Magnetic behavior of steel studied by *in-situ* Lorentz microscopy, magnetic force microscopy and micromagnetic simulations

Mari Honkanen, Suvi Santa-aho, Sami Kaappa, Lucio Azzari, Lasse Laurson and Minnamari Vippola

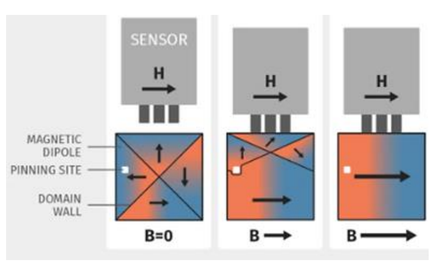
Tampere University, Tampere, Finland

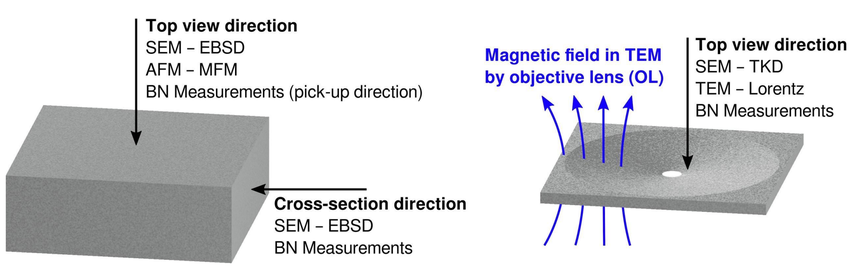
Henri Lukinmaa¤, Jaakko Kajan, Samuli Savolainen and Mikko Palosaari

Stresstech Oy, Jyväskylä, Finland, ¤Present: Verity, Zürich, Switzerland

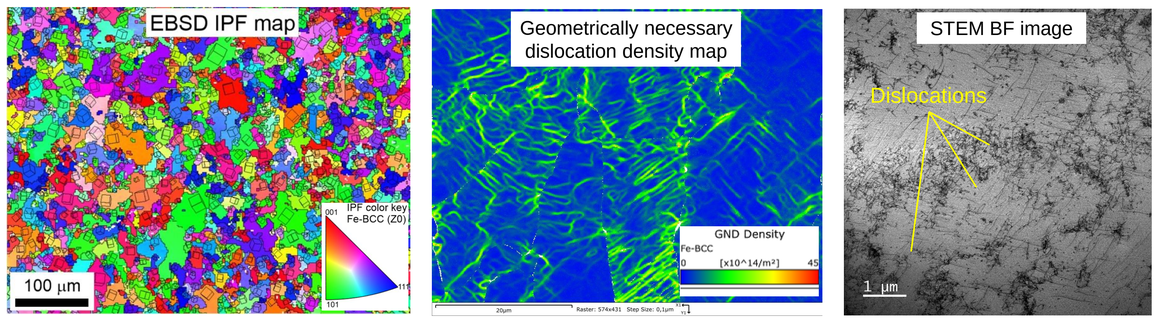
Background and motivation

- Barkhausen noise (BN) measurement is an important industrial non-destructive quality control method for ferromagnetic materials (evaluation of residual stresses and hardness, testing of surface defects)
- BN measurement: External AC magnetic field excites magnetic domain wall dynamics → Microstuctural features inhibit domain wall motion → Discontinuous changes in the magnetization → Barkhausen noise signal
- BN technique would have even wider potential in industry if the structural details of the material could be thoroughly linked with its BN signal → Our combined multi-instrumental and computational approach:
  - Characterizations for bulk samples (SEM-EBSD, magnetic force microscopy, MFM) and thin samples (SEM-TKD, S/TEM-EDS, (*in-situ*) Lorentz microscopy)
  - Micromagnetic simulations

