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Effects of Plastic Deformations on Magnetism and Microstructure in Hiperco

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SOCIETY FOR EXPERIMENTAL MECHANICS ANNUAL CONFERENCE

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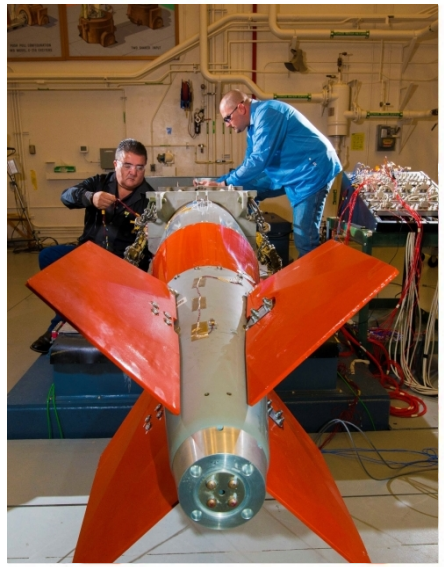
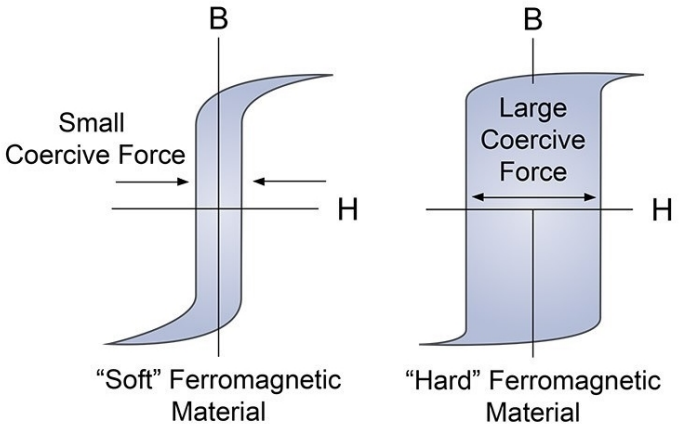


This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

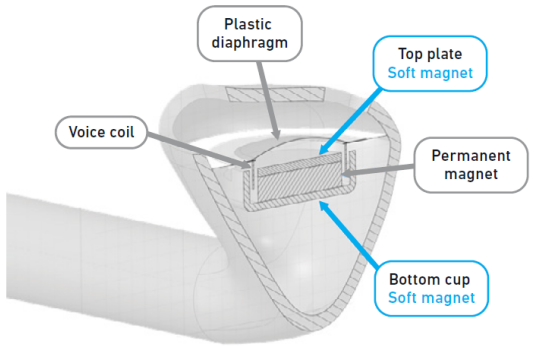
What is Hiperco?

Hiperco 50 – 49Fe-49Co-2V

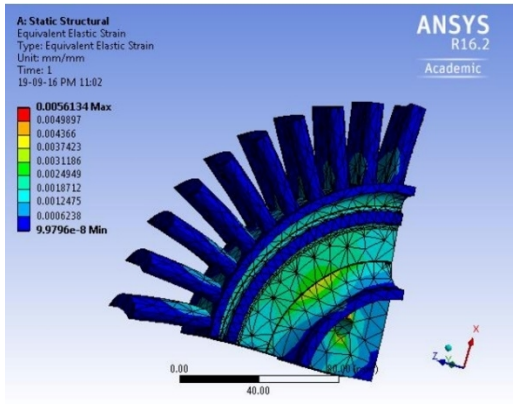
Soft Magnetic Material



- Highest saturation
- High permeability
- Low coercivity
- Low AC losses



CarpenterElectrification.com



Rotor, Rakesh, Kanchiraya (2017)

Uses:

- Micro-actuators/sensors (haptics, micro-speakers, voice coils)
- Flight safety systems (APU, ram air turbine)
- Electric motors/generators (aerospace)
- Magnetic (active) bearings

Key benefits:

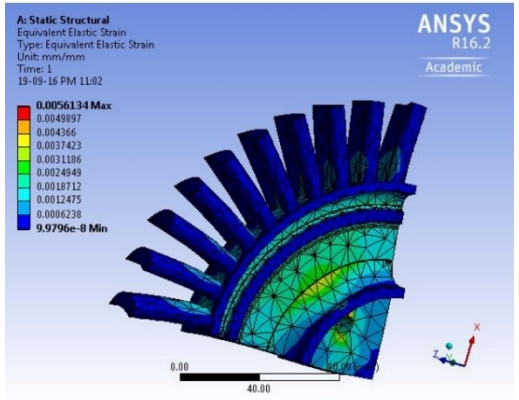
Higher performance at lower weight and size; Lower power consumption

What is the problem?

Key drawbacks:

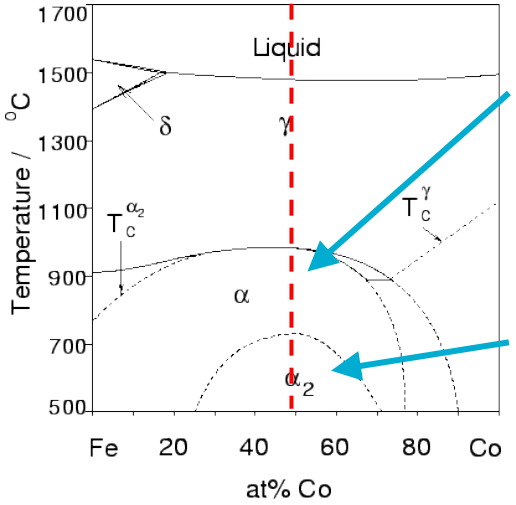
- Properties highly dependent on microstructure; High sensitivity to machining

Hiperco is used in applications where magnetic performance is critical, but components may be vulnerable to overload and plastic deformations

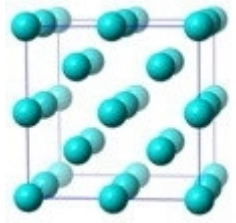


Rotor, Rakesh, Kanchiraya (2017)

