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Mitigation of hydrogen embrittlement by addition of ammonia impurity

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Objective and strategy

Mitigation of hydrogen embrittlement (HE) by deactivation of Fe catalyst by ubiquities small molecules. NH_3 is being studied.

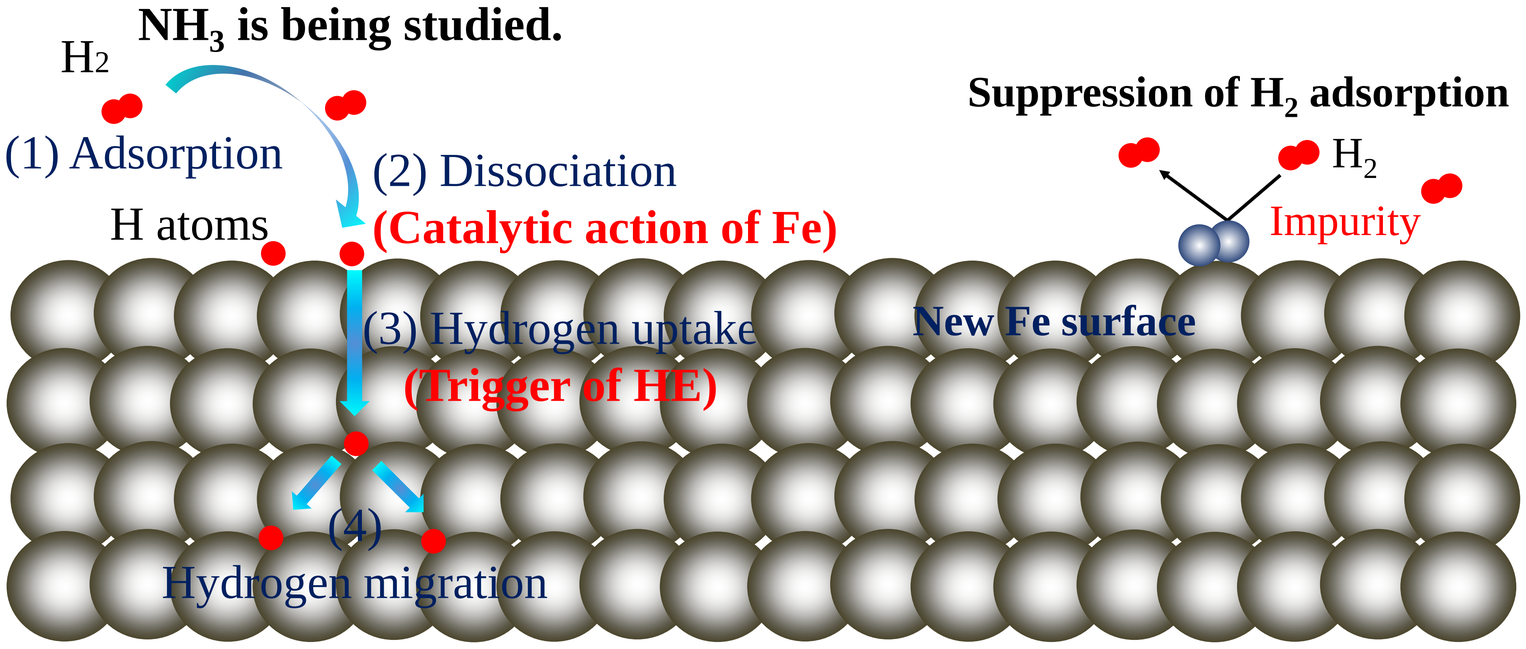


Fig.1 Hydrogen embrittlement process and impurity mitigation mechanism

Fracture toughness test (J_{IC} test)

ASTM E 1820 standard

- Crosshead speed (V) : 2.0 × 10^{-3} mm/s and 2.0 × 10^{-5} mm/s
- Gas temperature : 293 K (room temperature)
- Gas pressure (p) : 0.1MPa
- Material : SCM440 (HV329)