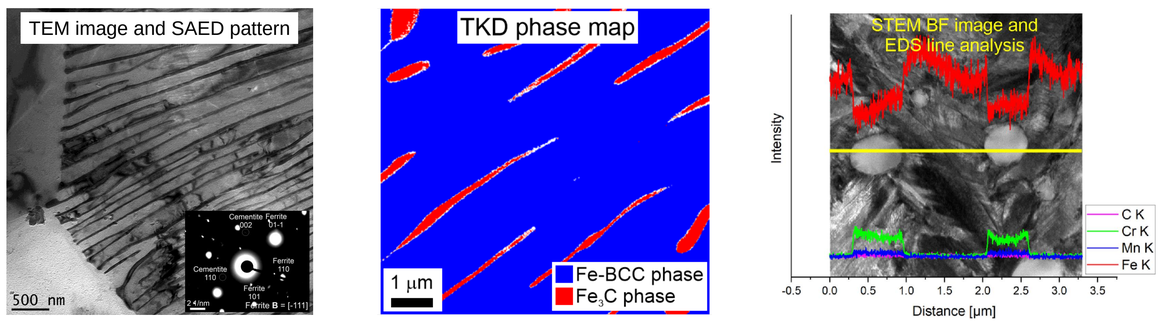




Microstructure

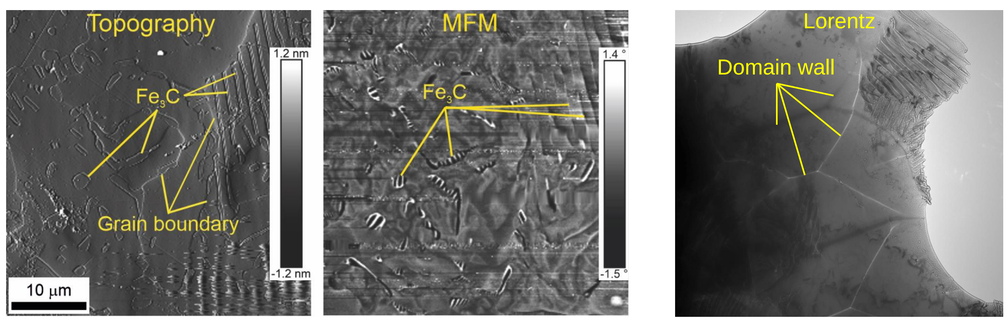


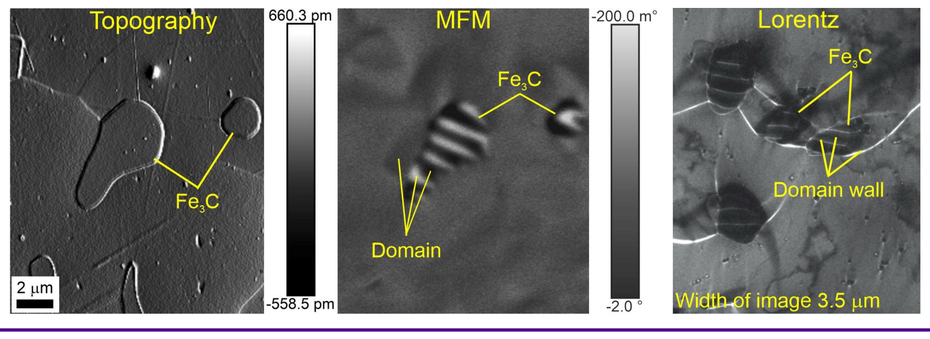
Grain size, orientation, texture, and dislocation analyses



