Toward tougher metallic materials for high-pressure hydrogen storage

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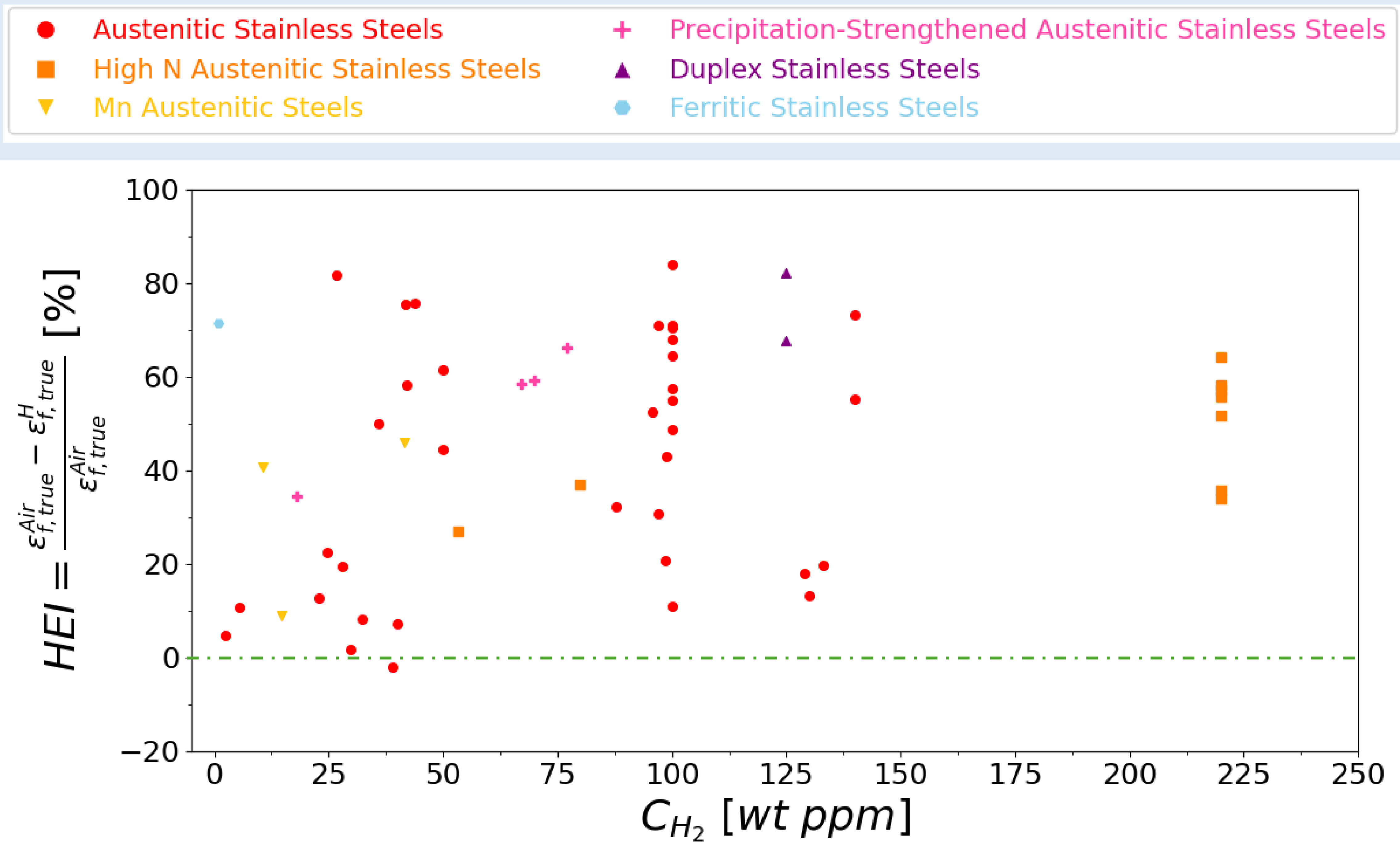
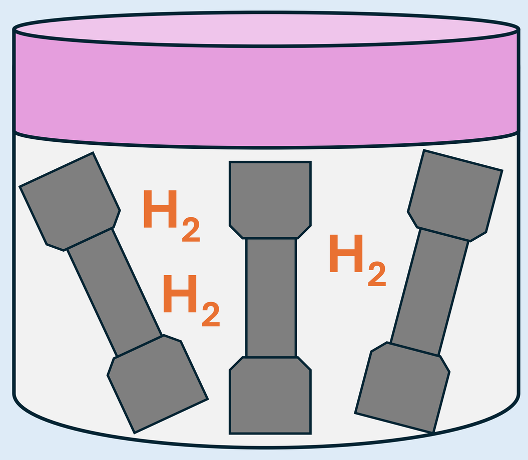
Context