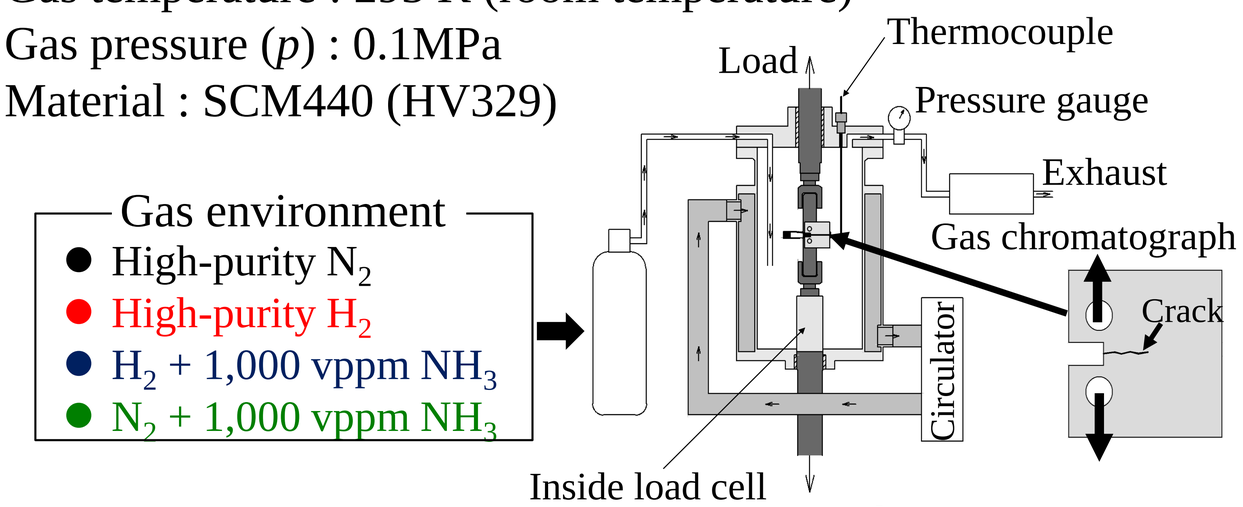


Fig.3 Fracture toughness test equipment

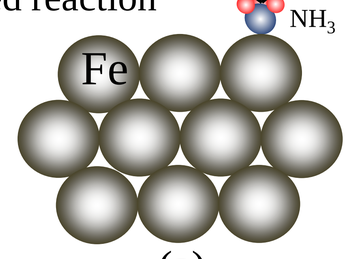
Discussion

Mechanisms of NH_3 mitigated and induced HE

Adsorption rate: NH_3 > H_2 Decomposition of NH_3 → **H** + NH_2

Mitigate HE

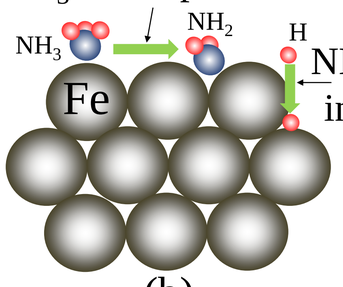
NH_3 occupied reaction sites of H_2



(a)

Induce HE

NH_3 decomposition



NH_3 derived H uptake into the material and induce HE

(b)

