

Improving the Fatigue Resistance of Ferritic Steels in Hydrogen Gas

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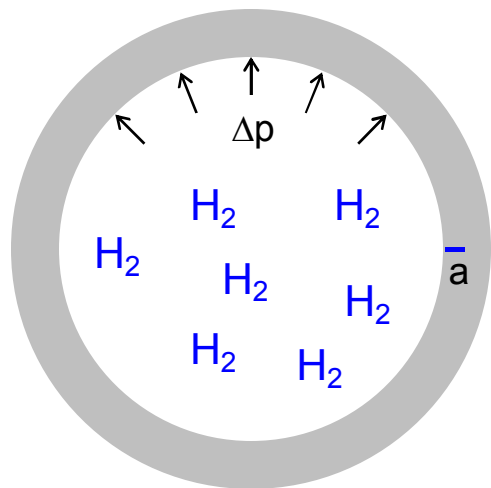
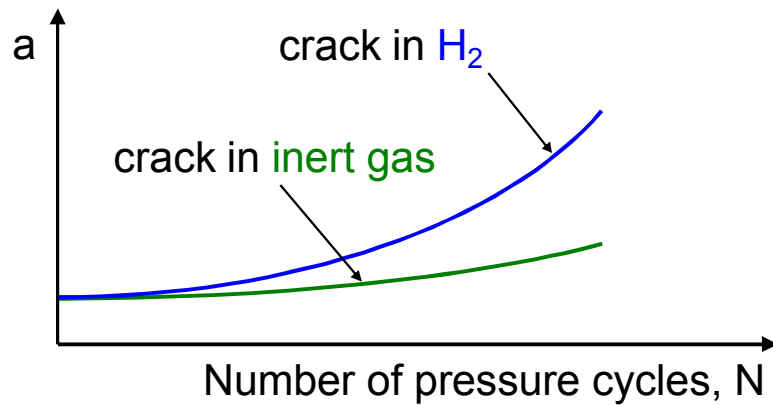


I²CNER Kick-off Symposium
Fukuoka, Japan
February 1, 2011



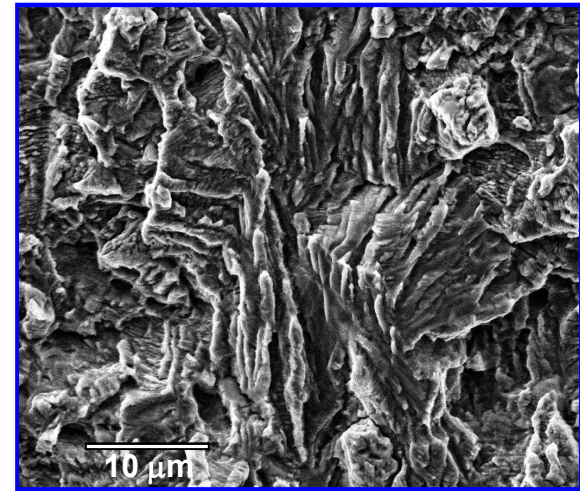
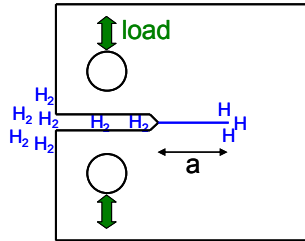
Hydrogen embrittlement is an important safety consideration for metal components

