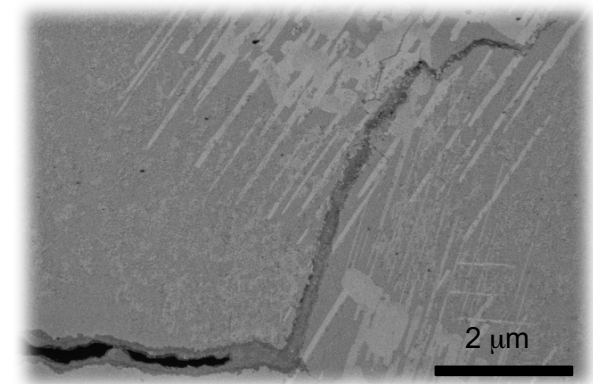
OUTLOOK

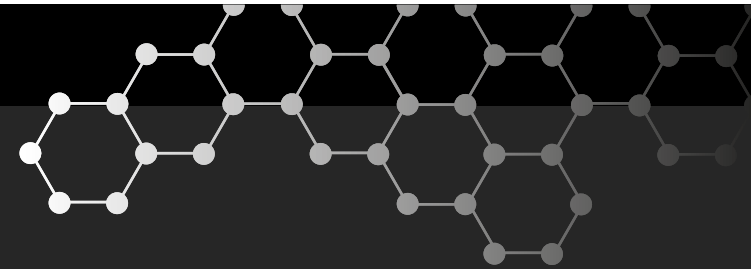
Next steps

- Continued characterization of cracks and oxides
- Method development for in-situ micro-mechanical testing
- **RESULTS!**

In the future?

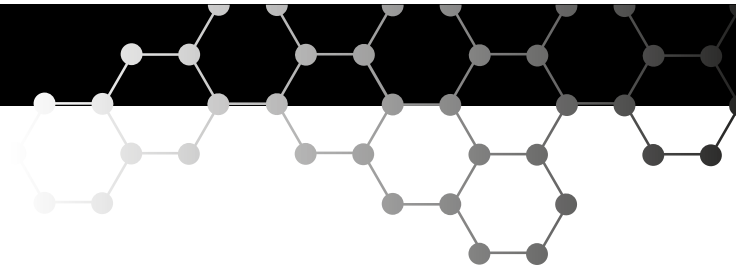
- Initial discussions with Oxford University on the possibility to do micro-beam bending at elevated temperatures (up to 700 °C in air, 800 °C in vacuum)
- Discussion with Prof. Krupp on the possibility to test diffusion-bonded bi-crystals in air and vacuum in order to have well-defined grain boundaries and test conditions





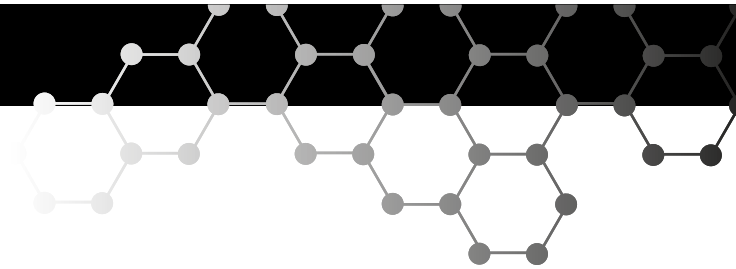
OUTLINE

- ⚙ **Motivation.**
- ⚙ **Method development.**
- ⚙ **Results.**



Motivation

- ⚙ **EBSD – Electron Backscatter Diffraction.**
 - ⚙ **XEDS – X-ray Energy Dispersive Spectroscopy.**
 - ⚙ **SEM and FIB (Focused Ion Beam microscopy).**
 - ⚙ **No surface modification between experiments.**
 - ⚙ **Damage free surface with excellent finish required.**
- } on the same surface



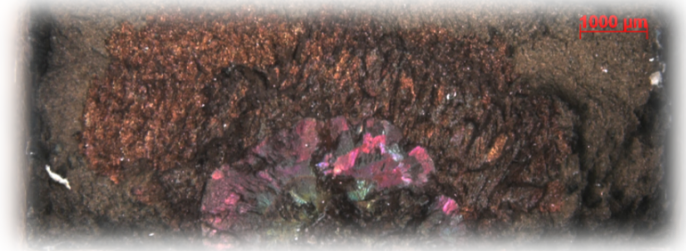
Outcome

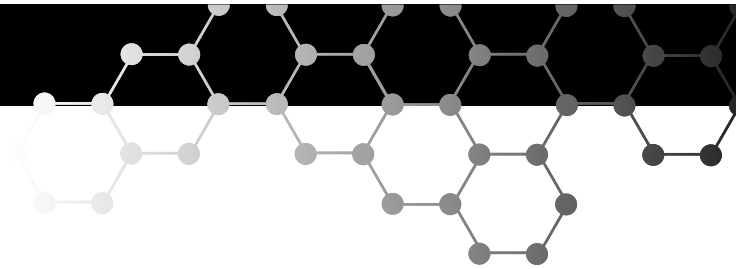
- ⚙ **Optimized grinding and polishing technique.**
- ⚙ **High quality surface.**
- ⚙ **Multiple analyses can be carried out.**
- ⚙ **Currently being used to characterize crack growth in welded IN718.**