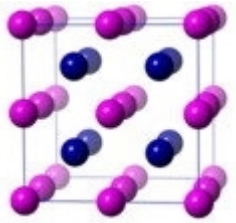
Hiperco 50 – 49Fe-49Co-2V

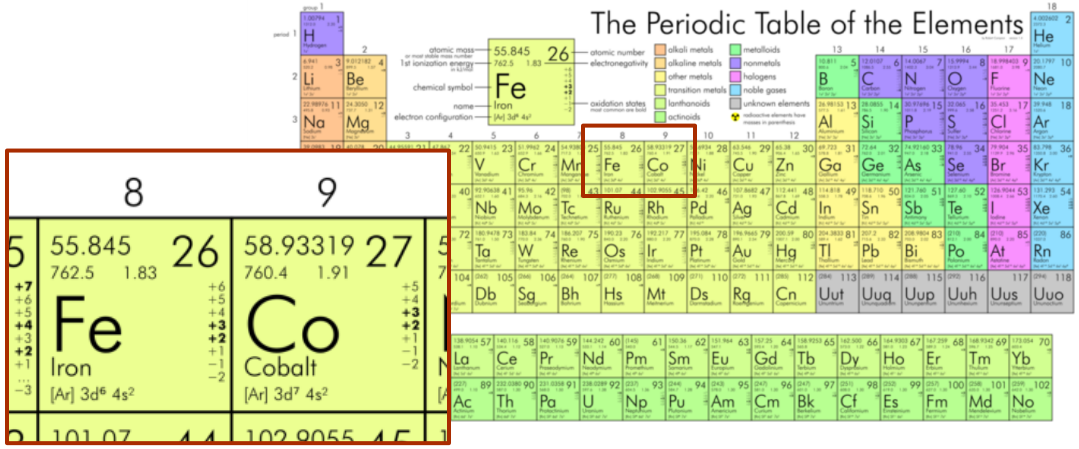


Disordered BCC
+ mechanical
+ magnetic



Highly ordered B2
− mechanical
++ magnetic

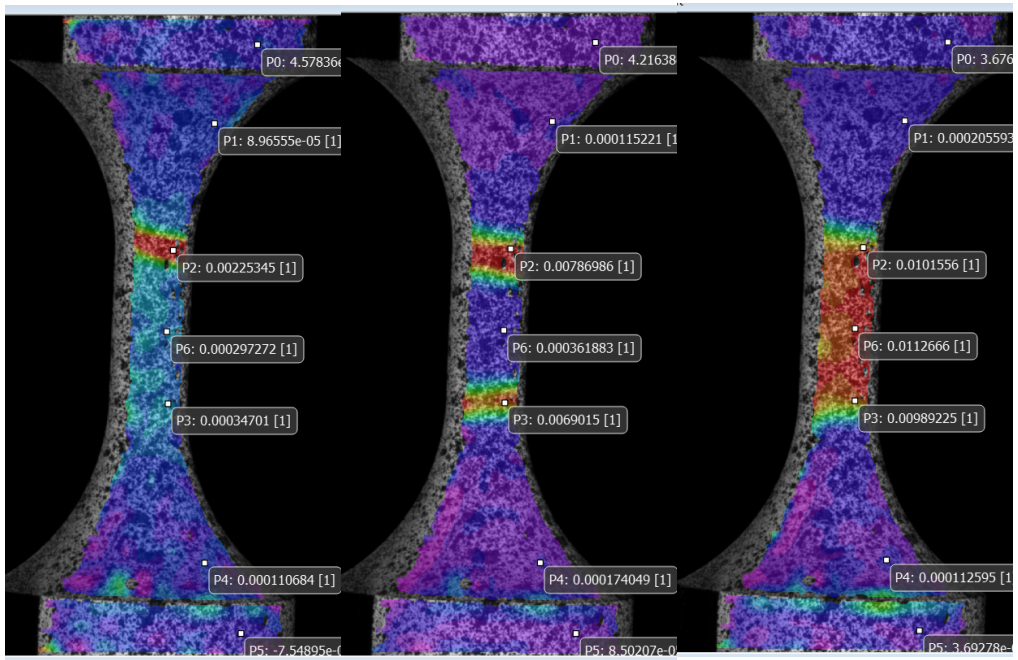


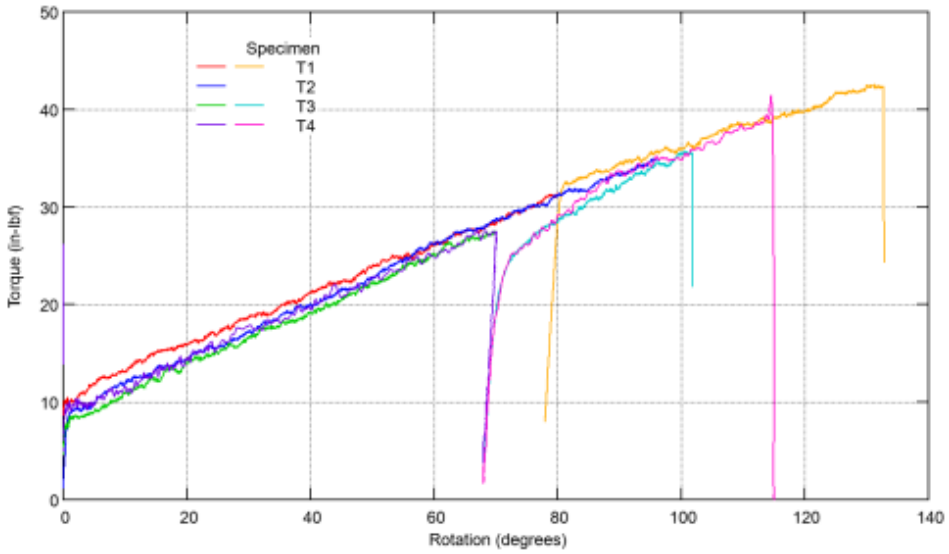


How does Hiperco's magnetic performance change as a result of plastic deformations?

And what microstructural mechanisms are linked to these changes?

Mechanical – Lüders Band phenomenon observed in tension, shear, and compressive loading configurations suggesting significant microstructural changes immediately post-yield





→ **We expect magnetism changes at low strain levels**

Approach:

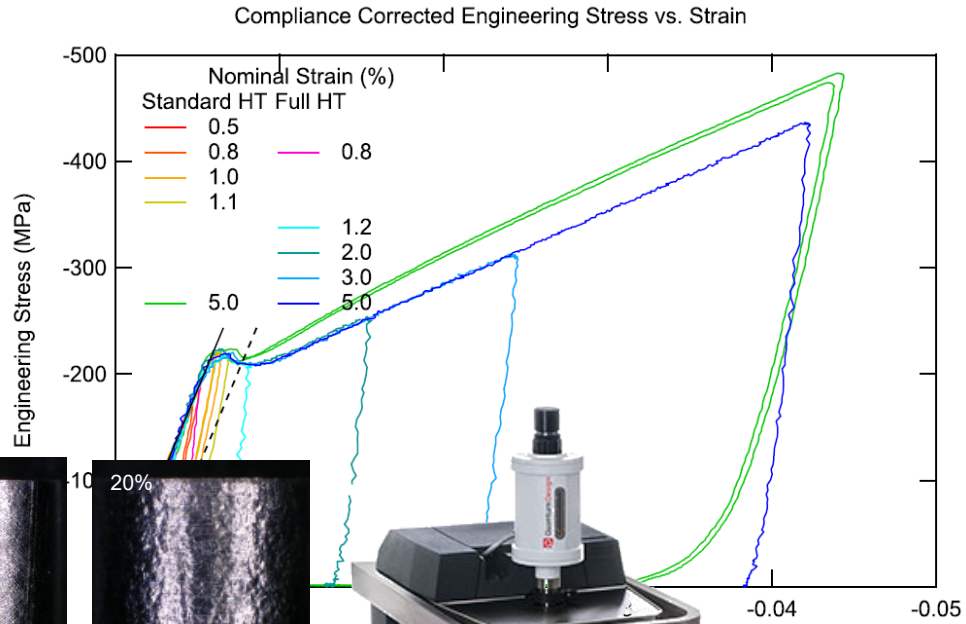
Mechanical characterization

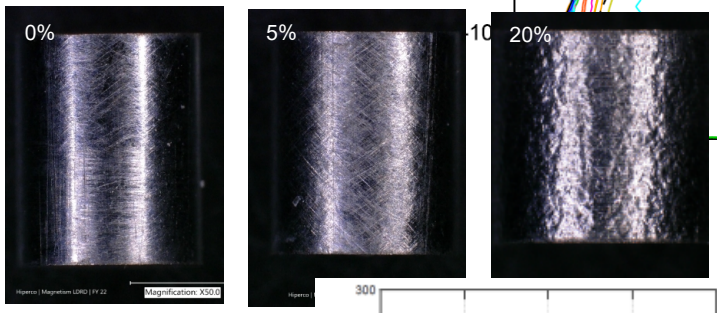
Induce plastic deformation – compression