Hydrogen embrittlement accelerates fatigue cracking

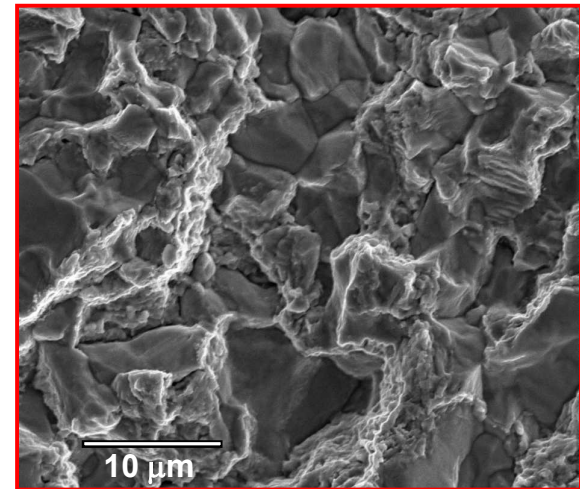


Barthélémy, 1st ESSHS, 2006

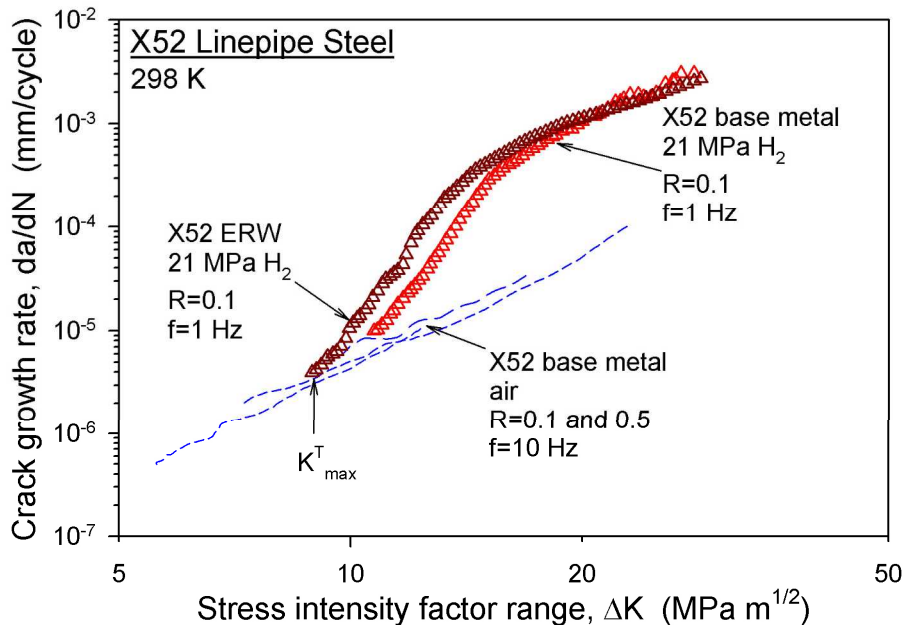
Low-cost ferritic steels exhibit pronounced H₂-enhanced fatigue crack growth



air



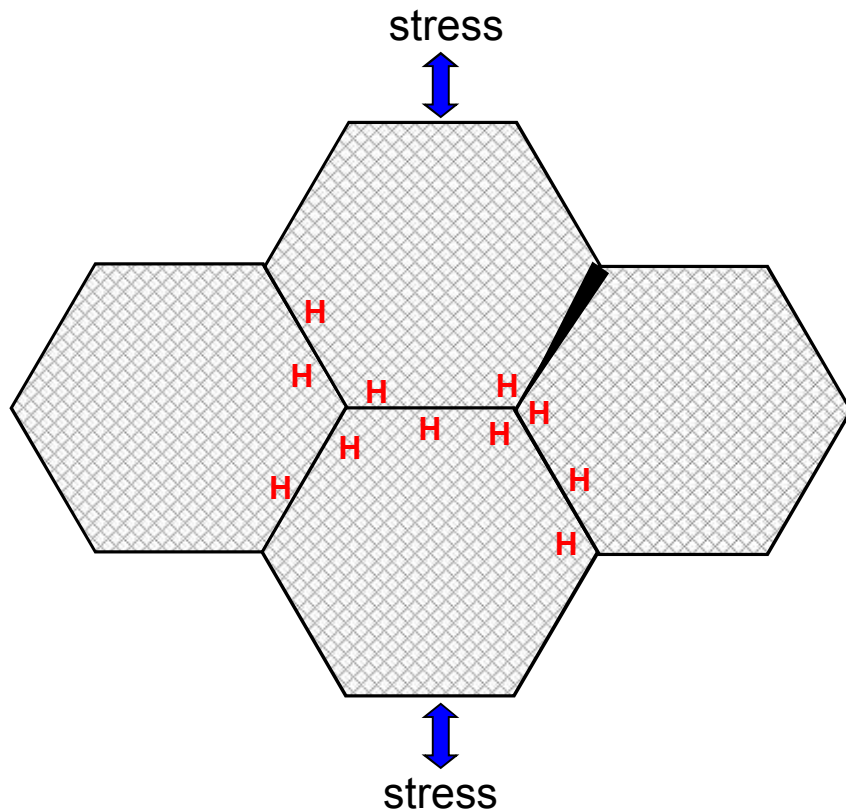
H₂



Improving fatigue crack growth resistance in H₂ must address intergranular fracture