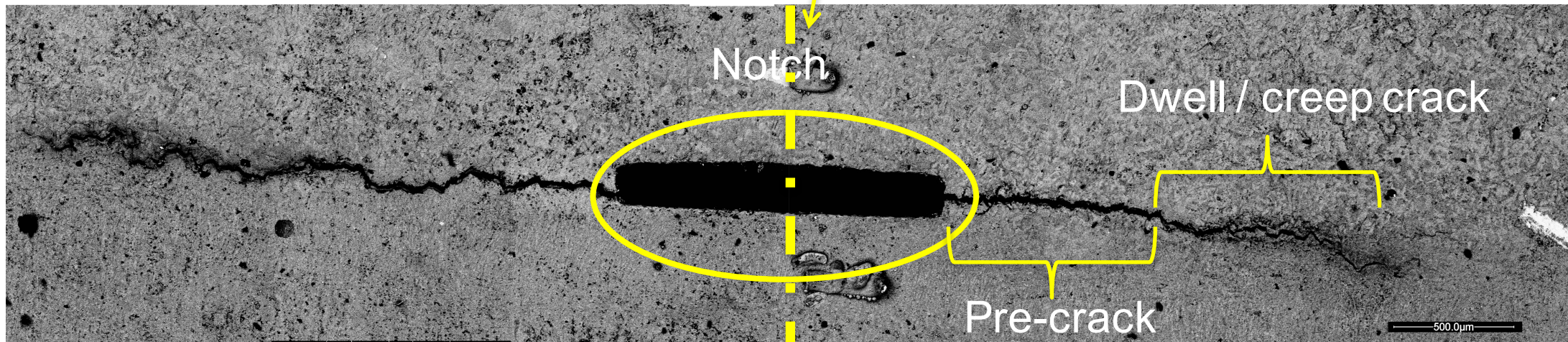
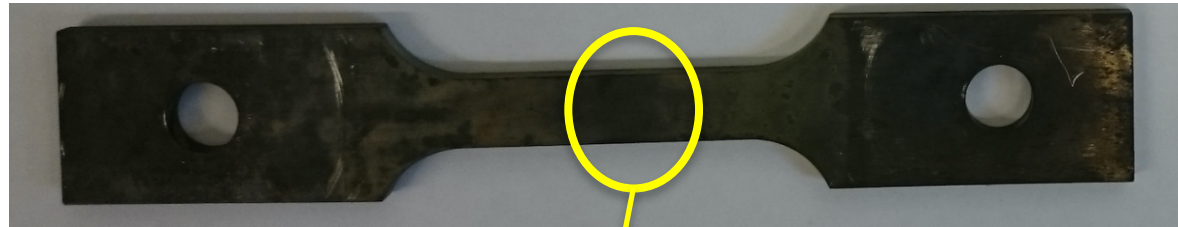
Fatigue crack growth in IN718 welds

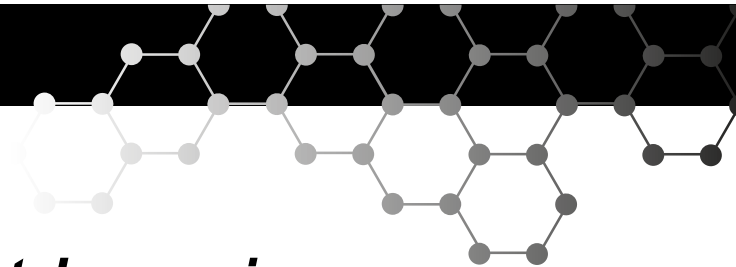
- ⚙ **Welded joints – complex microstructure.**
- ⚙ **Tensile samples of IN718 with weld at centre.**
- ⚙ **Notch at weld or HAZ for crack initiation.**
- ⚙ **Testing in two steps-**
 - ⚙ Fatigue pre-cracking at room temperature.
 - ⚙ Dwell fatigue or creep crack growth at 550 and 650°C in air.
- ⚙ **Testing stopped before complete rupture.**