Fig.5 Possible mechanism

Time dependent activation of HE by NH_3

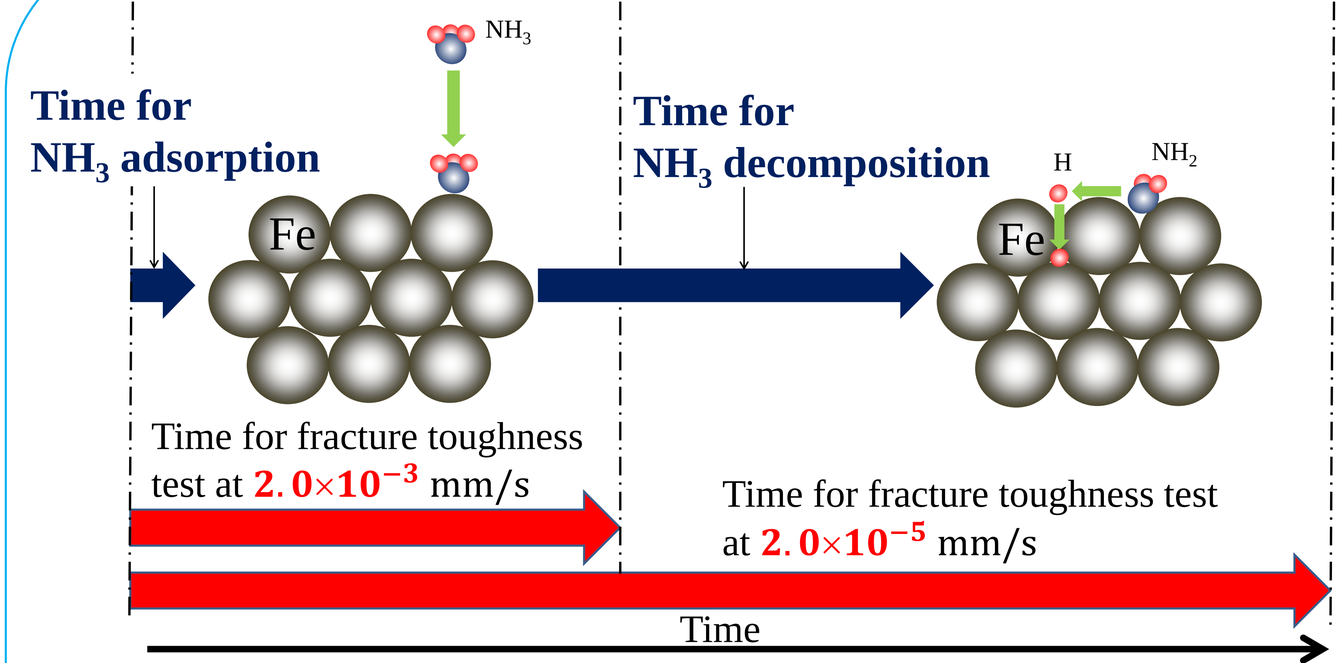
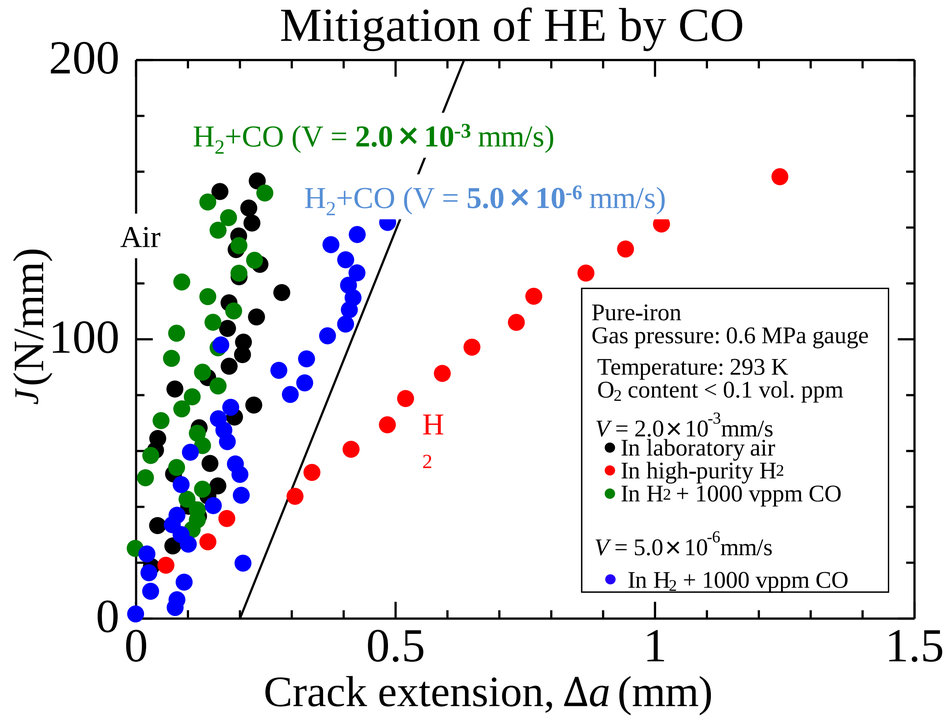


Fig.6 NH_3 adsorption and decomposition reaction occurred step with time

NH_3 mitigated HE at fast loading rate, while induced HE at slow loading rate.

