

Hydrogen Isotope Permeation Experiments in AM Steels

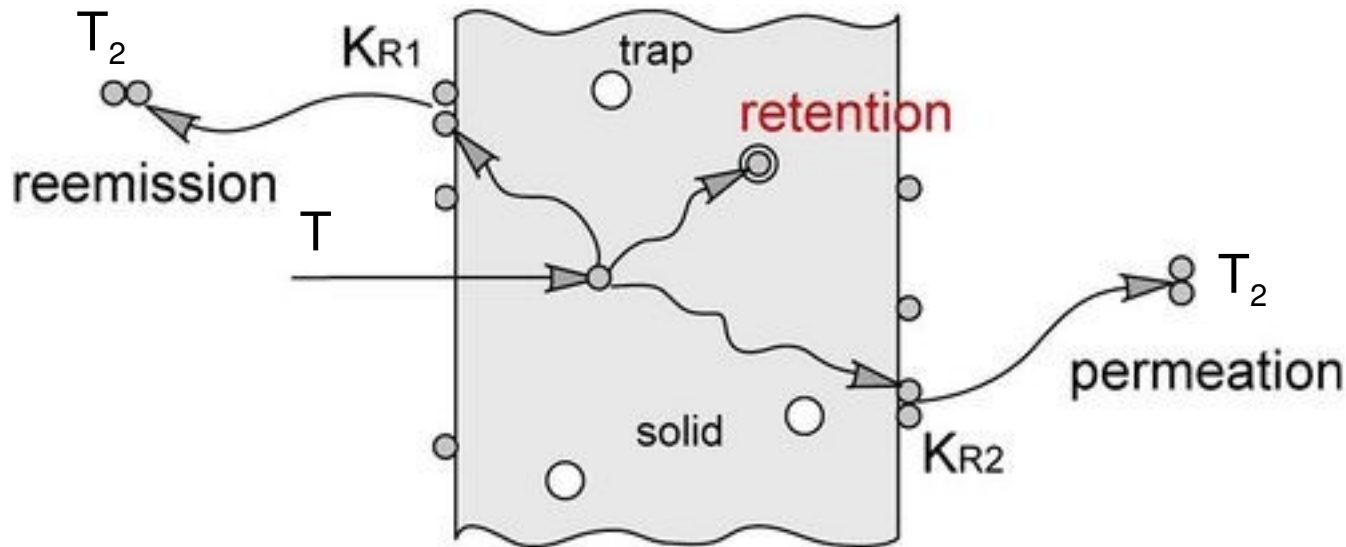
Richard Karnesky, Dean Buchenauer
Sandia National Laboratories, Livermore CA

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- Permeation process, Sandia capabilities
- Examples of diatomic gas-driven permeation in AM steels
 - LENS material, powder-bed
- Current efforts