Measure effect on magnetism

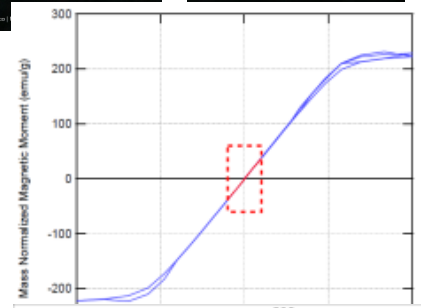
Assess microstructure

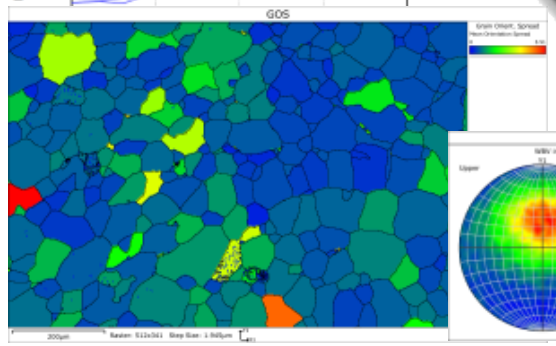
Link changes

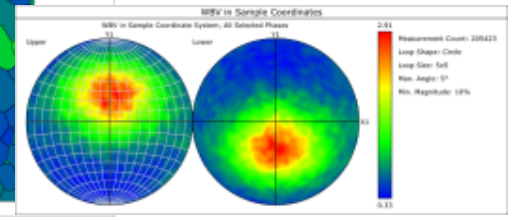


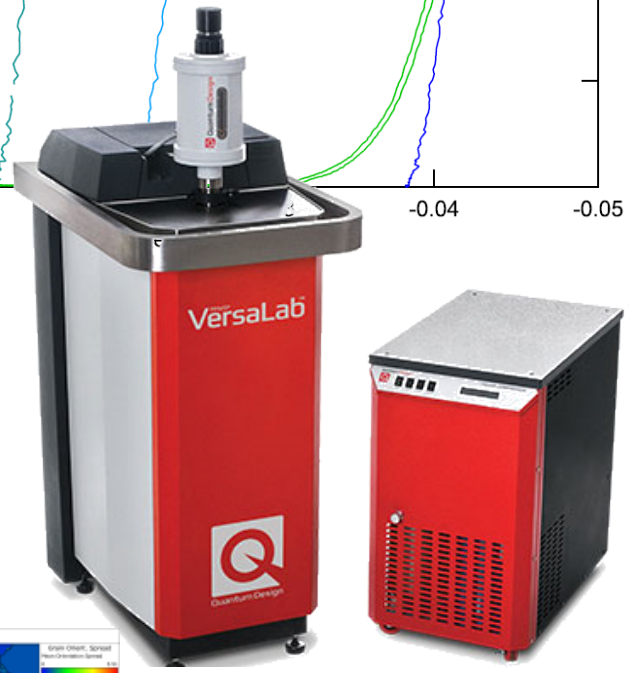


JEOL



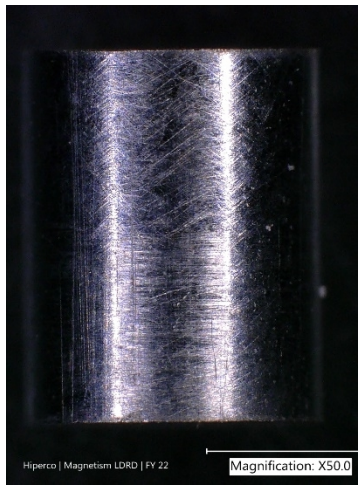


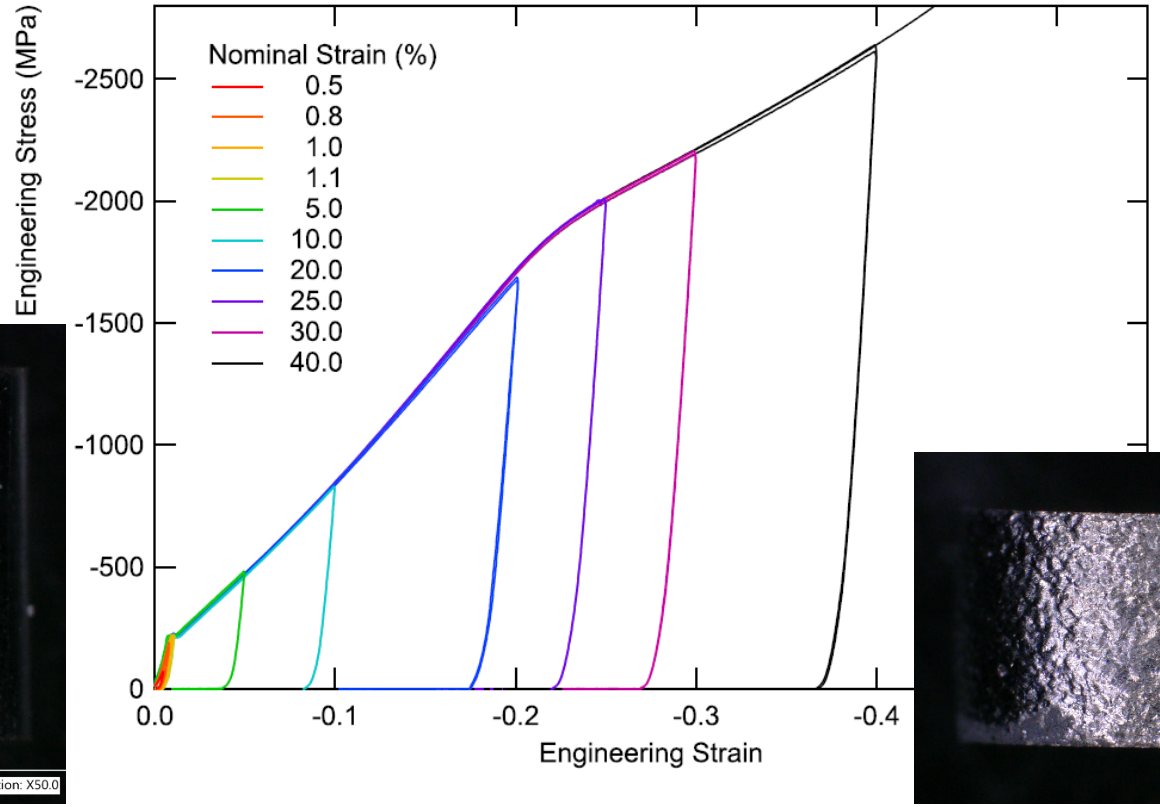




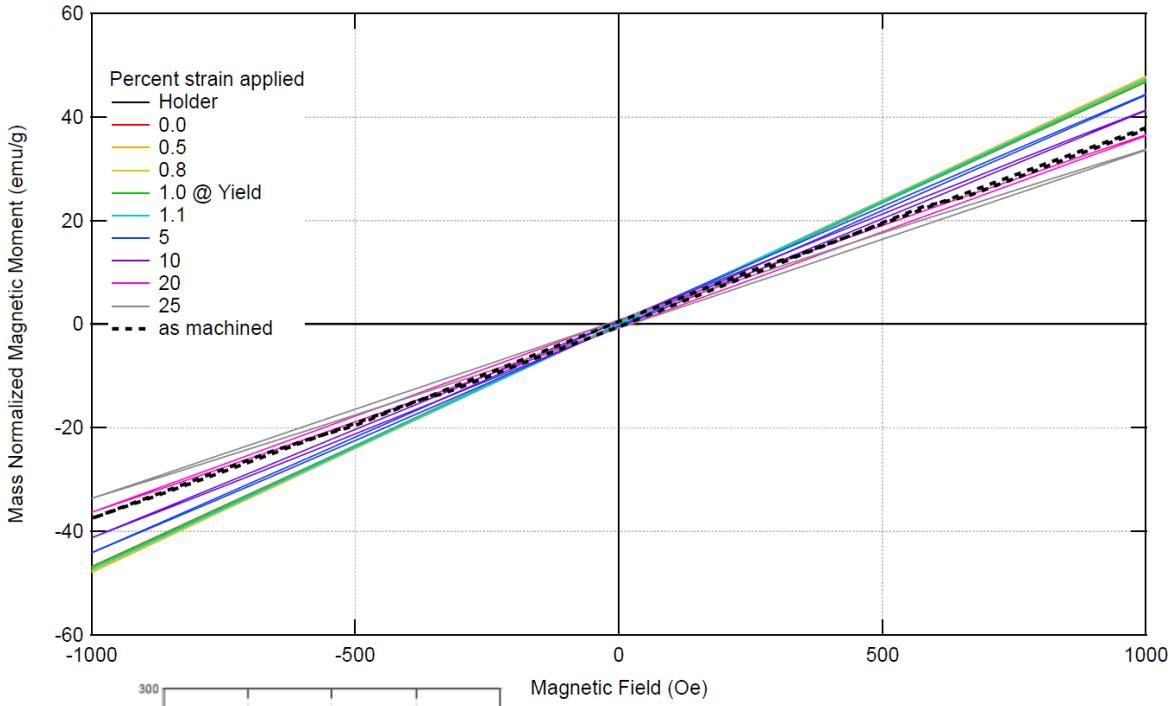
Quantum Design

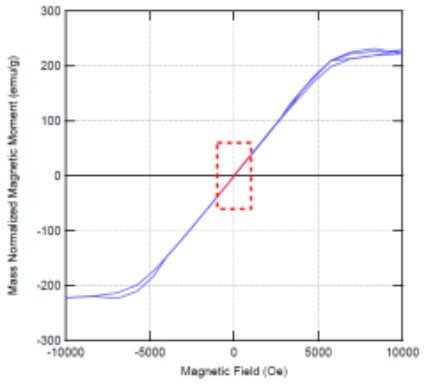
Mechanical Characterization and Plastic Deformation

