Can we measure plastic strains at the nanoscale?

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Tijmen Vermeij* & Johan Hoefnagels

***t.vermeij@tue.nl**

mechanics of materials

multi-scale lab

EINDHOVEN UNIVERSITY OF TECHNOLOGY

PROBLEM

- Deformations in **Advanced Steels** at small scales are hard to measure and quantify

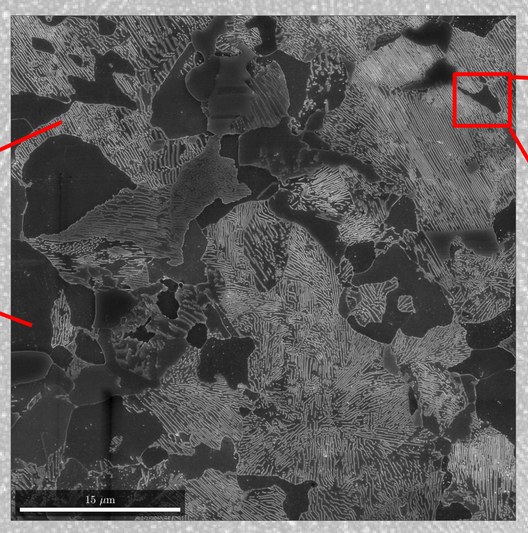
GOALS

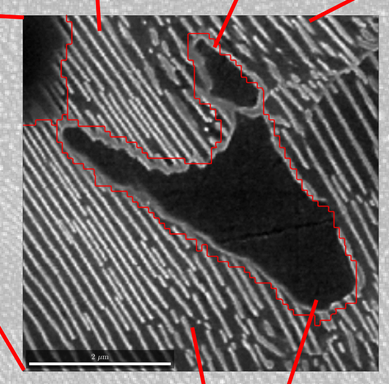
- Measure plastic strains in steel microstructures at high spatial resolution:
  - Retrieve strains over a large area (>50x50µm²)
  - Attain high spatial resolution at the nanoscale
  - Robustness to high strains
  - Allow direct comparison to the microstructure

HOW?

- High-Res Digital Image Correlation (DIC)
  - Apply a dense random pattern with nanoscale features [1]
  - Image pattern during deformation in the SEM
  - Attain high-resolution strain measurements at the nanoscale [1]
  - Retain robustness to high strains [1]
  - Align microstructure & strain fields

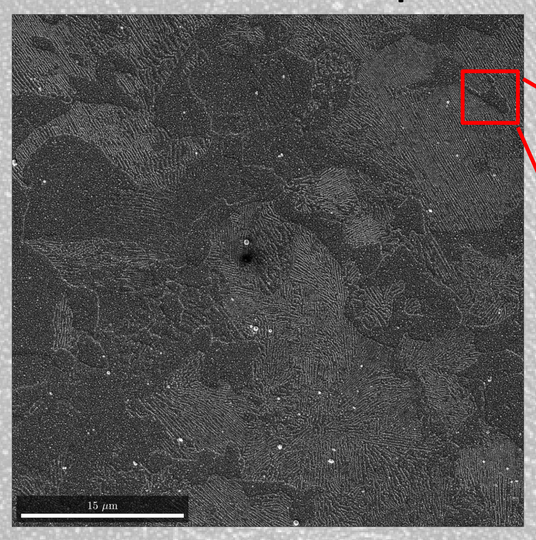
Microstructure





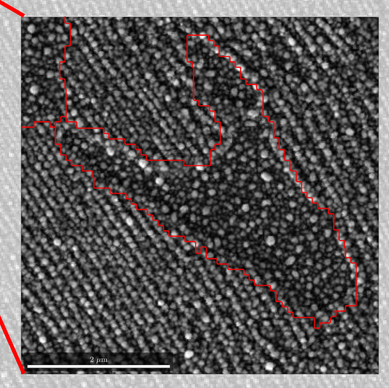
Strain localization during deformation? Where? How much? Why?

Microstructure with DIC pattern



Apply pattern by InSn sputter coating [1]:

- 50-100nm features (tuneable)
- High density (tuneable)

