On the Mechanism of Metal Dusting Corrosion

C.M. Chun and J.D. Mumford
Corporate Strategic Research
ExxonMobil Research and Engineering Company
Annandale, NJ 08801 USA

T.A. Ramanarayanan
Department of Chemistry
Princeton University
Princeton, NJ 08544 USA

Metal dusting is a severe form of corrosive degradation of metals and alloys at high temperatures (300-850^{o}C) in carbon-supersaturated gaseous environments. Fe, Ni and Co, as well as alloys based on these metals are all susceptible. The corrosion manifests itself as a break-up of bulk metal to metal powder- hence the term, metal dusting. Early research by Hochman and coworkers (1) identified the role of a metastable carbide, M_3C, in initiating metal dusting. Later work by Grabke and co-workers (2, 3) expanded on the formation-dissociation mechanism of the M_3C carbide. Their research also extended to the mechanistic aspects of alloy corrosion, in particular, the break-up of surface oxide films in initiating localized attack. The micro-mechanistic aspects of metal dusting have been investigated by transmission electron microscopy (4, 5).

The present work is a study of the metal dusting corrosion of pure metals, Fe, Ni and Co in high carbon activity environments. The main goal of the study was to advance the atomic level understanding of metal dusting. Investigations covered a temperature range from 350 to 1050^{o}C. Four regimes of corrosion were identified for Fe as a function of temperature (figure 1). In regime I the corrosion rate gradually increases with temperature, in regime II the corrosion rate undergoes a rapid rise, in regime III the corrosion rate decreases with temperature and in regime IV, the rate is more or less constant. Formation of metastable Fe_3C resulting from carbon supersaturation at the surface, followed by its dissociation triggered by interfacial graphite, are phenomena associated with regimes I, II and III. Intercalation and diffusion of iron atoms in graphite are the mechanisms whereby metal particles are carried away from the corrosion interface. In regime IV no metastable M_3C forms: there occurs direct intercalation of iron into graphite. For Ni and for Co, where no metastable carbide forms over the entire temperature range, the metal dusting mechanism is similar to regime IV for iron. These mechanisms are schematically illustrated in figure 2.

References

1. R.F. Hochman, *Proc. 4th Int. Congress on Metallic Corrosion*, ed. by N.E. Hammer, 260 NACE (1972).
2. H.J. Grabke, R. Krajak and J.C. Nava Paz, Corrosion Science, 35 1141 (1993).
3. H.J. Grabke, *Materials and Corrosion*, 49 303 (1998).
4. E. Pippel, J. Woltersdorf and R. Schneider, *Materials and Corrosion*, 49 309 (1998).
5. C.M. Chun, J.D. Mumford and T.A. Ramanarayanan, *J. Electrochem. Soc.*, 147 3680 (2000).

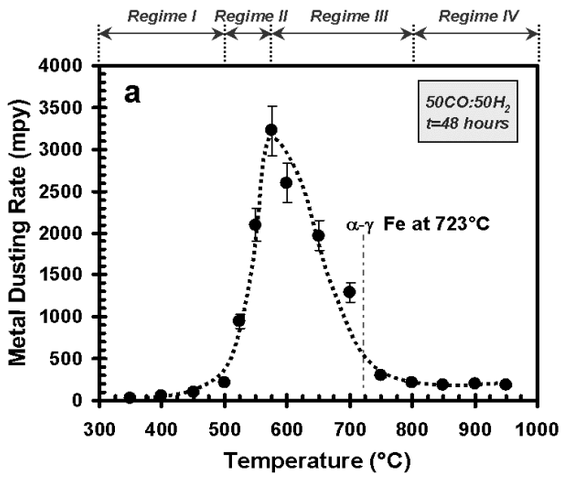

Figure 1. Temperature dependence of the metal dusting corrosion rate of iron in 50CO:50H_2 gas mixture.

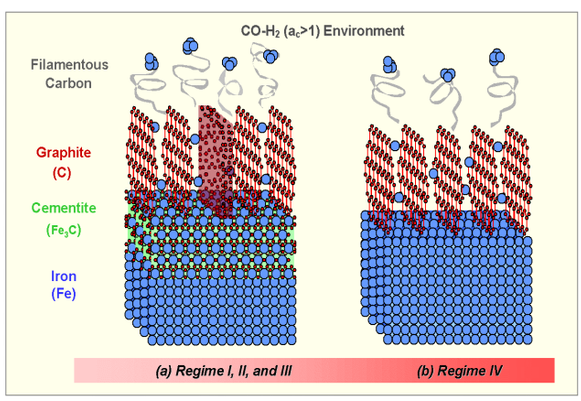

Figure 2. Schematic representation of the mechanism of metal dusting corrosion of iron.