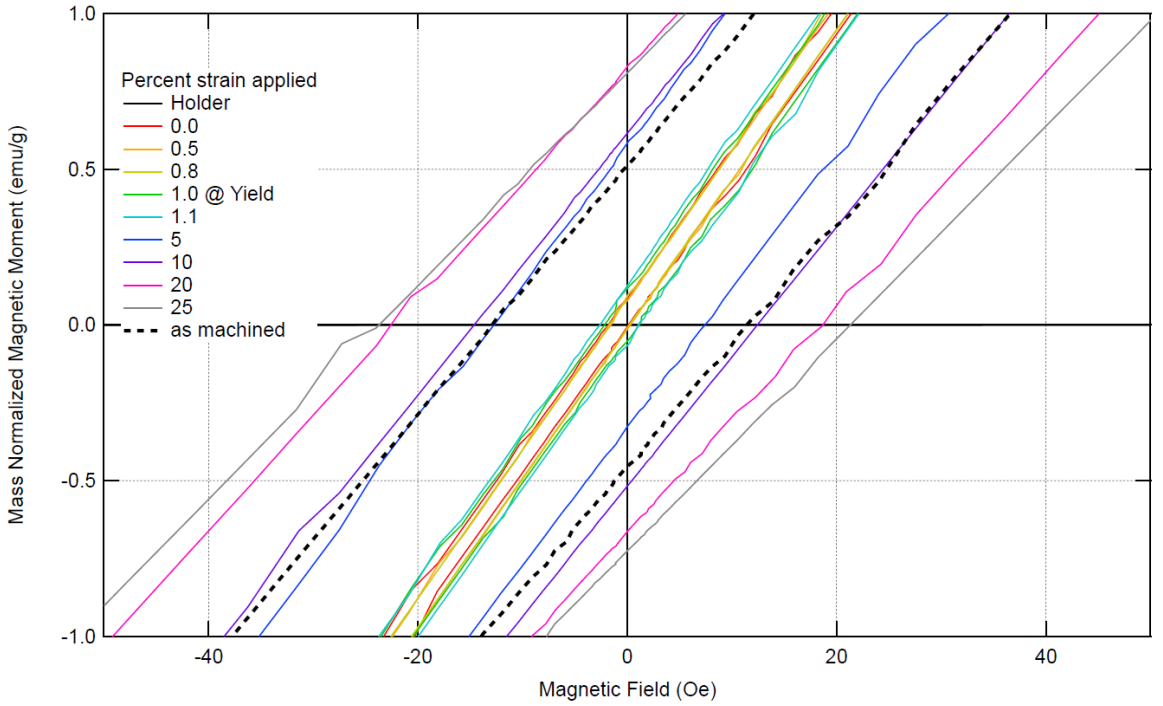




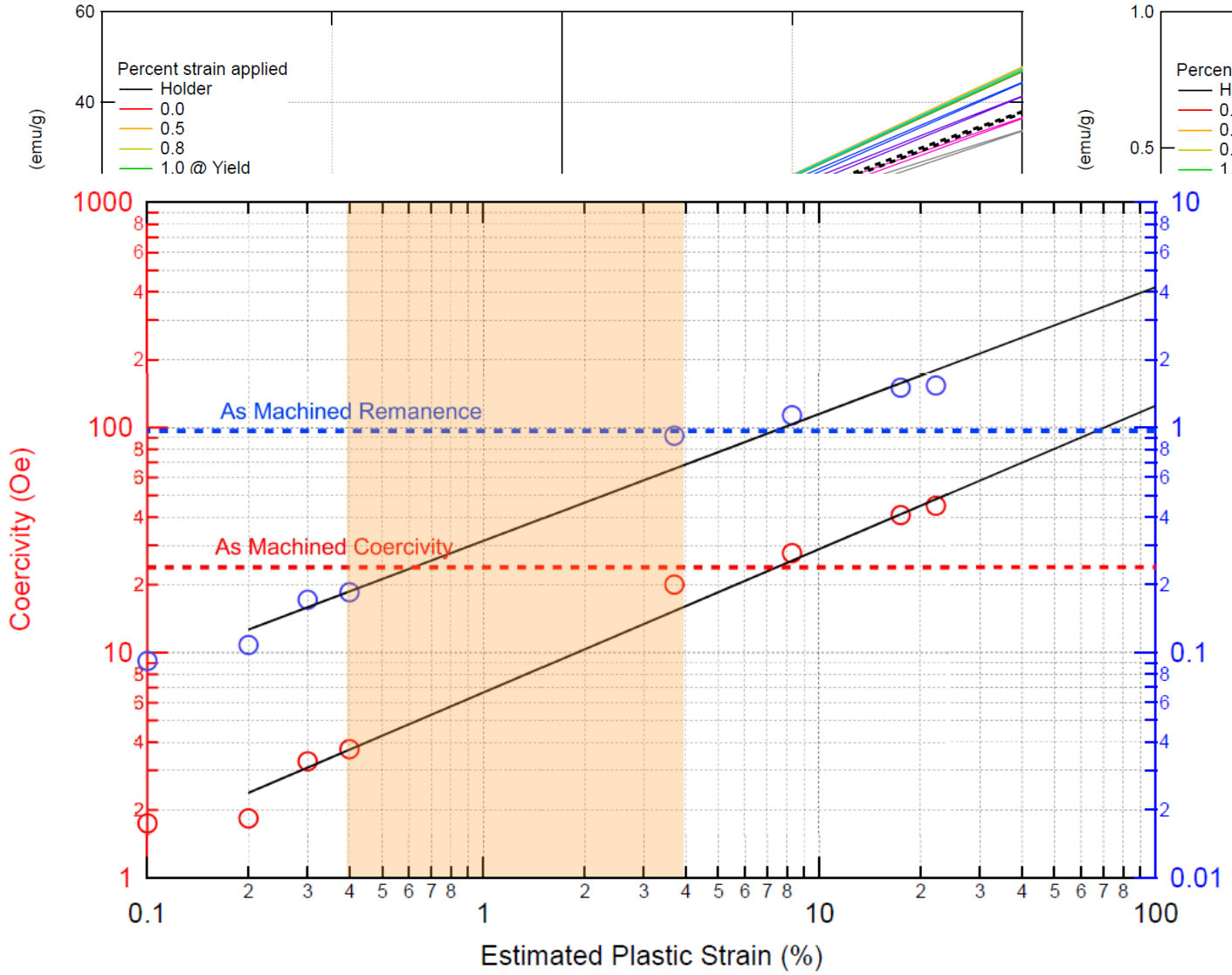
Permeability decreases with increasing strain