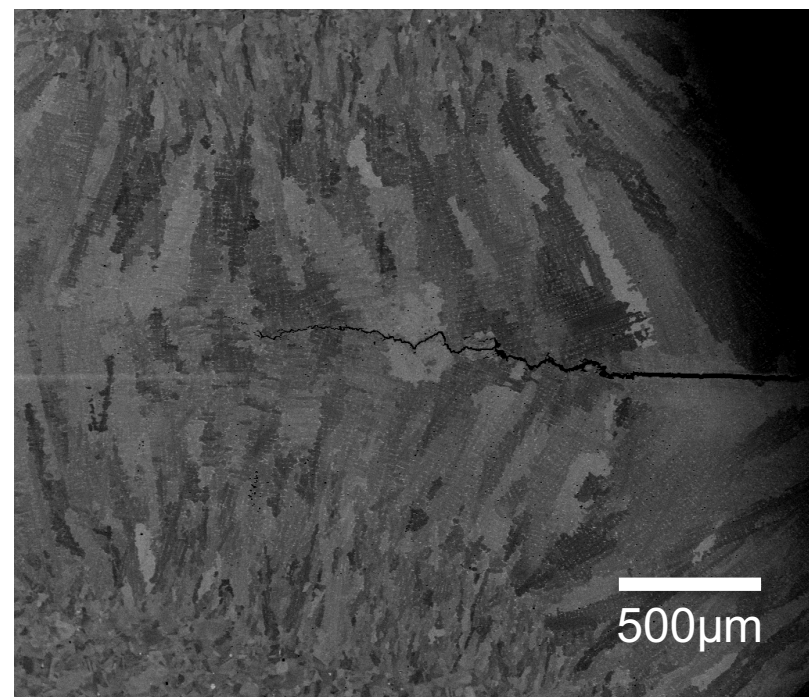
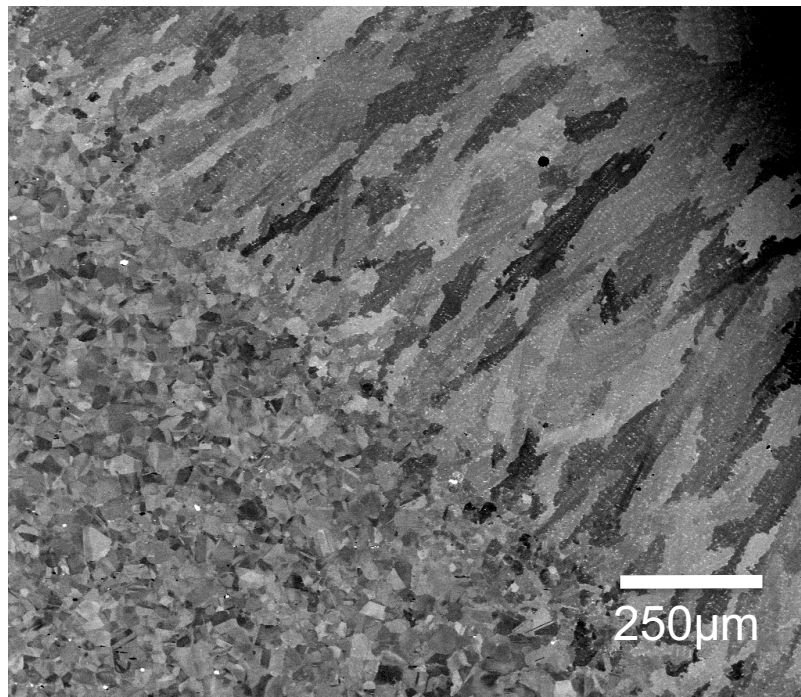
Tensile
sample





Results