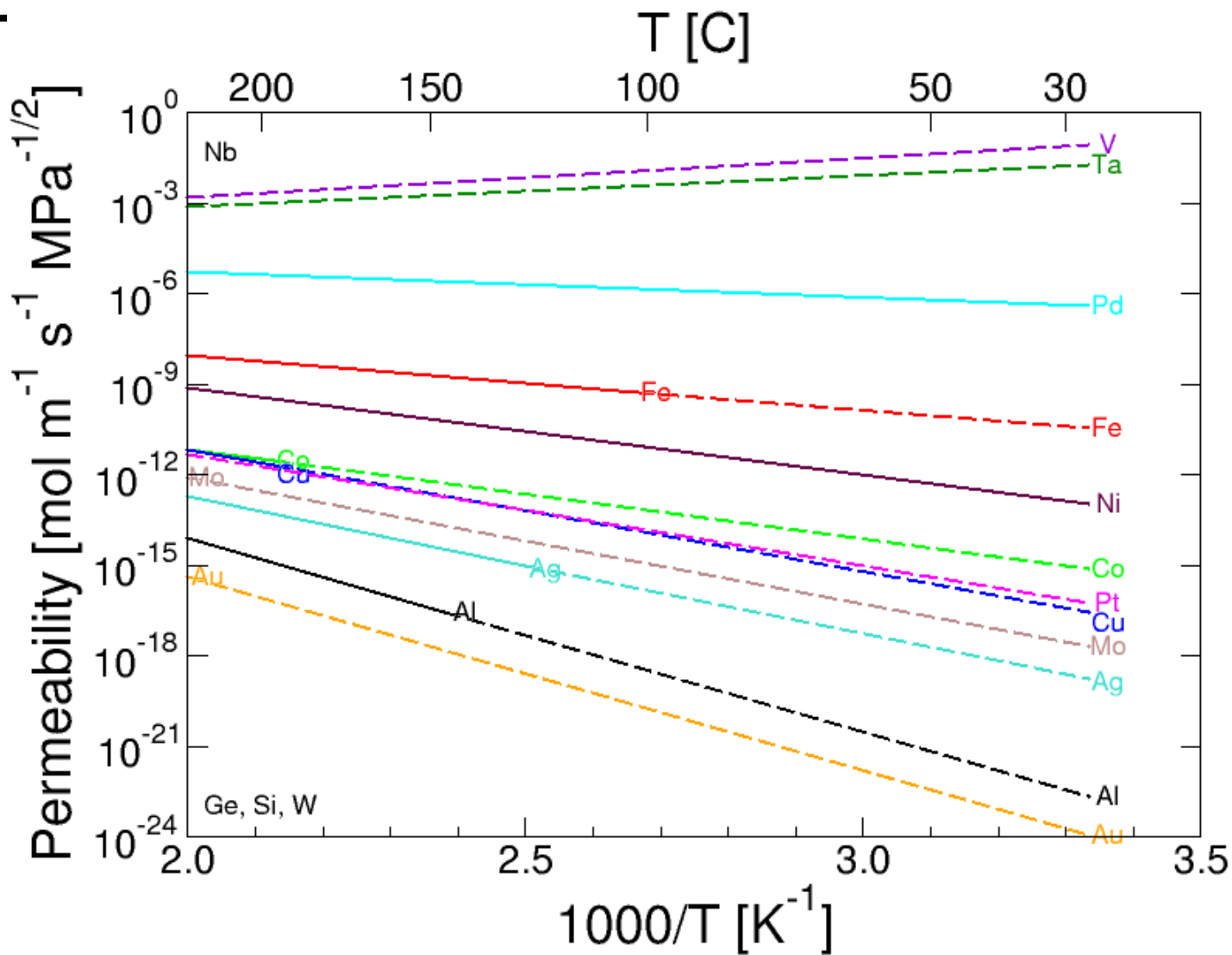


Schematic of T permeation



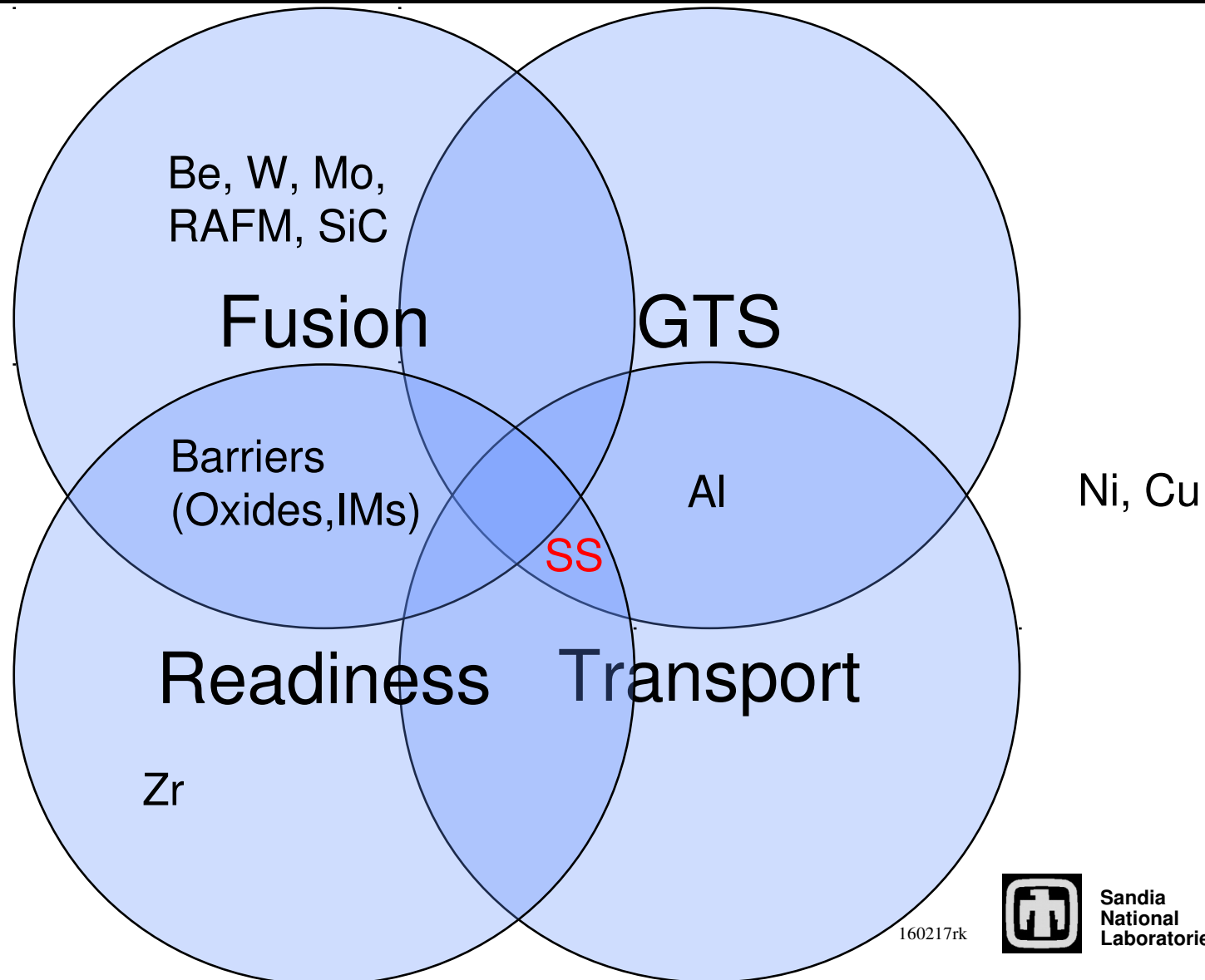
Most materials exhibit diffusion-limited permeation at sufficient pressures
 Recombination is often neglected because it is fast
 (e.g. $K_R \sim 1e-16 \text{ cm}^4/\text{s}$ for Ni)

Permeability of Metals



Who cares about which materials?

