Effect Of Water Vapor On The Void Growth In Magnetite Scale At 823 K

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Introduction- Growing scales in high temperature oxidation of metals frequently contain voids. Maruyama et al.[1)] have demonstrated semi- quantitatively that the formation of voids is explained by the divergence of the smaller flux of oxide ion which diffuses in the chemical potential distribution in the scale. The chemical potential distribution is fixed by the larger flux of metal ion.

This study deals with the growth of voids and the effect of water vapor on the growth of the voids in magnetite scale.

Experimental- Iron specimens (10 x 20 x 1 mm^3 in size) were oxidized at 823 K in the atmospheres of P_{O2} = 2.1 x 10^4 Pa with various P_{H2O} ranging from 64 Pa to 1.4 x 10^4 Pa (dew-point : 243-348 K) for up to 432.0 ks. After the oxidation test, mass gain of the sample was measured. Phase identification and microstructure observation of the scale formed on the iron specimen was evaluated by XRD, SEM and EPMA.

Results- Figure 1 shows the fracture surfaces of oxide scales at various water vapor partial pressures. The scale consists of thick magnetite covered with thin hematite. The thickness of magnetite scale is almost independent of water vapor partial pressure. Hematite scale is thicker at higher water vapor pressure. The voids are small at higher water vapor pressures but elongate at lower water vapor pressures. The boundary between these two different growth modes is around P_{H2O} = 10^3 Pa.

Discussion- All scale growth conditions are thermodynamically identical from the viewpoint of oxygen chemical potential. The iron/magnetite and magnetite/hematite interfaces are reasonably assumed to be at the their equilibrium oxygen potentials, and the hematite/gas interface is fixed at P_{O2} = 2.1 x 10^4 Pa. The only difference is the water vapor potential. The proton, which may dissolve into scales, did not affect the iron transport in magnetite, which is the rate-determining step in growth of magnetite. However, the dissolved proton enhanced the inward oxygen diffusion in hematite, which is the rate-determining step in growth of hematite. The behavior of void growth was largely affected by water vapor. This fact may be explained by the absence and existence of water vapor in voids for dry and wet conditions, respectively.

Reference

1) T. Maruyama, N. Fukagai, M. Ueda and K. Kawamura, Proc. 6th Symp. High Temp. Corros.
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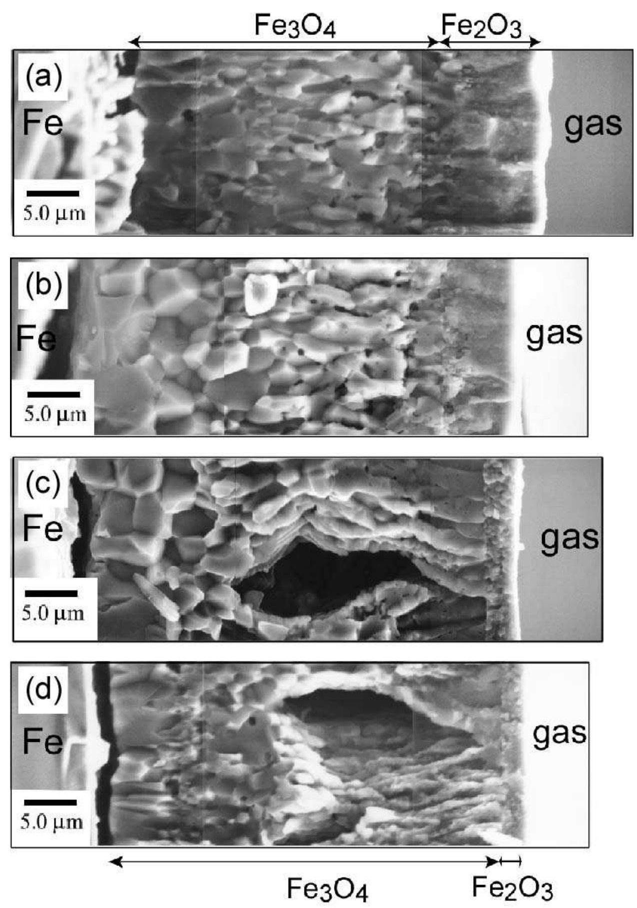

Figure 1 The fracture surfaces of the oxide scales formed on the iron specimens in the atmospheres of P_{O2} = 2.1 x 10^4 Pa with various water vapor partial pressures. (a) P_{H2O} = 1.4 x 10^4 Pa, (b) P_{H2O} = 5.6 x 10^3 Pa, (c) 611 Pa and (d) 64 Pa.