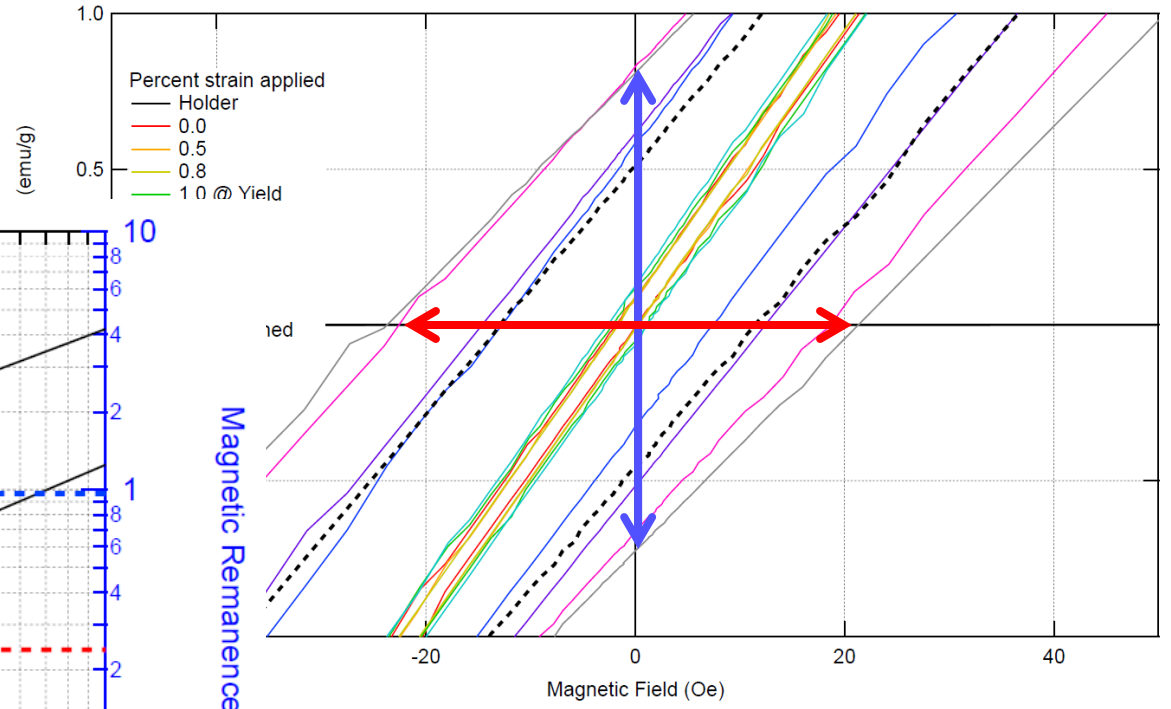




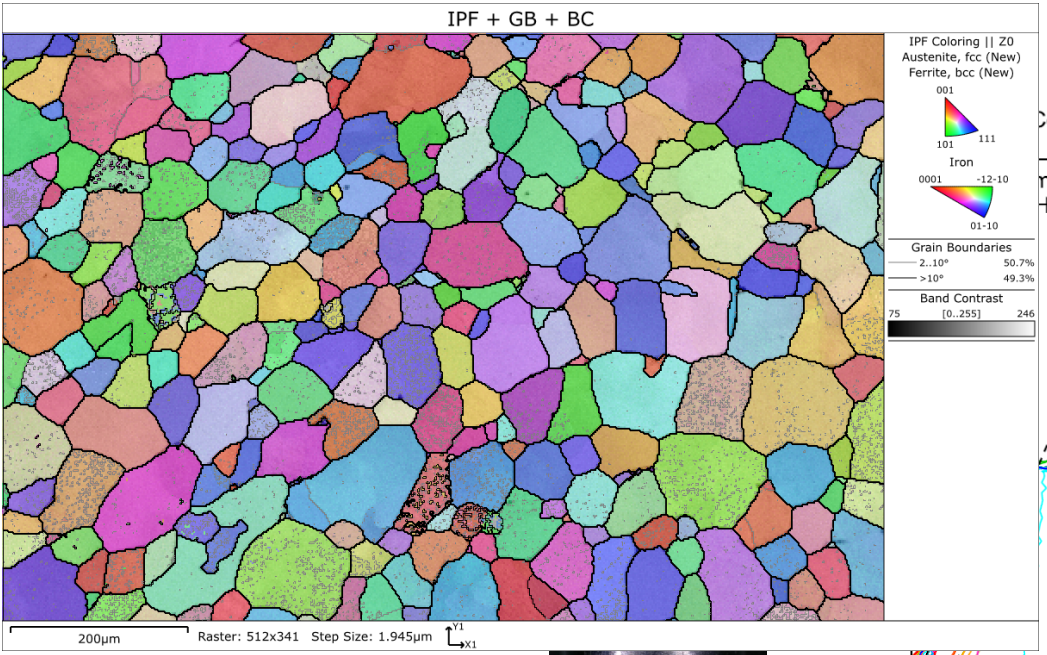


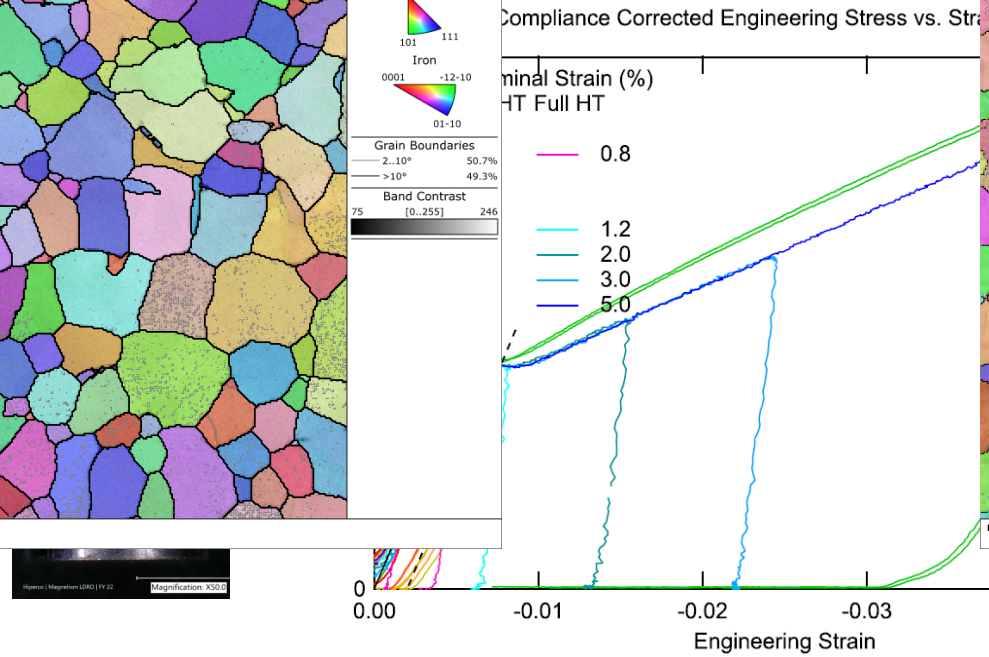
Coercivity and remanence increase with increasing strain