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Permeation Experiments at Sandia California

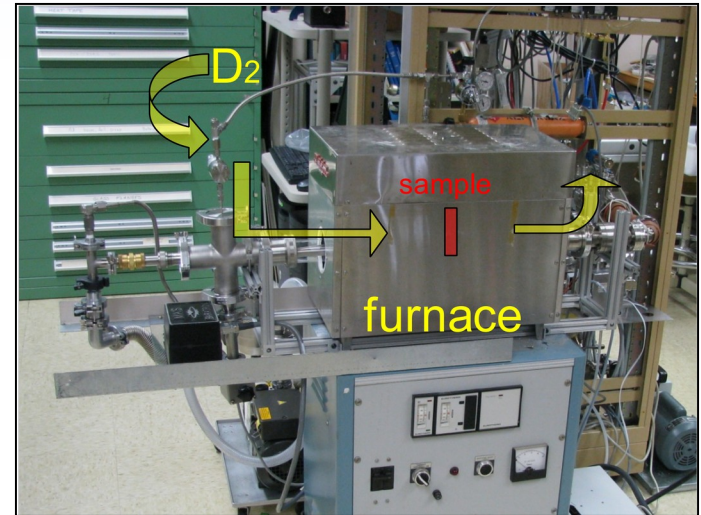
- Deuterium gas driven permeation capabilities presently in use at SNL
 - 1st generation ($150 < T < 500\text{ }^{\circ}\text{C}$) used stainless steel construction (VCR seals), evacuated quartz outer tube to reduce D_2 bypass, and low flow to prevent surface contamination

Materials studied: stainless steels, steel alloys, welds, aluminum alloys, nickel, **AM steel**

- 2nd generation ($50 < T < 1150\text{ }^{\circ}\text{C}$) uses Al_2O_3 construction and soft, pressure loaded seals for brittle specimens (funded by “Work For Others” program to measure SiC permeation barriers for fusion blankets)

Materials studied: stainless steels, SiC, **tungsten**

$$P_{\text{SiC}} < 10^{-12} \text{ mol H}^2 \text{ m}^{-1} \text{ s}^{-1} \text{ MPa}^{-0.5}$$