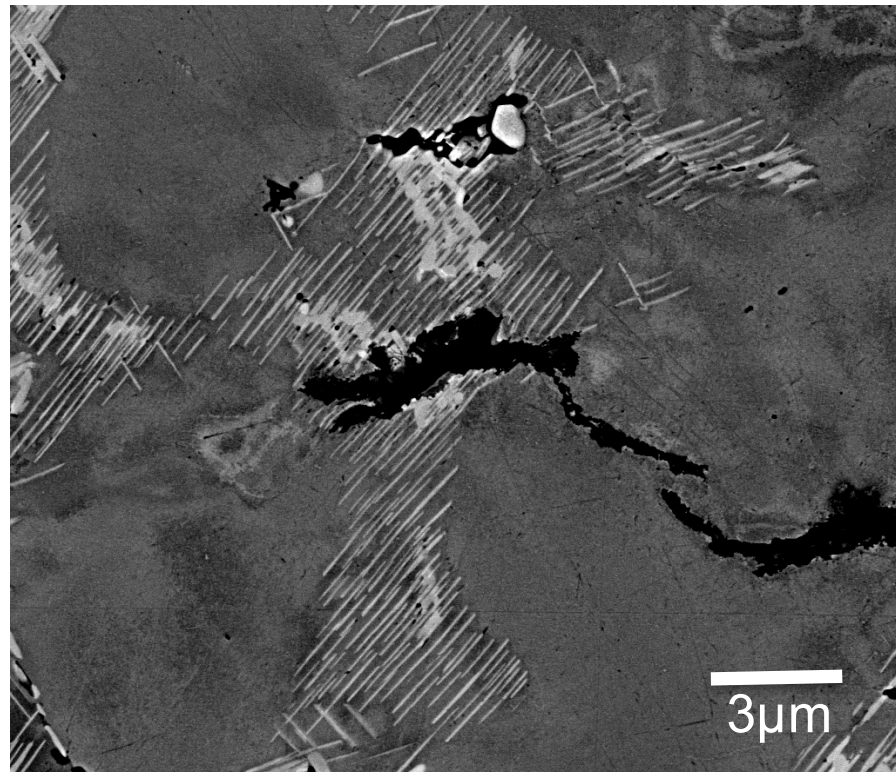
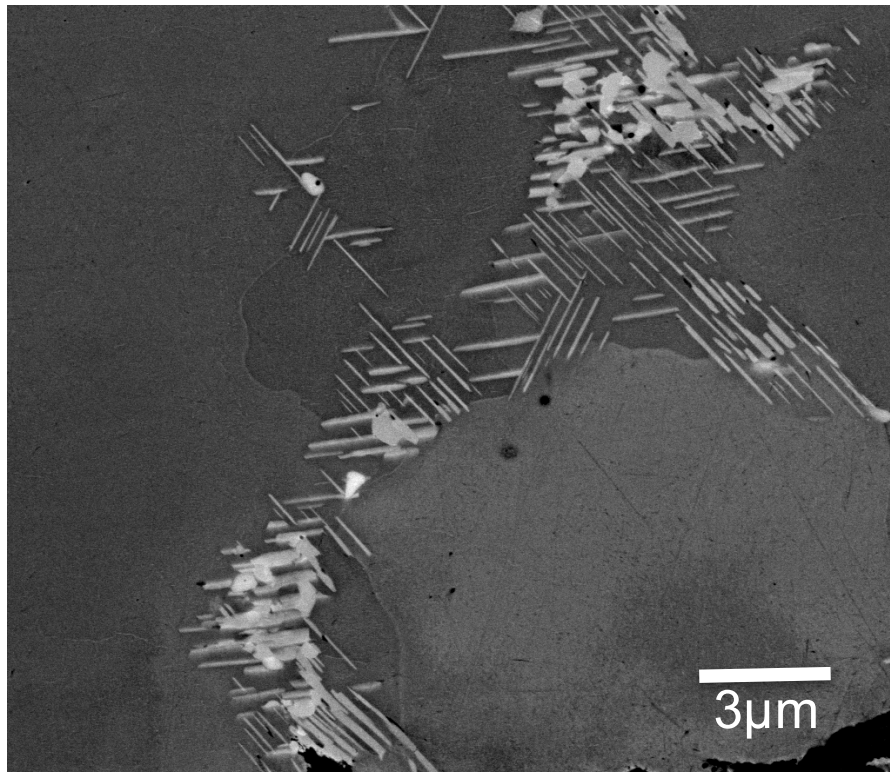
Electron Channeling Contrast Imaging