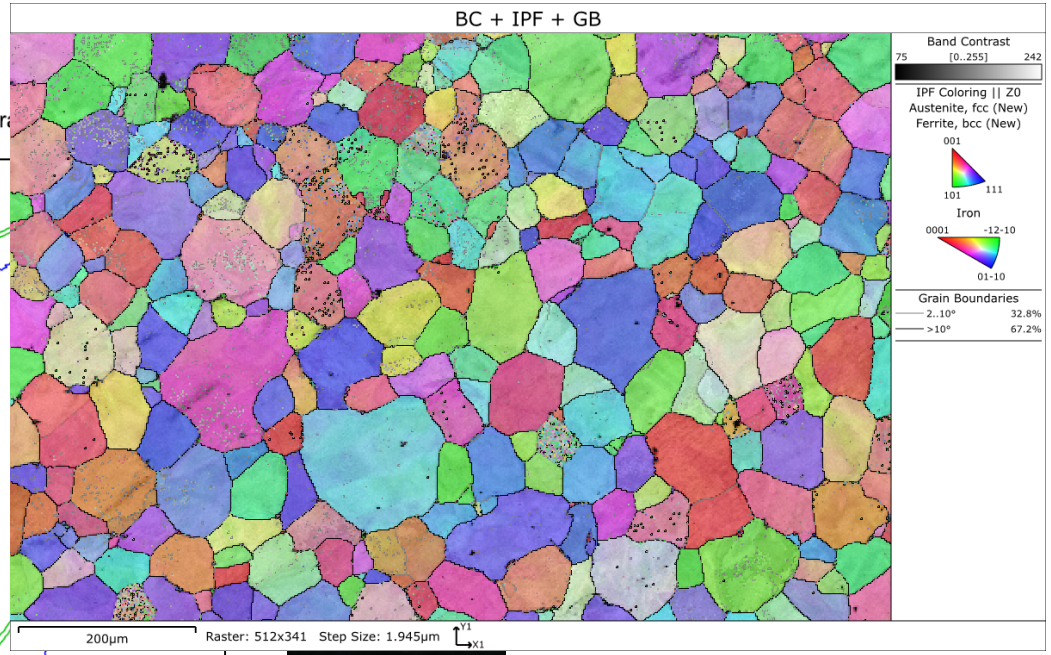




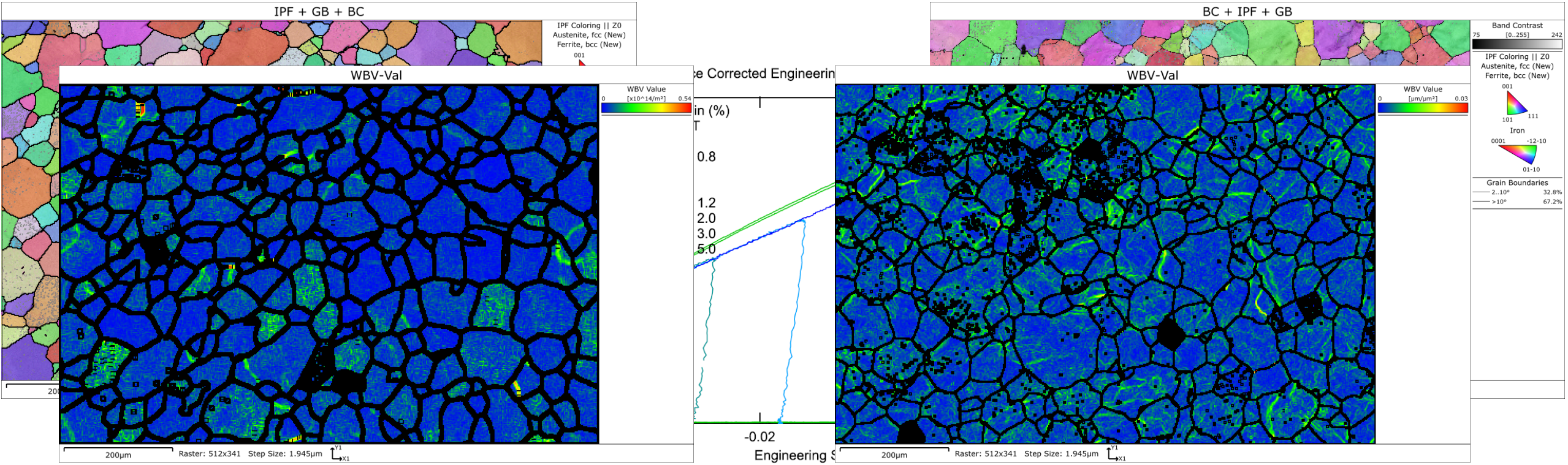
Grain-scale changes due to plastic deformations



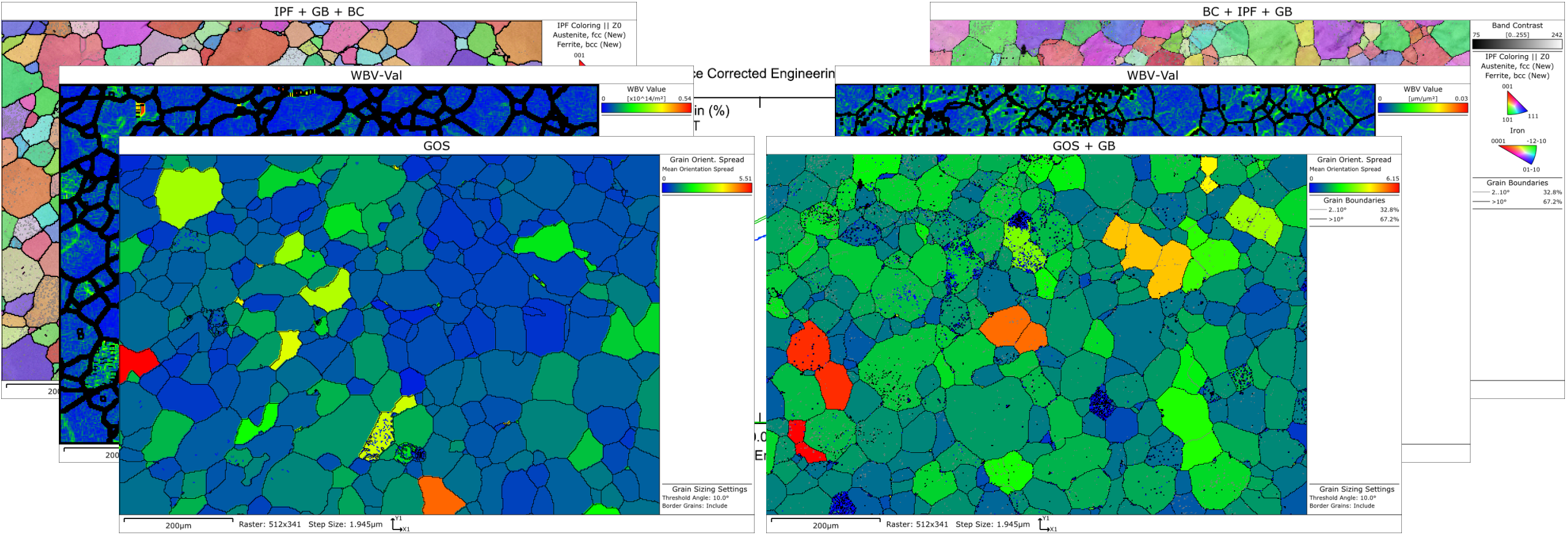




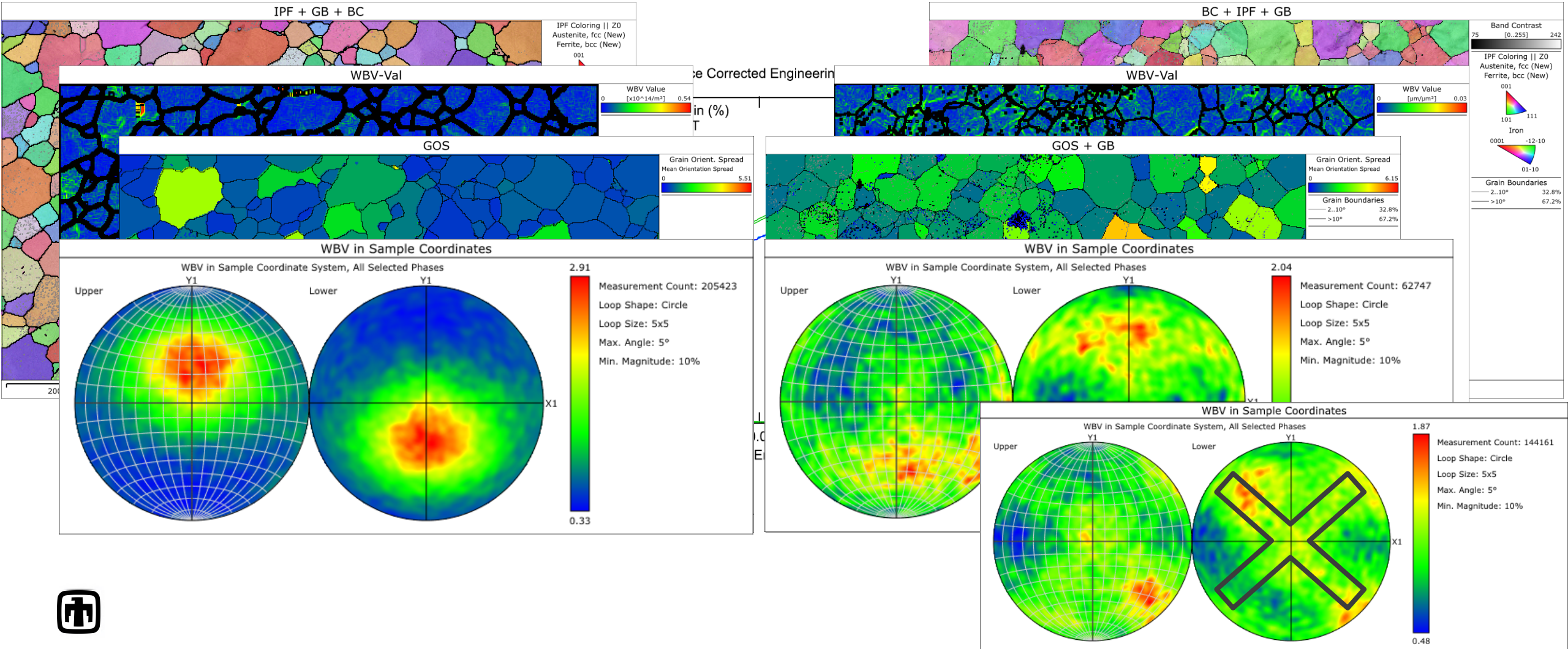
Increase in magnitude and localizations of WBV