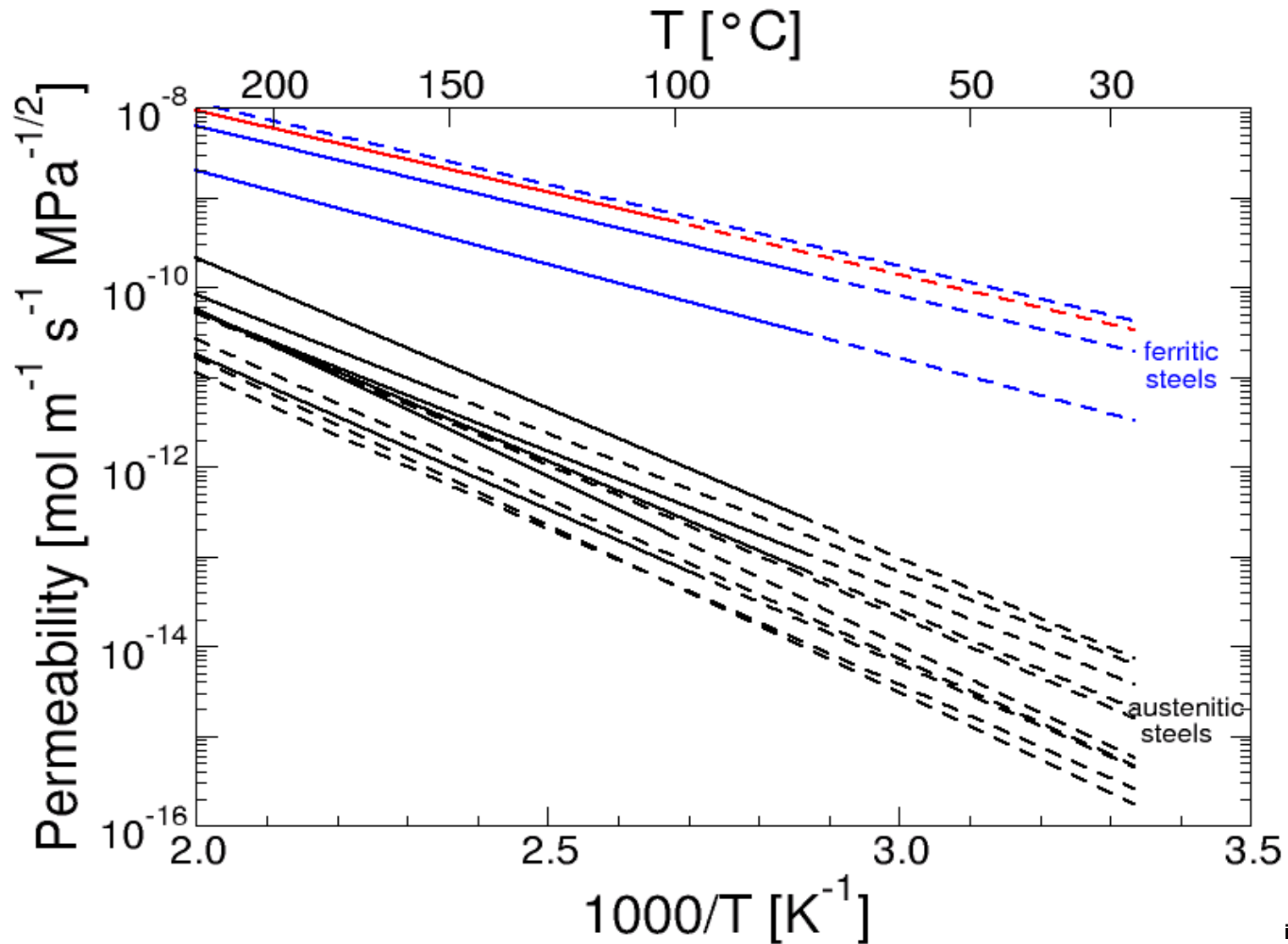
1st Generation System



2nd Generation System

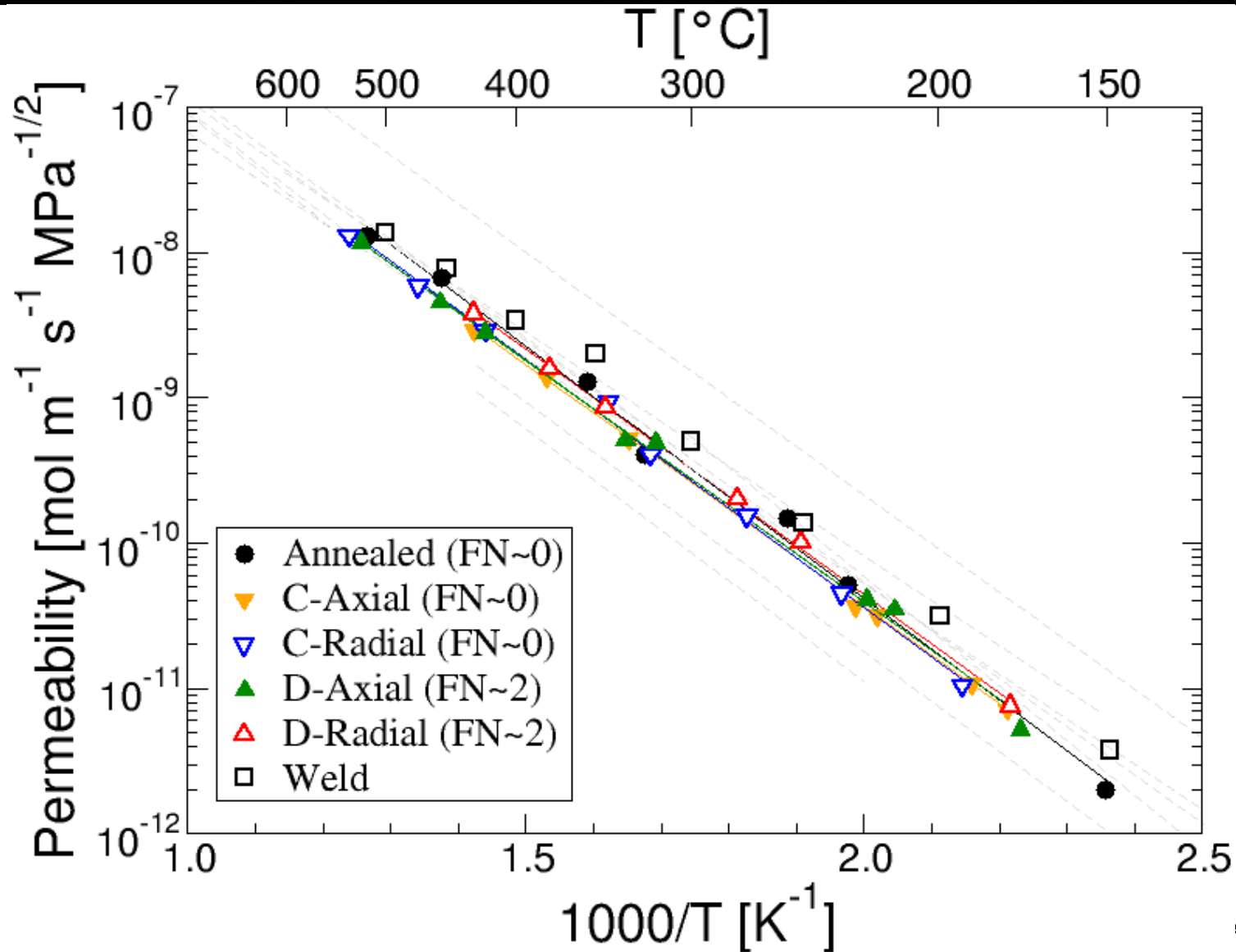