Result

HE in fracture toughness test & Mitigation of HE by CO



A. Staykov et al, J. Phys. Chem, C 2019, 123, 30265-30273.

Fig.2 Fracture toughness test of pure iron

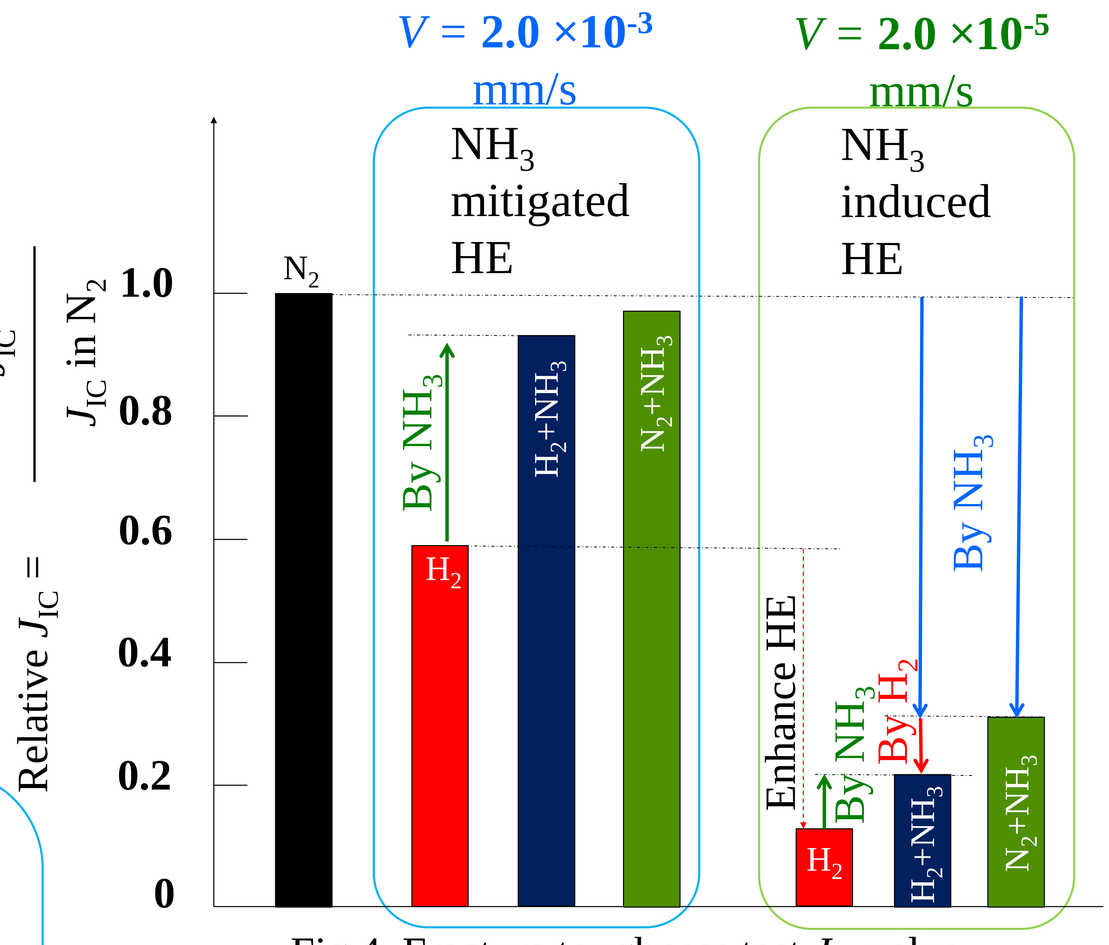


Fig.4 Fracture toughness test J_{IC} value

Another candidate mechanism: Incomplete coverage of Fe surface by CO

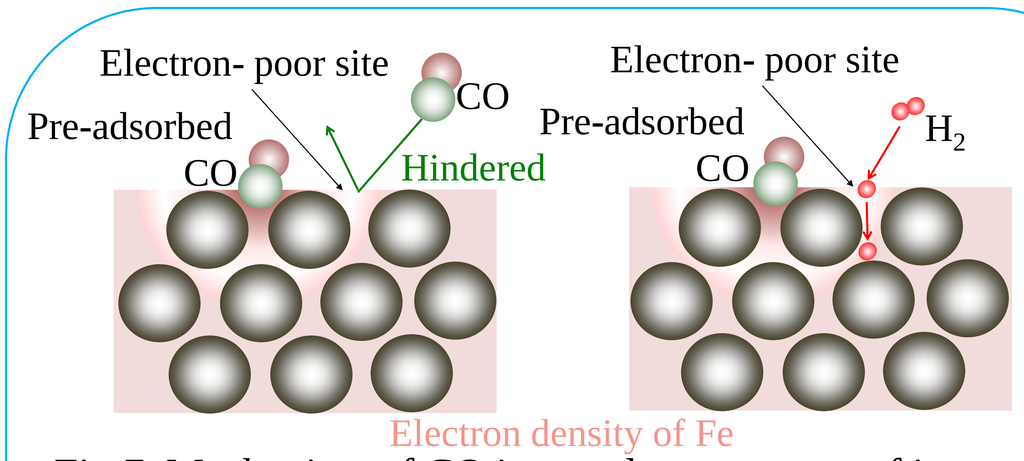


Fig.7 Mechanism of CO incomplete coverage of iron surface

CO adsorbs on Fe surface
CO withdraw and localize the electron density
Form electron-poor site at adjacent adsorption site
Hinder subsequent CO adsorption, but H2
CO can't cover entire Fe surface
Decrease the loading rate decrease the mitigation effect
(same mechanism may work in the case of NH_3 mitigation)

Conclusions

NH_3 works as both mitigator of HE and inducer of HE depending on conditions.