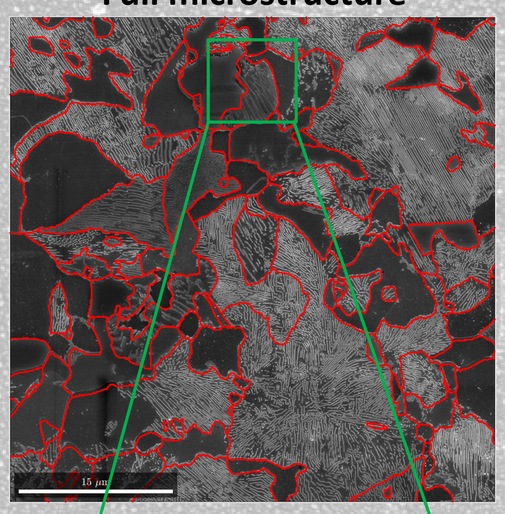


RESULTS

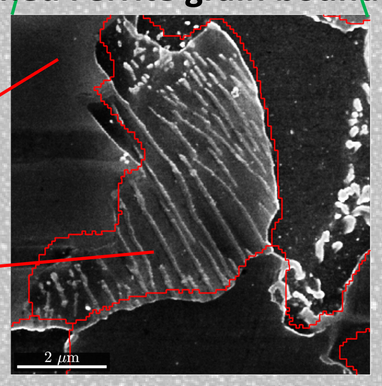
- High-Res plastic strains

Perform DIC on *in-situ* tensile test in Scanning Electron Microscope

Full microstructure



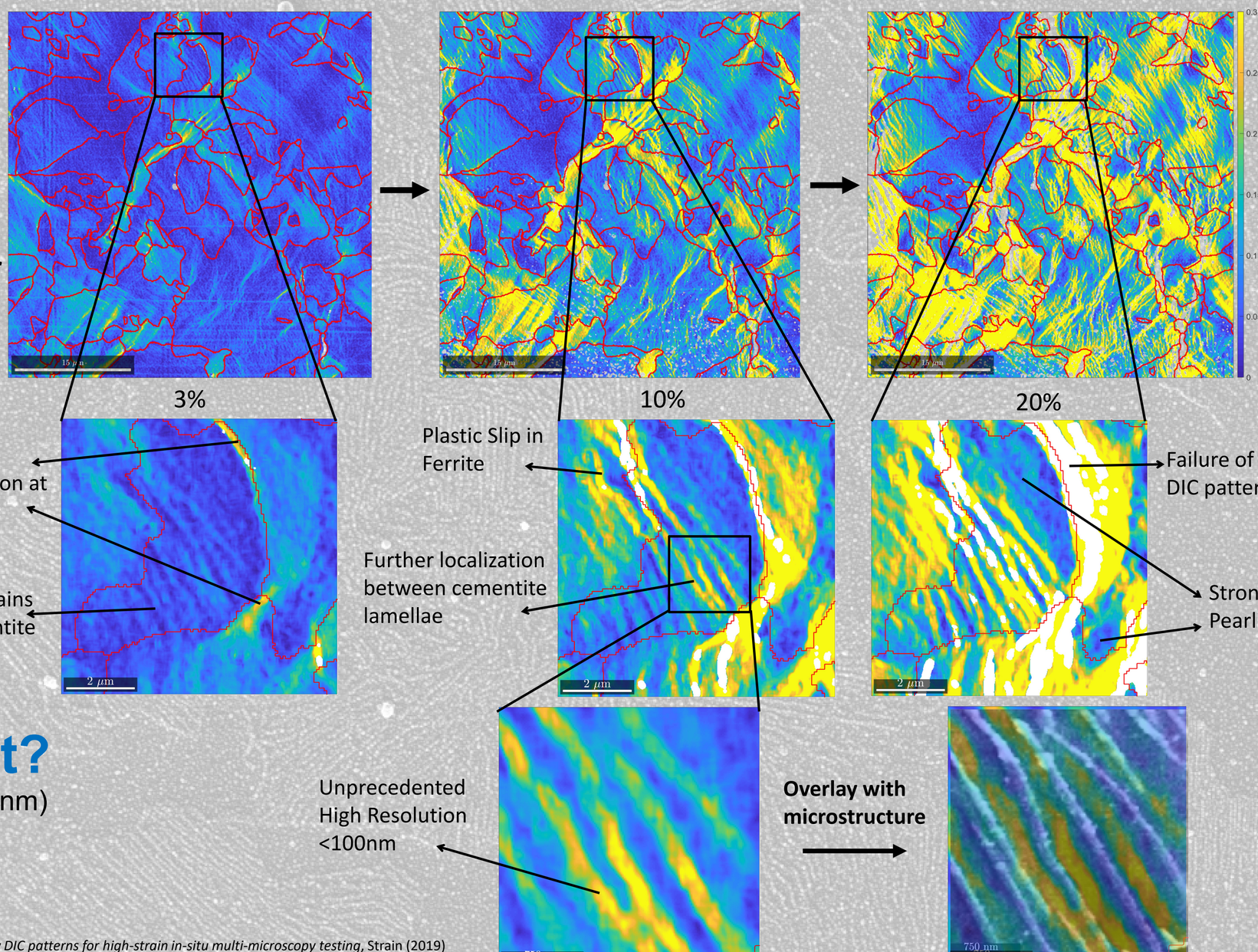
(with aligned Ferrite grain boundaries from EBSD)



***In-situ* testing**

Apply DIC on SEM images for strain calc.

Evolving plastic strain fields



So, can we do it?

- Yes! High spatial resolution for strains (~100 nm)
- Good alignment with microstructure
- **Next:** identify new mechanisms
- **Next:** compare to simulations

Unprecedented High Resolution <100nm

Overlay with microstructure

[1] J.P.M. Hoefnagels, M.v. Maris, T. Vermeij, *One-step deposition of nano-to-micron-scalable, high-quality DIC patterns for high-strain in-situ multi-microscopy testing*, Strain (2019)

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