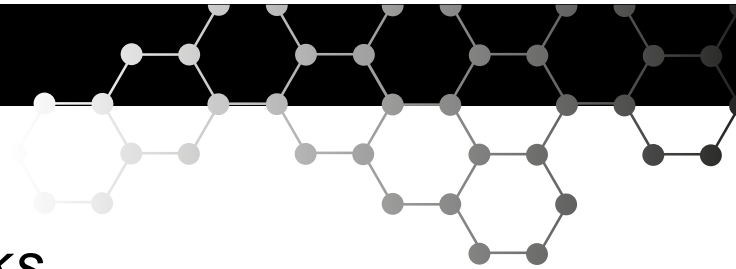




Secondary phases – δ , Laves phases and MC.

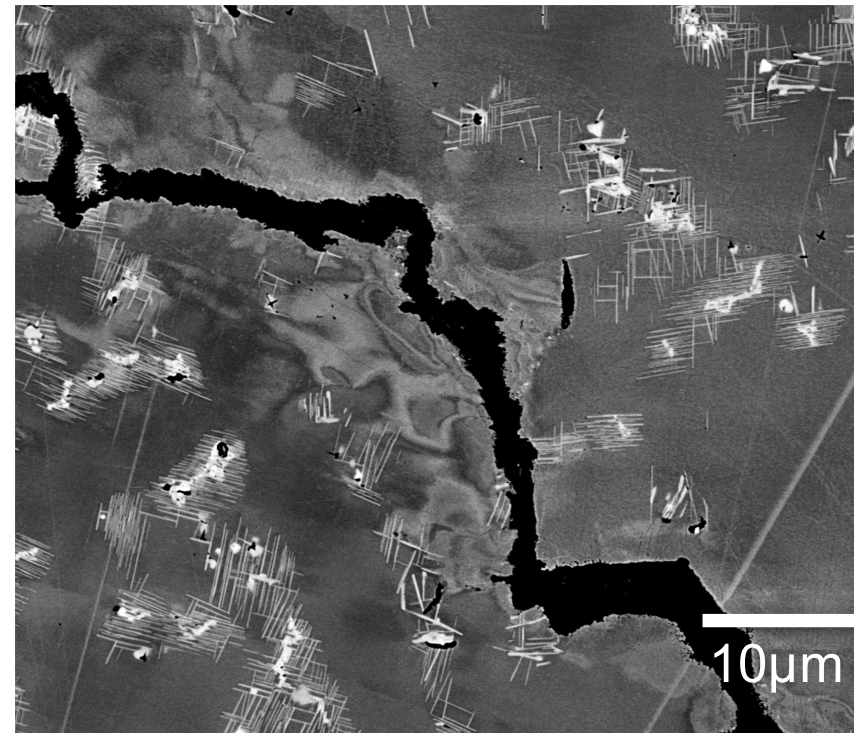
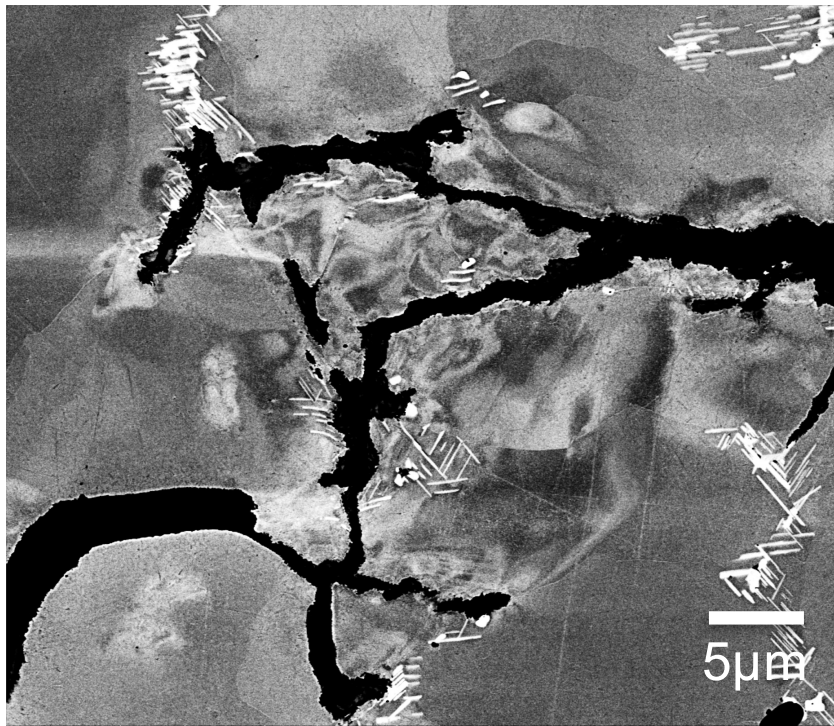
To study crack interaction with microstructure