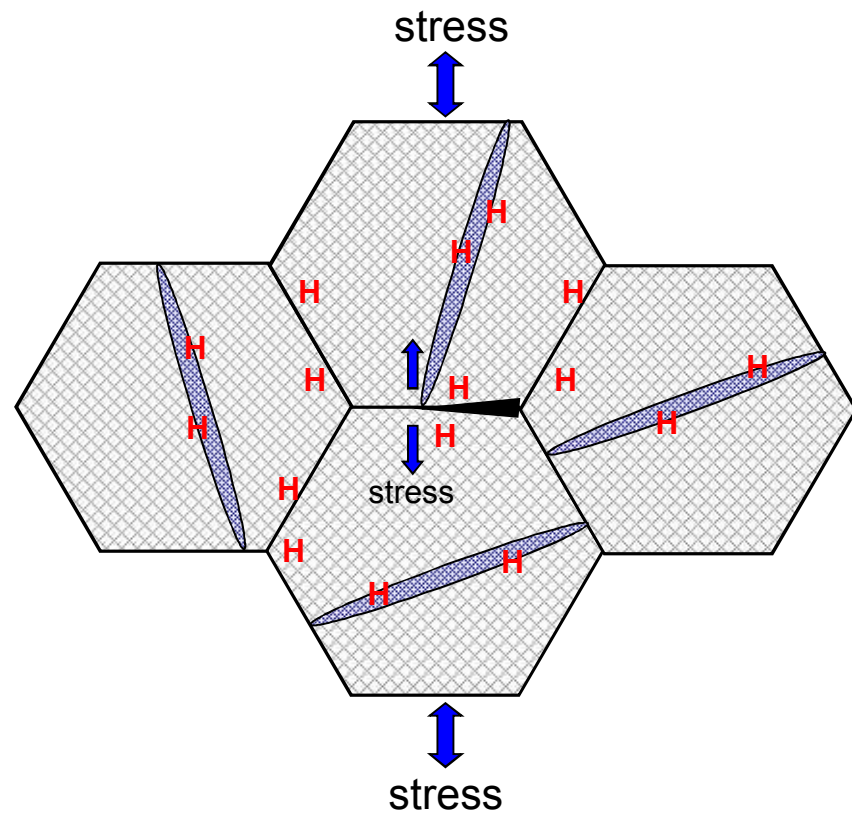
What is intergranular (IG) fracture?

Hydrogen can enable fracture along crystal interfaces



- We do not understand:
 - Why H_2 -induced IG fracture in low-strength steels under cyclic stress?
 - How can IG fracture be mitigated?

Does cyclic plastic deformation enable H₂-induced intergranular fracture?