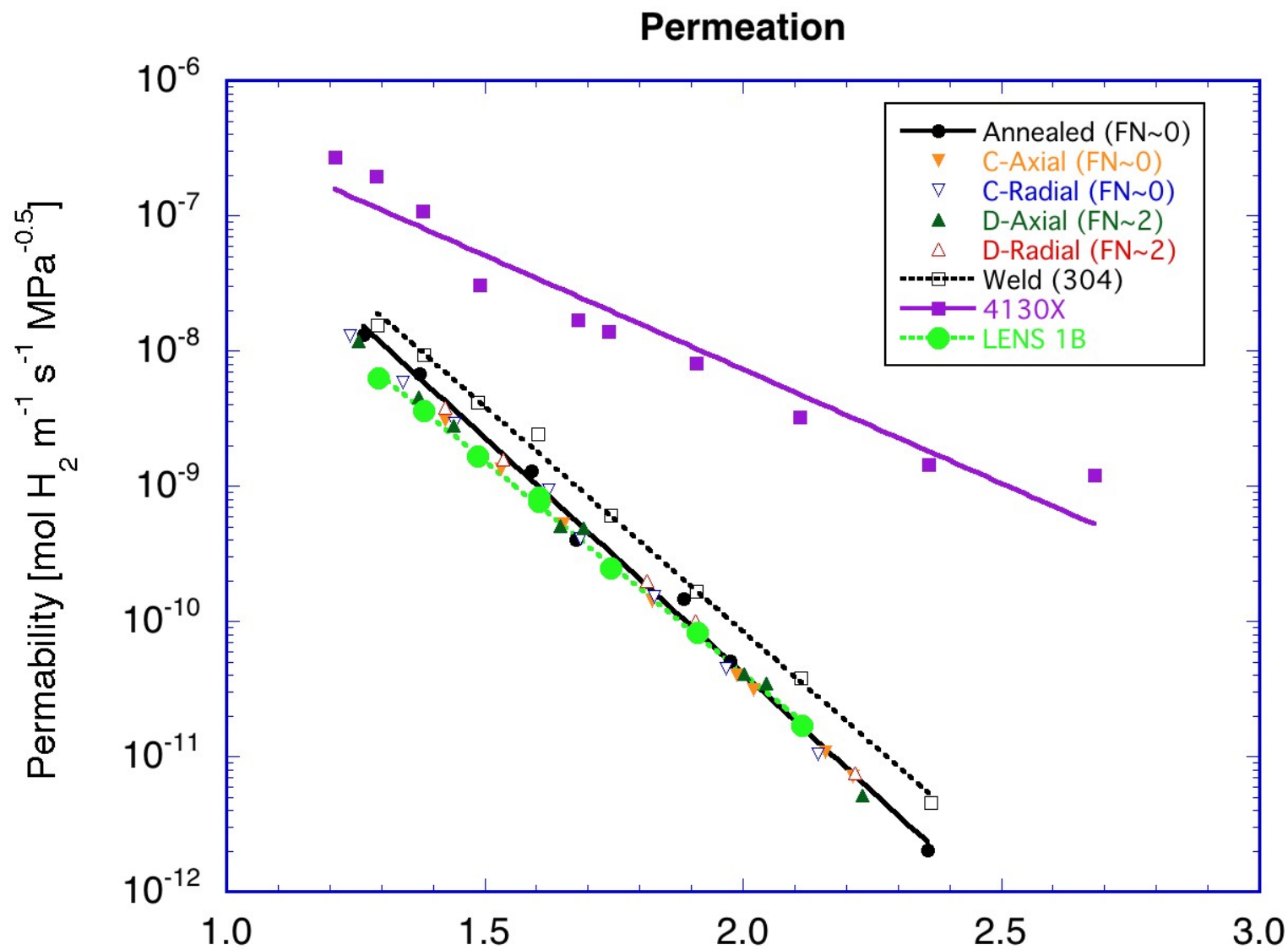
Permeation in ferrite exceeds ⁶ that in austenite