Phase and elemental analyses

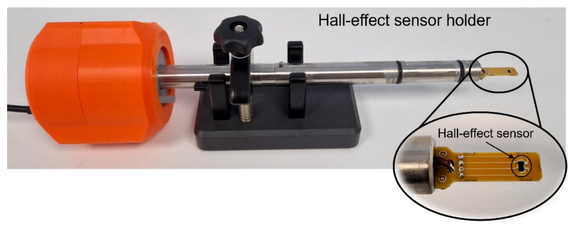
Magnetic structure



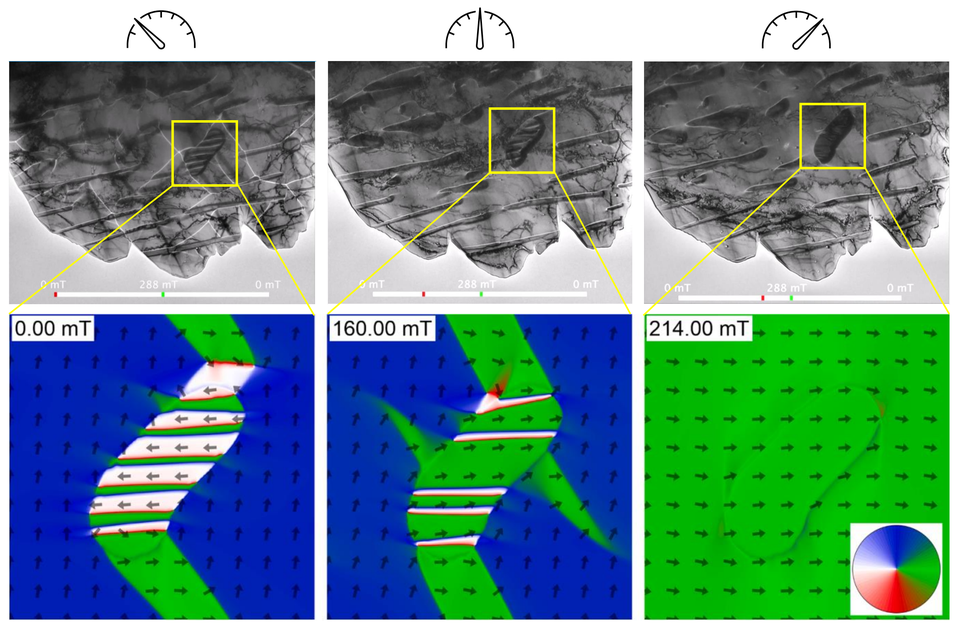


Combined multi-instrumental and computational approach

Domain wall dynamics

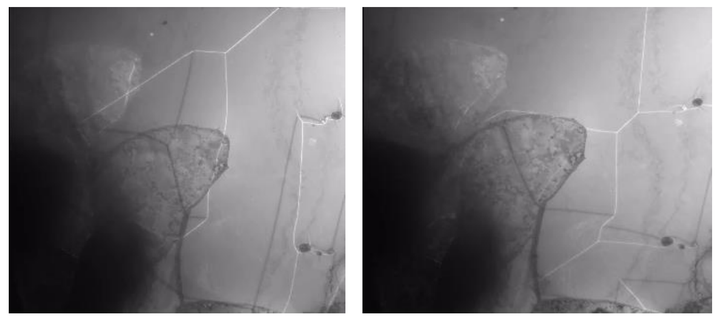


- We built a custom-made holder with a Hall-effect sensor to measure a single point flux density at the sample location in the TEM JEOL JEM-F200.
- We generated time-varying external magnetic fields to the sample using TEM's objective lens, imaging with an objective mini lens.

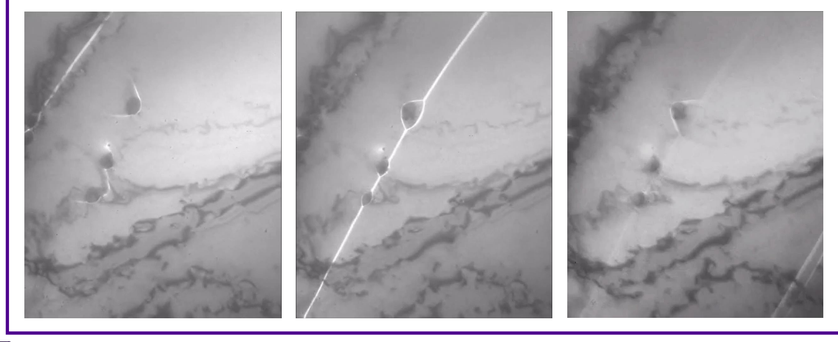


Video

Micromagnetic simulations



Video



Video

Novel knowledge on magnetic behavior of ferromagnetic steel

In the future: Together with DTU Nanolab, off-axis electron holography and transport of intensity equation (TIE) studies are going on.

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BarFume

TMC

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