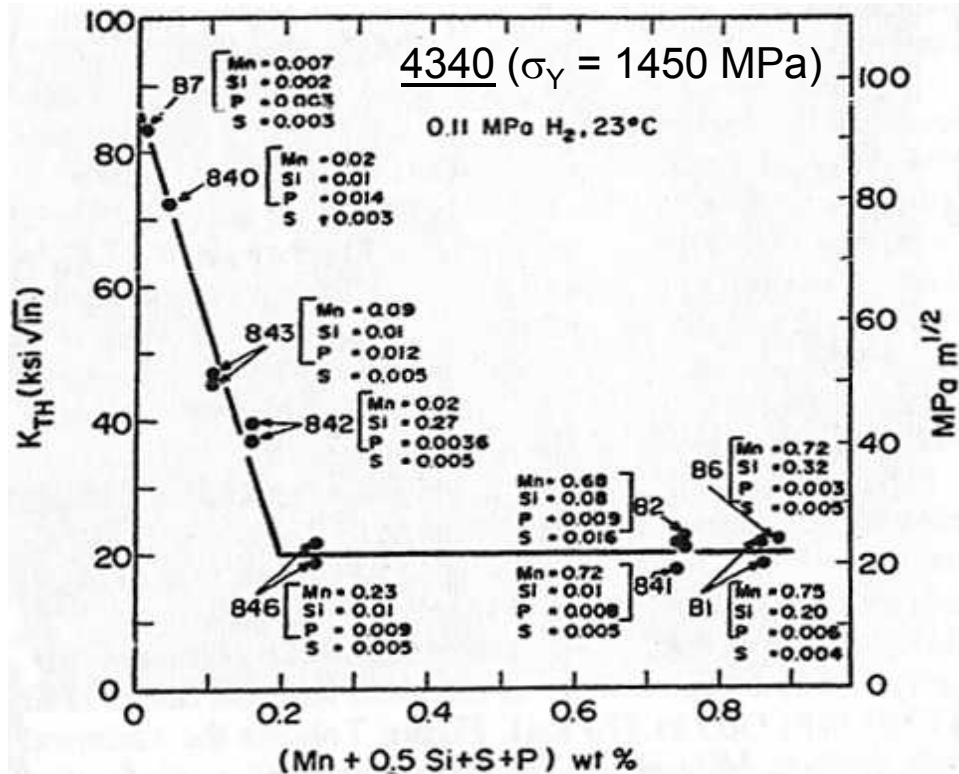
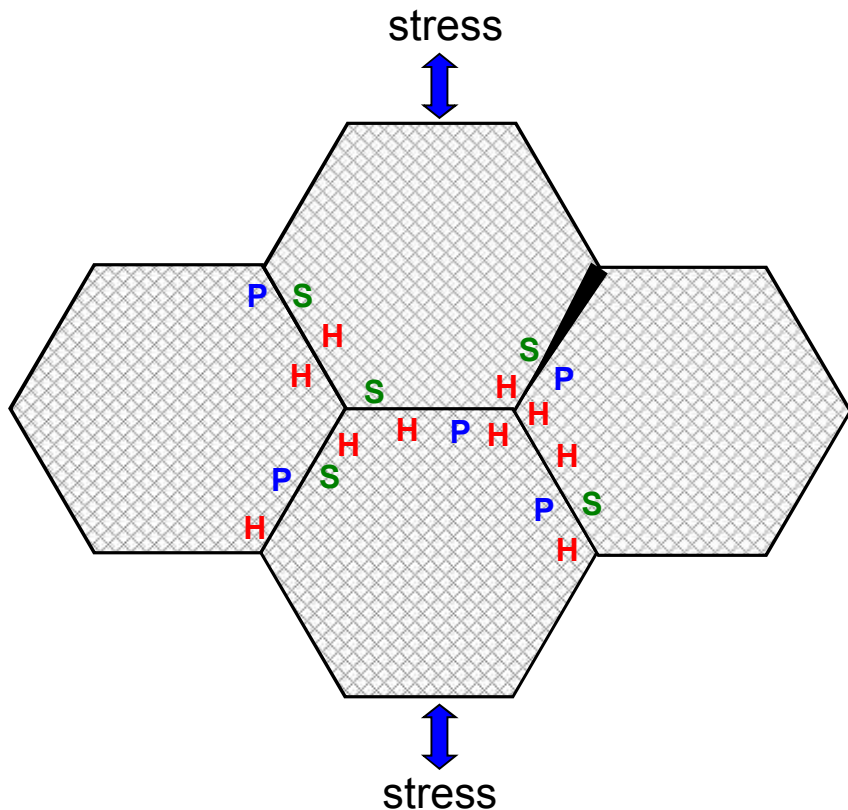


- Investigate interaction of deformation with interfaces
 - Quantify local stress using simulations
- Explore possible role of H₂-enhanced cyclic deformation
 - Are H₂-enhanced deformation and H₂-induced interface decohesion synergistic?

(Ritchie, Sofronis, Somerday, et al., *J. Mech. Phys. Solids*, 2010)