- ❑ Fully metallic (Type I) pressure vessels are limited by hydrogen embrittlement.
- ❑ The problem intensifies at high pressures, requiring new alloys and multilayer solutions, combining:
  - ❖ Low hydrogen permeability
  - ❖ High resistance to hydrogen embrittlement
  - ❖ Excellent mechanical strength
  - ❖ Cost-effectiveness to enable large-scale deployment

Hydrogen embrittlement of steels

Hydrogen gaseous pre-charging and test in air





Higher susceptibility to hydrogen embrittlement

Austenitic stainless steels have the **highest resistance to hydrogen embrittlement** but:

- High amount of Ni: Expensive
- Low yield strength (200-320 MPa)

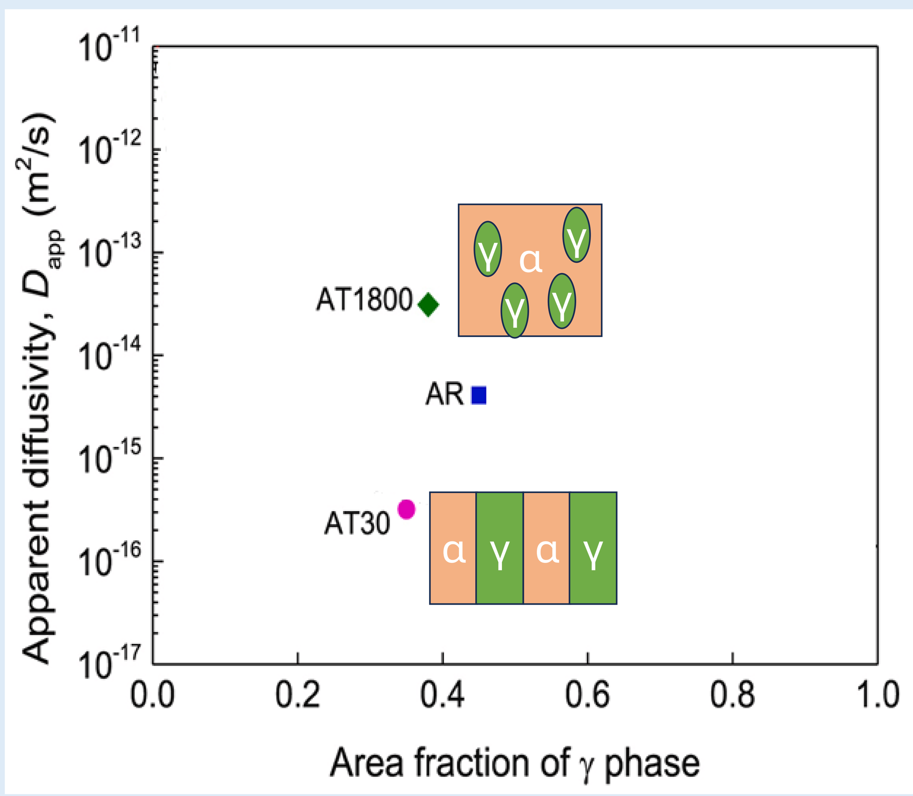
Material selection

Materials with reduced or no Ni content and high yield strength:

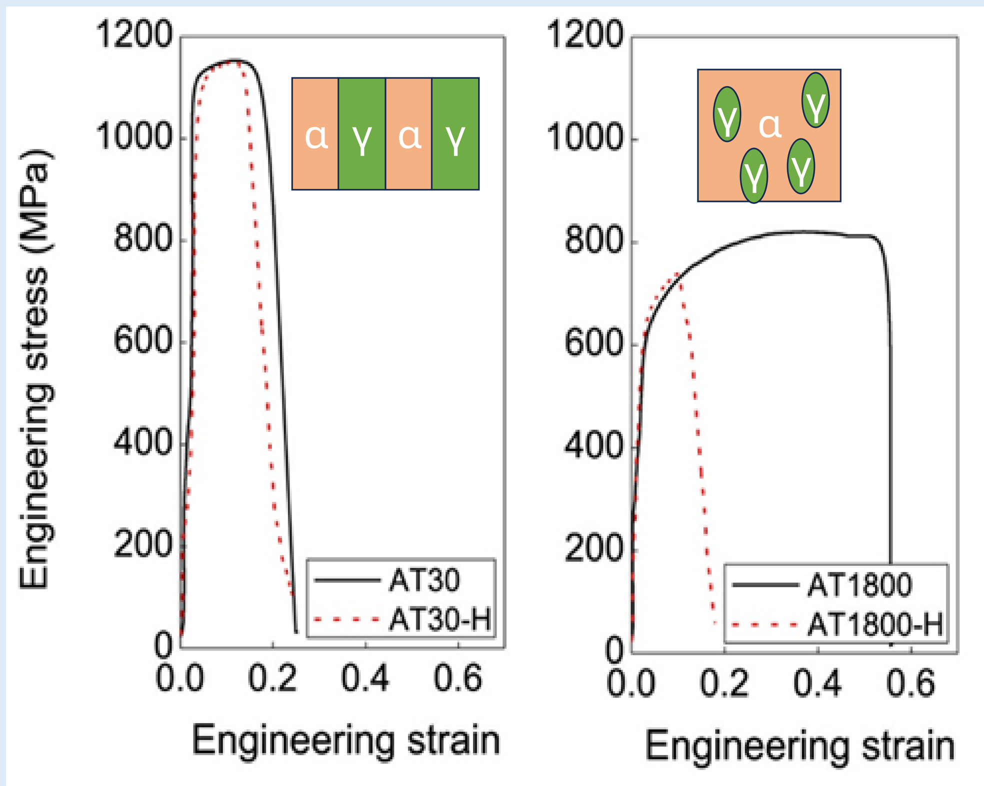
- ❖ **Fe-Cr-Ni duplex stainless steels**: Ferrite/Austenite
- ❖ **Fe-Mn dual phase steels**: Ferrite/Austenite

Impact of:

1. Austenite phase fraction
2. Percolation of austenite

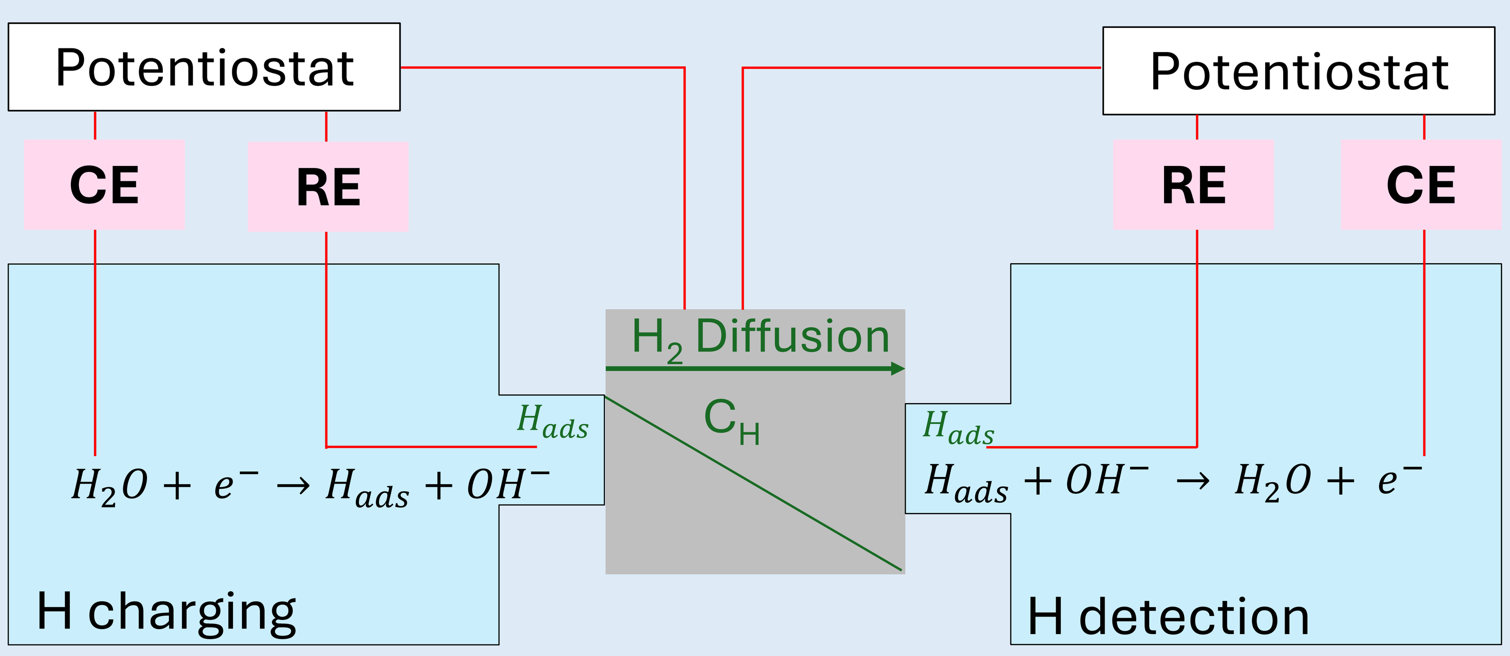


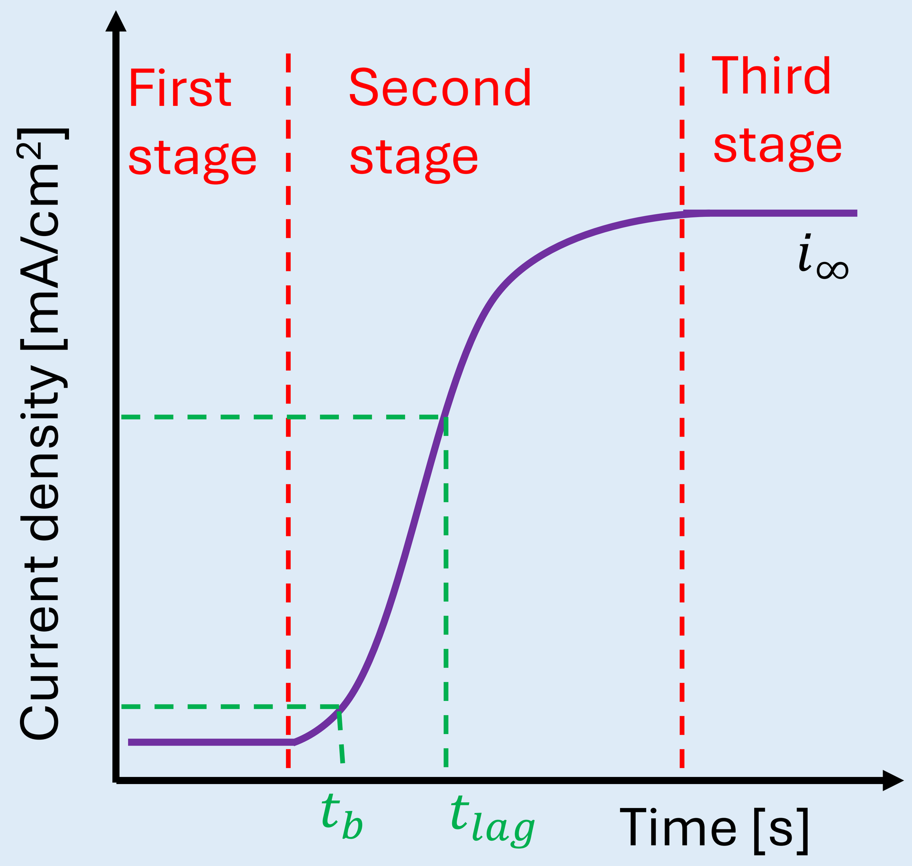
(Y. Wang et al.)



Electrochemical permeation

3-electrode cells:





Diffusivity measurements:

- ❖ Breakthrough time method:

$$D_{eff}(t_b) = \frac{L^2}{7.7\, t_b}$$

- ❖ Time-lag method:

$$D_{eff}(t_{lag}) = \frac{L^2}{2\, t_{lag}}$$

- ❖ Numerical methods

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