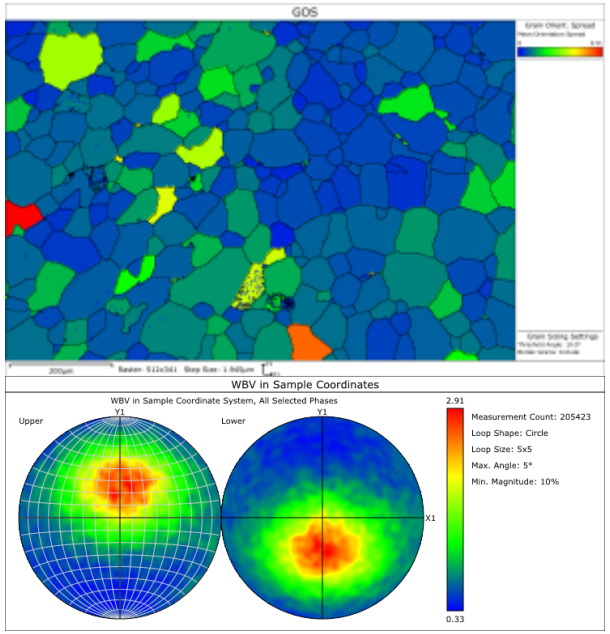
Increase in grain orientation spread magnitude and average

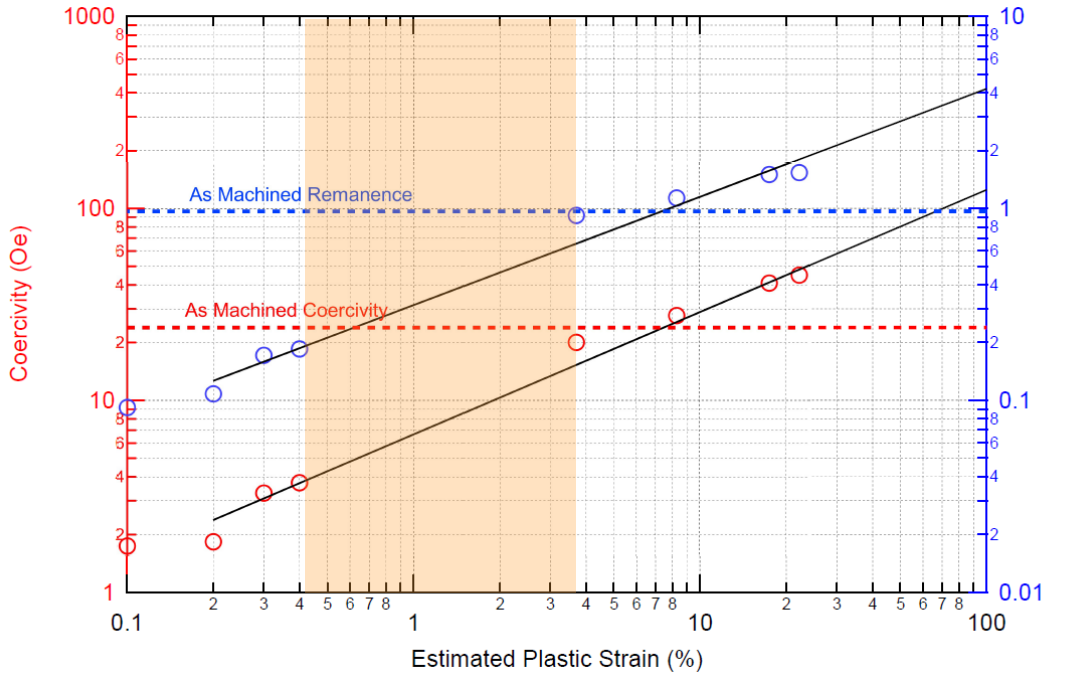


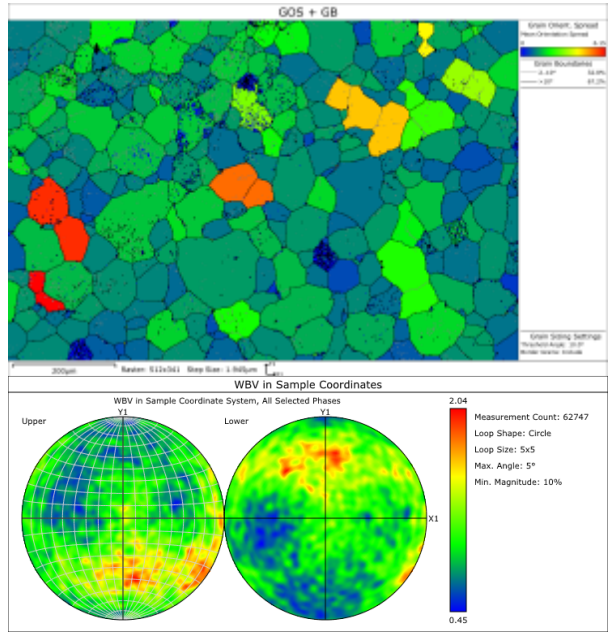
WBV coordinate pattern evolves



Hiperco's magnetic performance and grain structure change significantly between yield and 5% strain







- Mechanics – Lüders Band phenomenon suggests significant microstructural changes immediately post-yield
- Magnetics – Coercivity and remanence ⇧ Permeability ⇩(expect saturation ⇩
- Microstructure – Significant microstructural changes correlate with changes in magnetic performance

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