But modest ferrite increases don't increase permeability

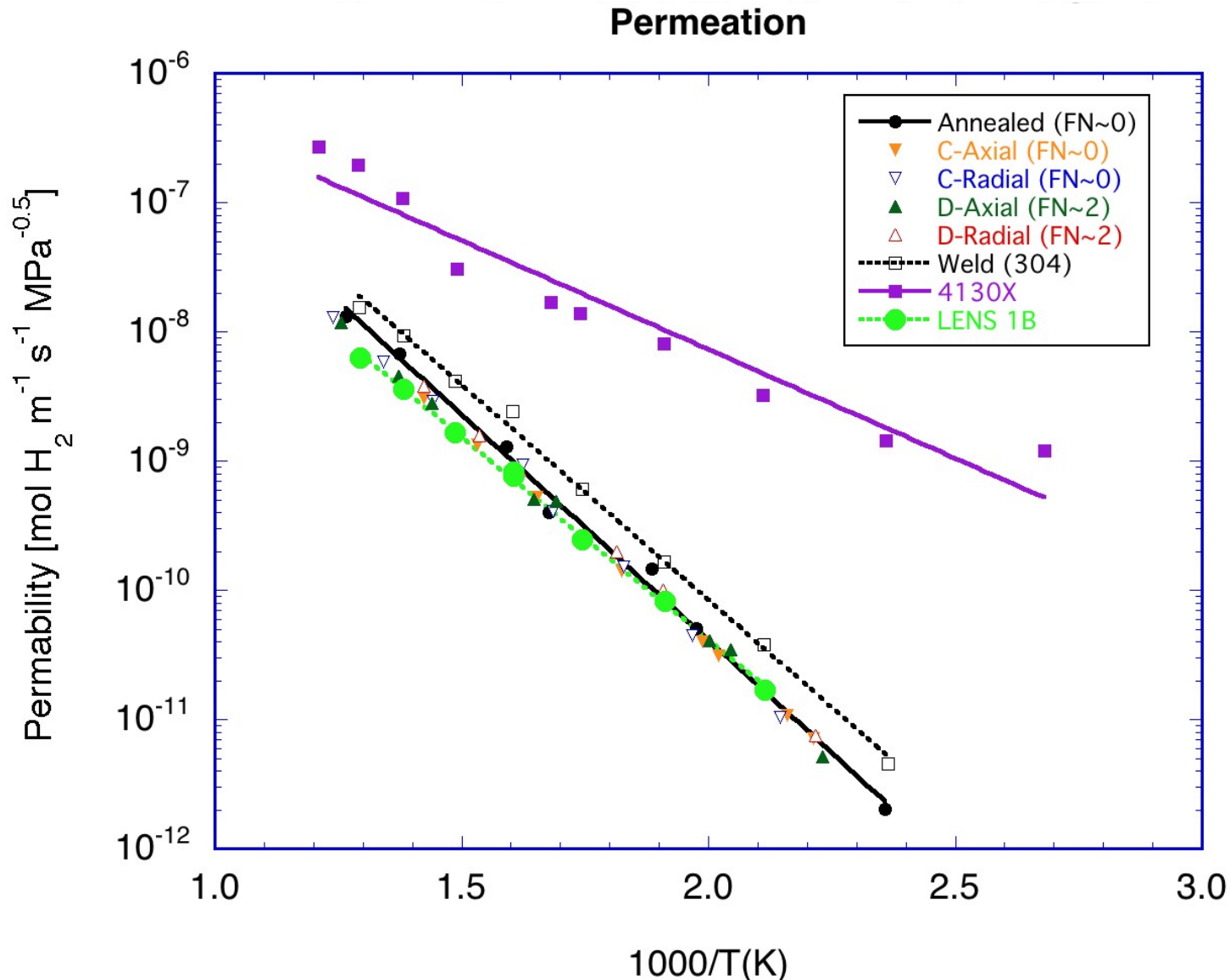
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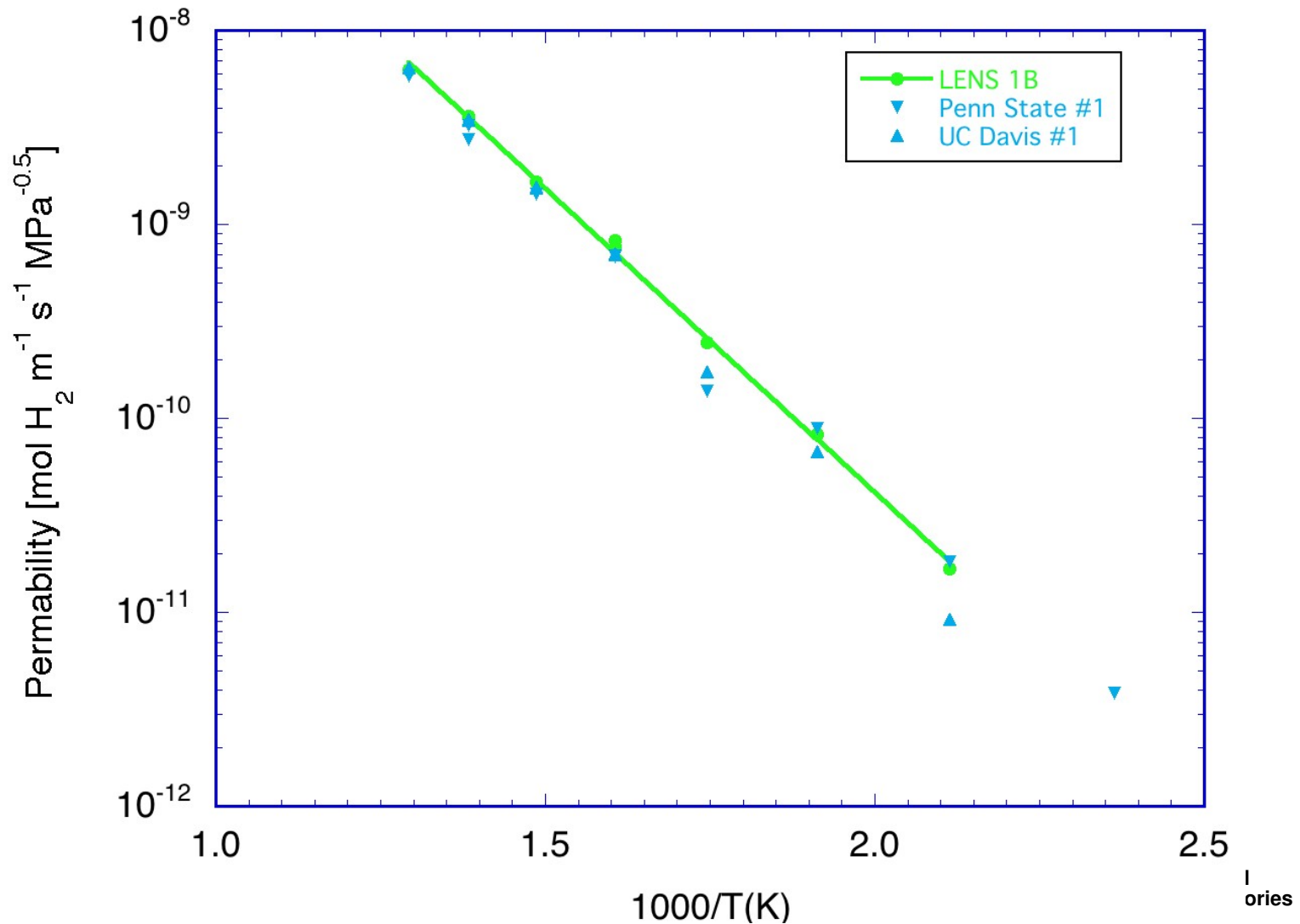
AM SS also shows similar permeabilities