Deformation contrast

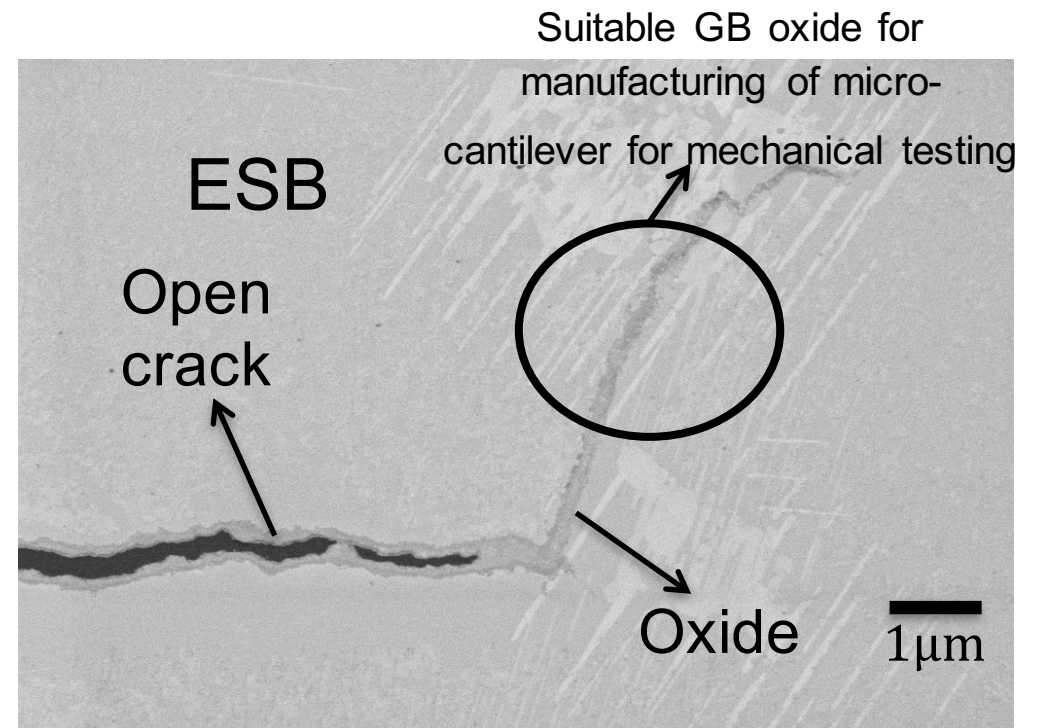
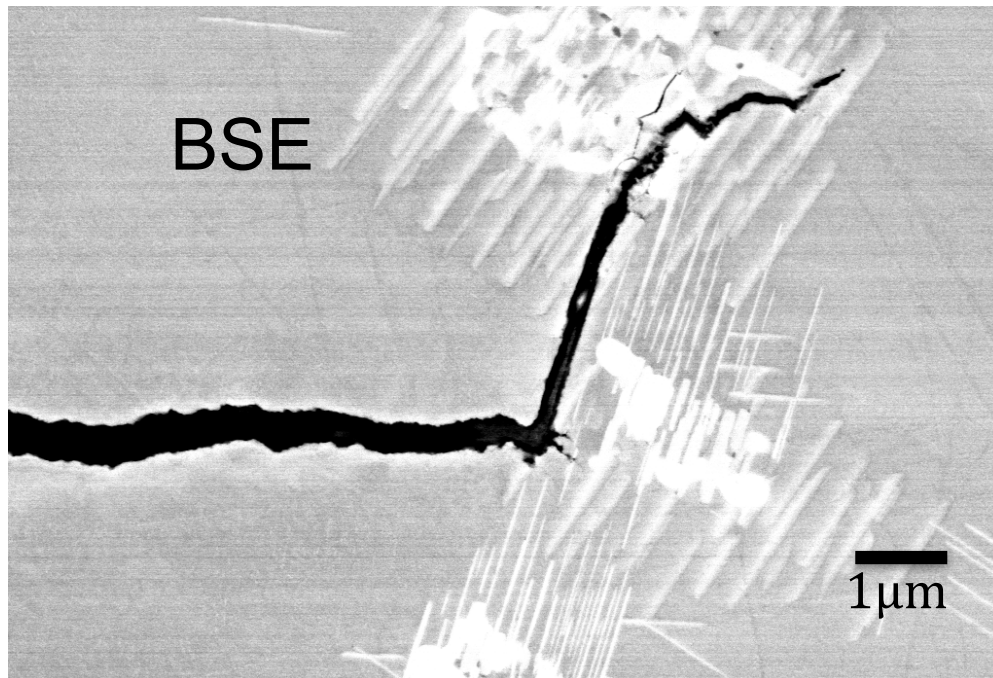
To detect plasticity around cracks