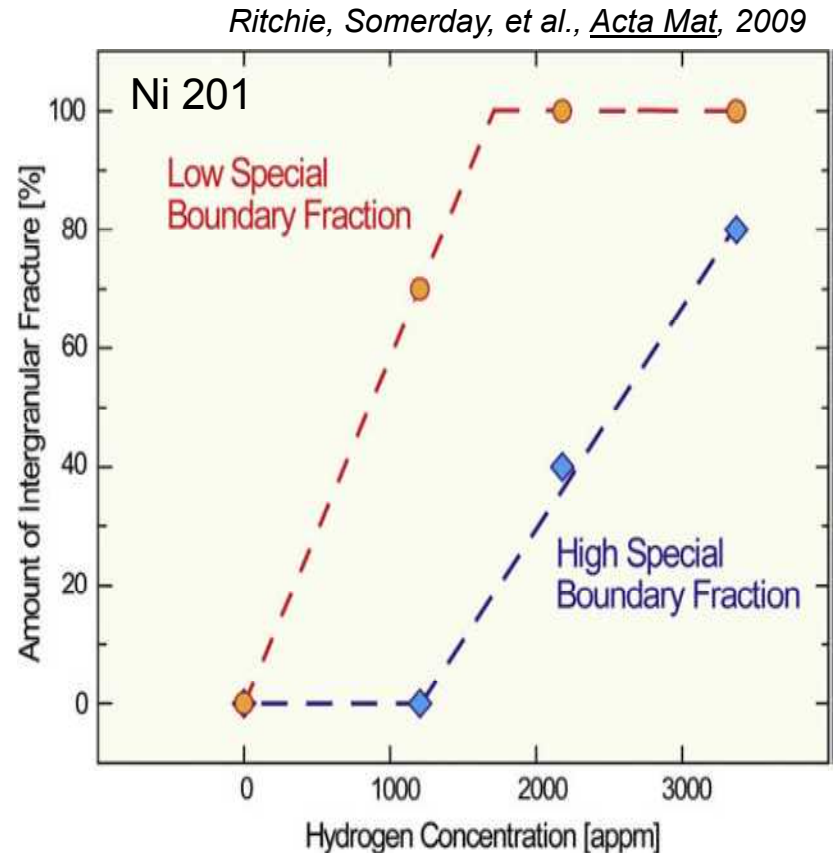
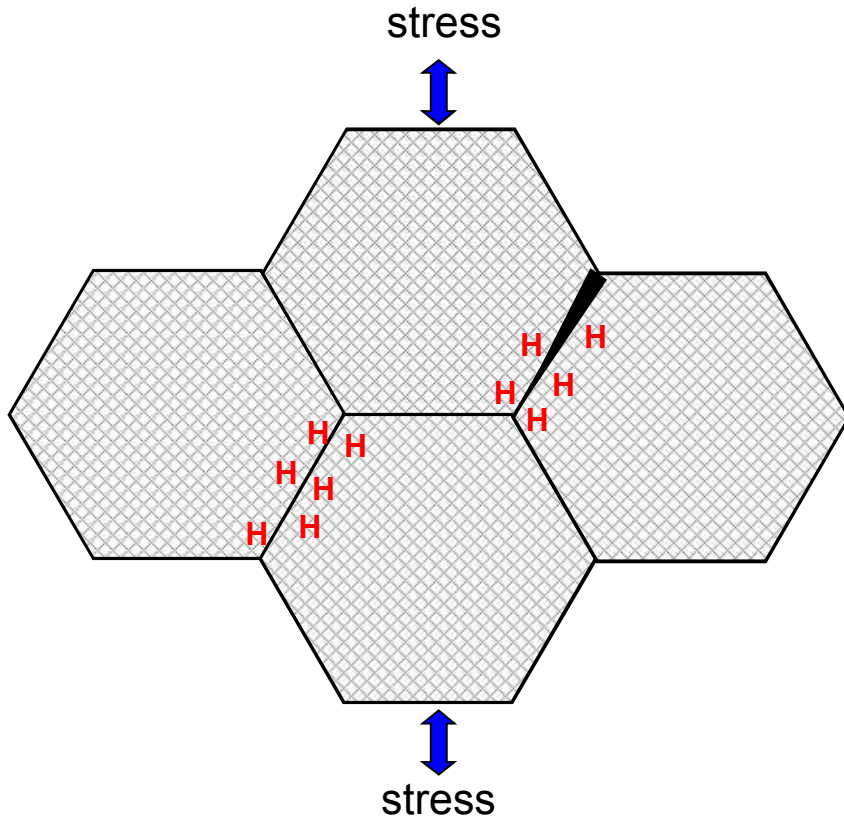
Do impurities at interfaces promote IG fracture?