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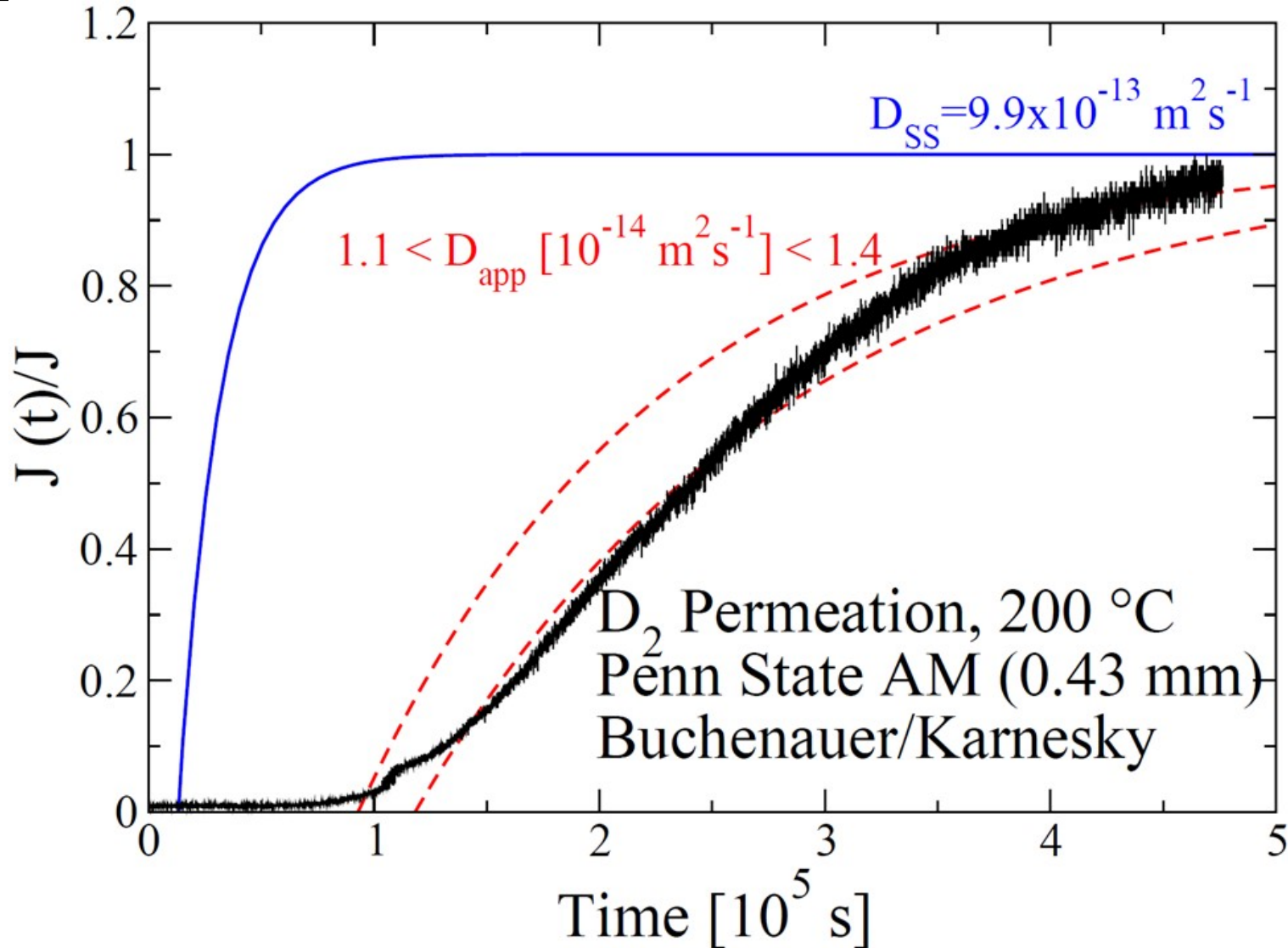
...Apparently regardless of ferrite content or manufacturer