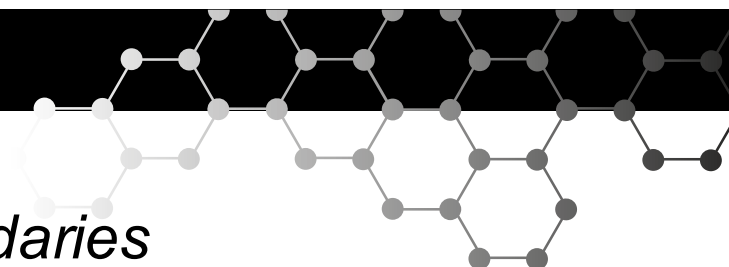




Energy Selective Backscatter (ESB) Imaging

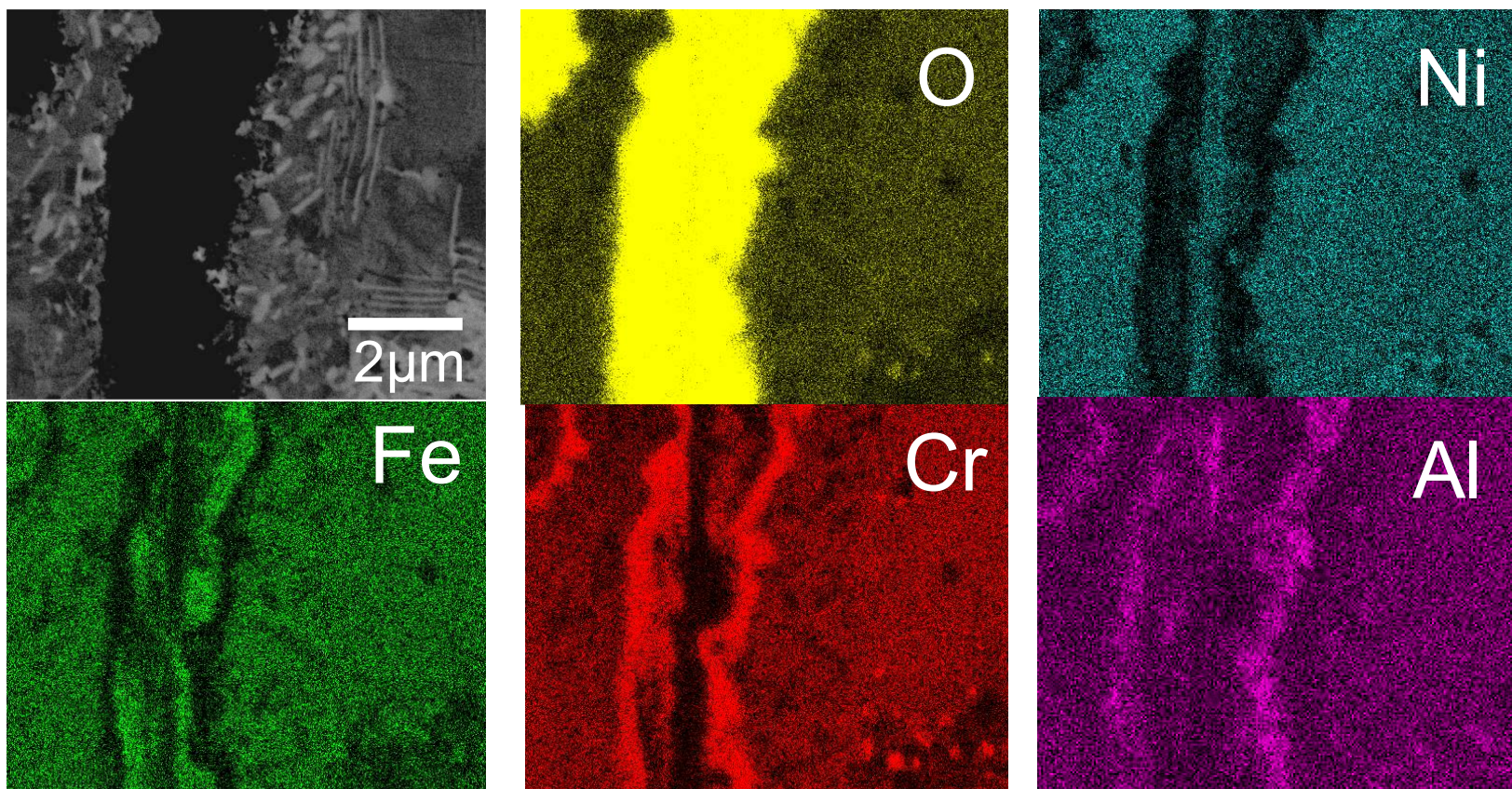
To detect oxidation ahead of crack tip

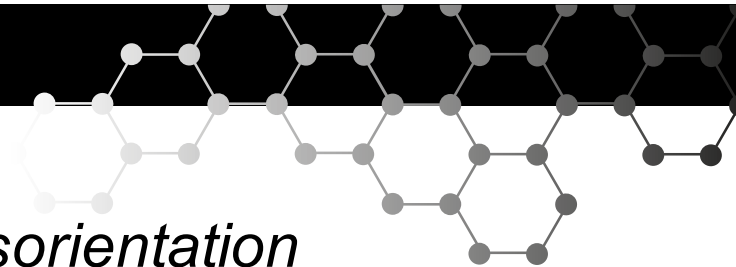




EDS

Oxide formation in cracks/grain boundaries





EBSD

Relation between crack growth and misorientation

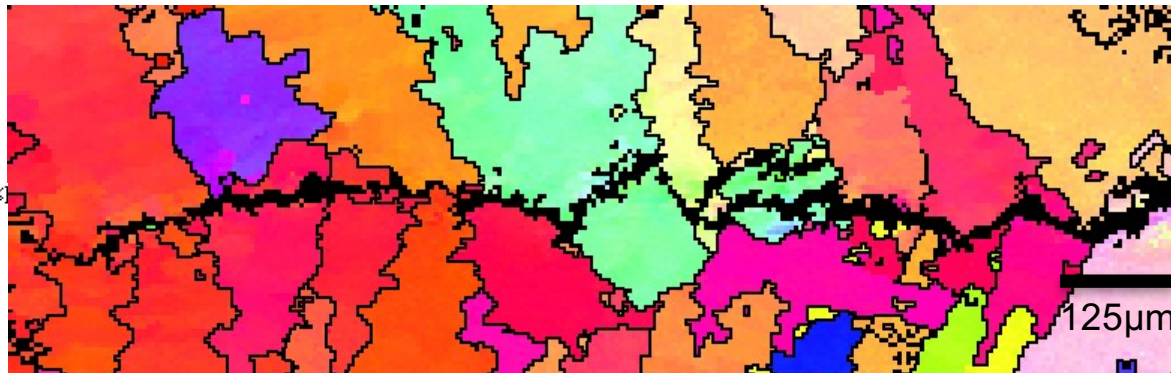
IPF colouring
Y0

Ni-superalloy [87.4%]