McMahon et al., *Met. Trans. A*, 1983



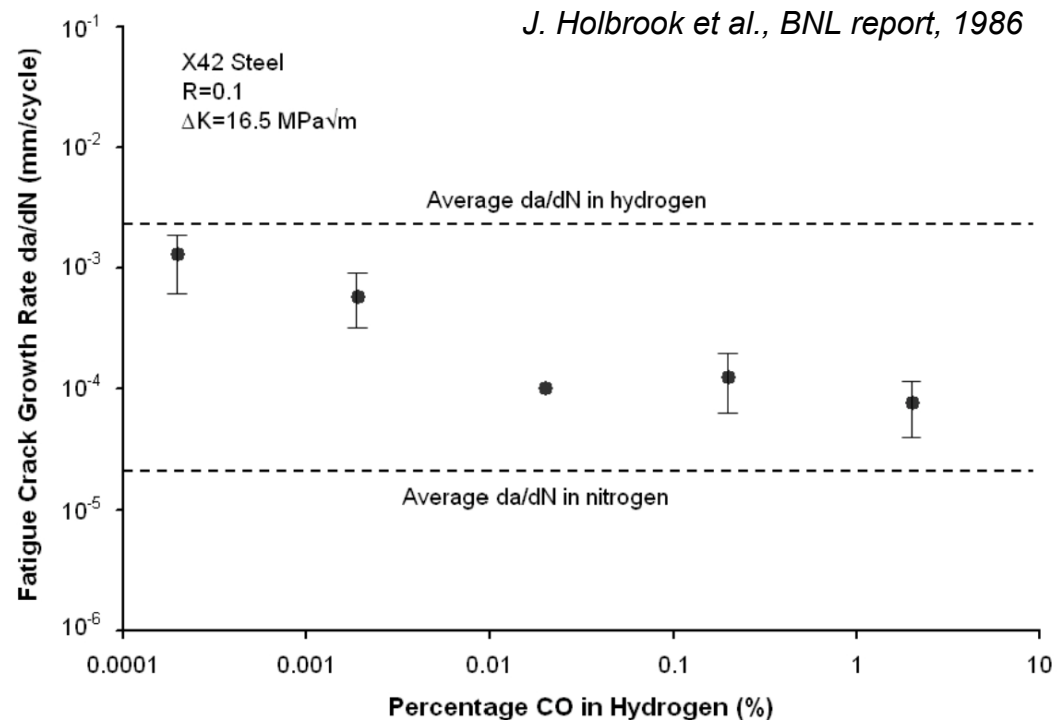
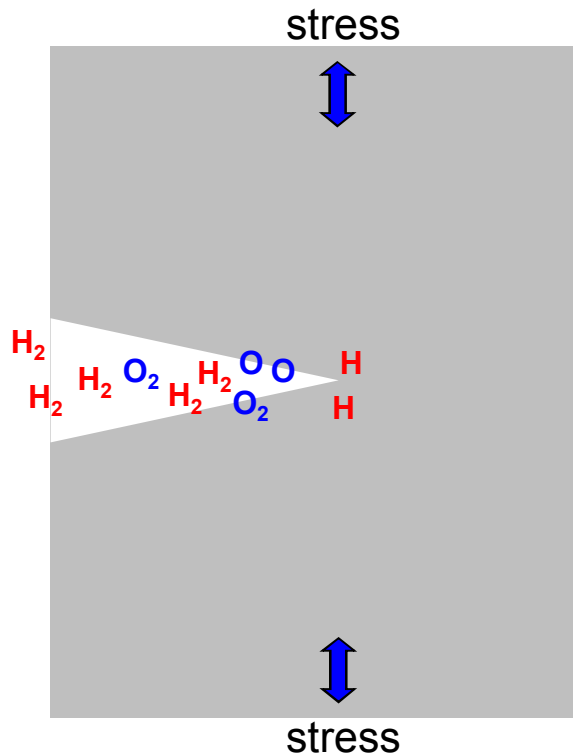
- Characterize composition of interfaces using modern analytical instruments
- Develop steels with “clean” interfaces

Can interface structure be modified to improve resistance to H₂-induced IG fracture?



- Explore possibility of altering interface structure (orientation, defects, etc.)

Can extrinsic mechanism mitigate H₂-accelerated fatigue crack growth in steels?



- Investigate effect of deformation on competitive adsorption of H₂ and inhibitor (e.g., O₂)
- Include inhibitor-affected H₂ uptake kinetics in crack growth models

Summary

- Hydrogen-accelerated fatigue crack growth is an important safety consideration for low-cost ferritic steels
- Improvement of fatigue crack growth resistance in H₂ requires better understanding of *interfaces*
 - Interaction of cyclic deformation with grain boundaries
 - Alloy impurity content of grain boundaries
 - Structure of grain boundaries
 - Competitive adsorption of H₂ and inhibitors on free surfaces