Permeation of Additive Manufactured Steels

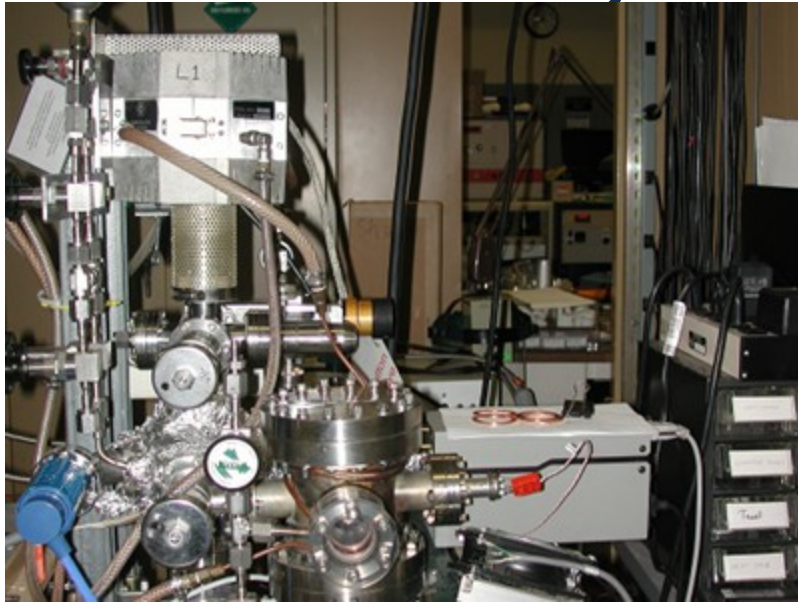


But AM has much lower apparent diffusivity

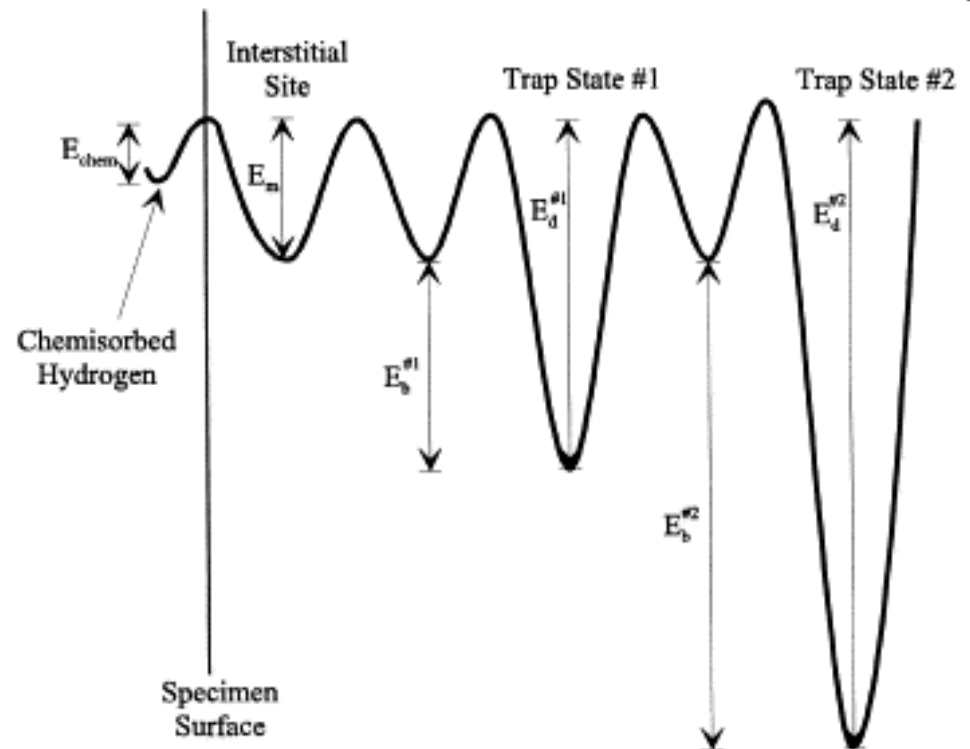
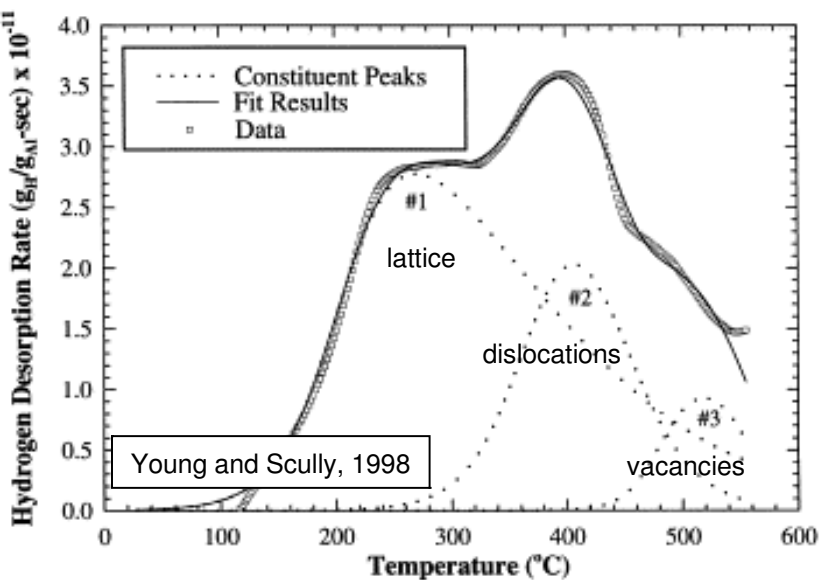
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Bulk Analysis Using TDS



- Measures total dissolved and trapped hydrogen and deuterium using an RGA
- Peak fitting spectra reveals trapping energies and occupancies
 - IR furnace ($>1000\text{ }^{\circ}\text{C}$)





Plans

- Characterize trapped D2 using Thermal Desorption Spectroscopy
- Seek microstructural origins of these traps
 - Porosity?
 - Ferrite or Ferrite/Austenite boundaries?
- Study various materials produced through the AM GTS round robin