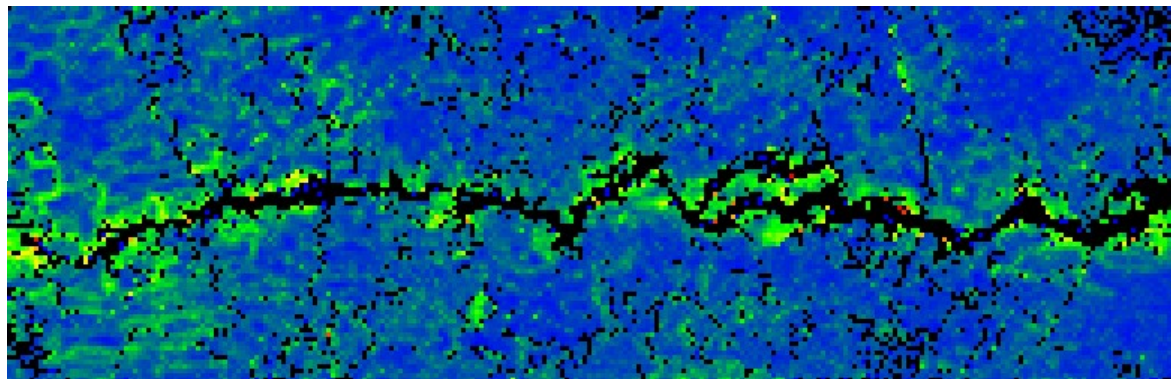
111

001

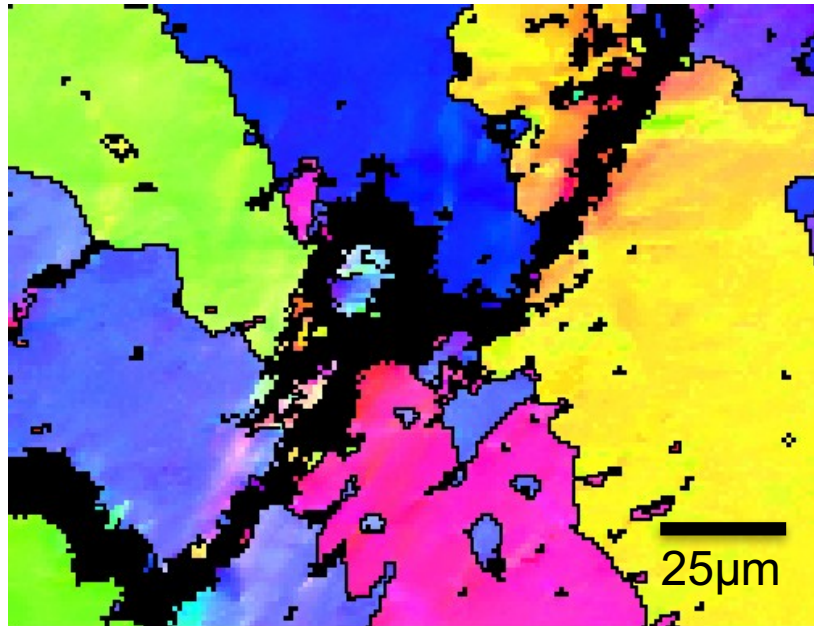
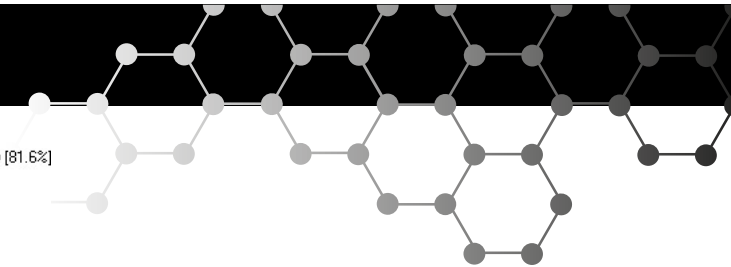
101



Inverse pole
figure map
shows grain
orientations

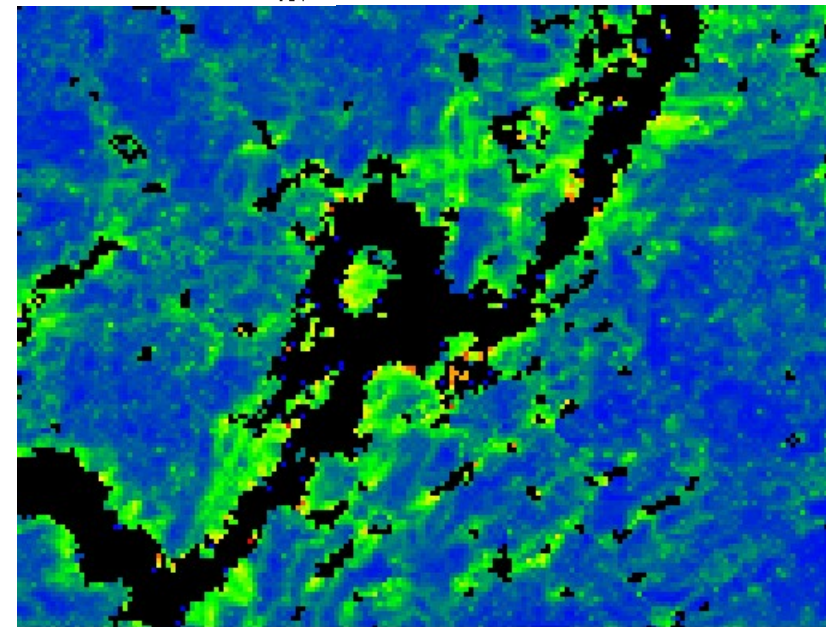
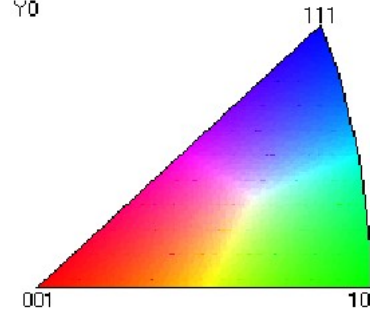


Kernel
Misorientation
Average maps
show strain

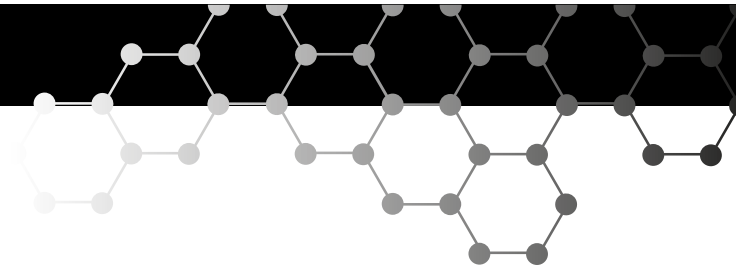


IPF colouring
 γ_0

Ni-superalloy [81.6%]



Presence of both intergranular
and transgranular cracks



Summary

- ⚙ Optimized sample preparation method developed.
- ⚙ SEM, EDS and EBSD done on unmodified surface.
- ⚙ Electron channeling contrast imaging ideal for this study.
- ⚙ Presently working with this method in welded IN718.
- ⚙ Next step – micromechanical testing.



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