

Corrosion Resistance of Oxide Scales Formed in High-Temperature Oxidation of Al-Bearing Ferritic Stainless Steels

Yu Sugawara¹, Misako Ogiwara^{1,2}, Izumi Muto¹, Toru Inakuma³, Hiroaki Sakamoto³, Nobuyoshi Hara¹

¹Department of Materials Science, Tohoku University
6-6-02, Aramaki, Aoba-ku, Sendai 980-8579, Japan

²Present address: EBARA Corporation
4-2-1, Honfujisawa, Fujisawa, 251-8502, Japan

³Technical Research & Development Bureau
Nippon Steel & Sumitomo Metal Corporation
20-1, Shintomi, Futtsu, 293-8511, Japan

Al-bearing ferritic stainless steels with the oxide scales formed in a high temperature oxidation are used as a support material of a catalytic converter in vehicles. Aqueous condensates are produced in the exhaust system during the short-distance driving. The condensates cause localized corrosion of the stainless steel components. In this study, the corrosion resistance of the oxide scales on Al-bearing ferritic stainless steels under the aqueous condensate environment was investigated.

Two kinds of ferritic stainless steel foils (Fe-20Cr-5Al, Fe-20Cr-8Al), which were 32 μm in thickness, were used as specimens. All the specimens were heat-treated at 973, 1173, and 1373 K for 1 h in air to form oxide scales on the surface. Electrochemical measurements were conducted in the condensate at 363 K simulating the exhaust system of vehicles. The ionic composition of the simulated condensate is shown in Table 1. The condensate was adjusted to pH 3.5 using a H_2SO_4 solution.

Figure 1 shows the cathodic polarization curves of Fe-20Cr-5Al and Fe-20Cr-8Al oxidized at temperatures (T_{ox}) of 973, 1173, and 1373 K. Cathodic reactions were inhibited with the increase of T_{ox} and the additive amount of Al. The polarization curve in a phosphate buffer solution (pH = 3.5) in Fig. 2 reveals that the cathodic behaviors of the oxide scales are not affected by the ionic composition of the condensate.

Figure 3 indicates the depth profiles of cation fractions for the oxide scales of Fe-20Cr-5Al and Fe-20Cr-8Al measured by GD-OES. In this study, just the cation fractions of Fe, Cr, and Al (X_{Fe} , X_{Cr} , and X_{Al}) were taken into account; $X_{\text{Fe}} + X_{\text{Cr}} + X_{\text{Al}} = 1$. Thickness of the oxide layer was calculated on the basis of oxygen profiles by GD-OES. In the case of Fe-20Cr-5Al oxidized at 973 and 1173 K, Fe-rich oxide was formed in the outermost layer of the scale. This result indicates the cathode current detected in Fig. 1 was caused by the reductive dissolution of Fe_2O_3 . The depth profiles of the cation fractions for Fe-20Cr-5Al oxidized at 973 K after the potentiostatic polarization at -0.1 V vs. Ag/AgCl (3.33 M KCl) in the condensate at 363 K are shown in Fig. 4. It is confirmed that the thickness of the oxide layer decreased, and the Fe-rich outer layer disappeared in comparison with Fig. 3a. Figure 4 certainly supports the reductive dissolution of Fe oxides. Figure 3c and 3d suggest that the increases of T_{ox} and the additive amount of Al brought the growth of Al-rich oxide layers instead of Fe-rich ones. The inhibition of cathodic reactions shown in Fig. 1 corresponds to the form of the inert Al-rich oxide layer. It is expected that the oxide scales formed by the high-temperature oxidation of Fe-20Cr-8Al have high corrosion resistance.

Table 1 Ionic composition of the simulated condensate.

($\times 10^2$ ppm)					
CH_3COO^-	HCOO^-	NO_3^-	Cl^-	SO_4^{2-}	NH_4^+
31	31	72	9	710	275

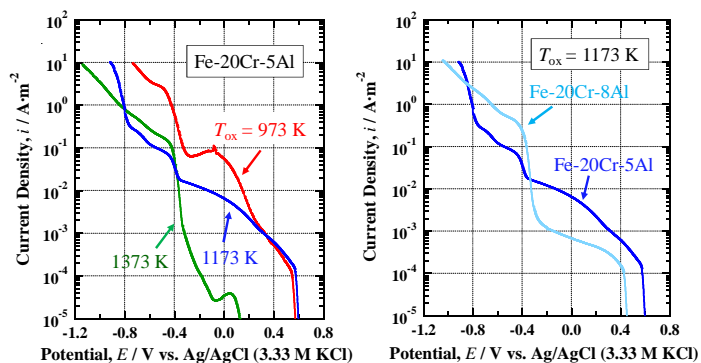


Fig. 1 Cathodic polarization curves of (a) Fe-20Cr-5Al oxidized at 973, 1173, and 1373 K, and (b) Fe-20Cr-5Al and -8Al oxidized at 1173 K in the simulated condensate.

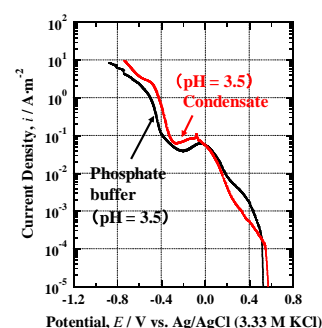


Fig. 2 Cathodic polarization curves of Fe-20Cr-5Al oxidized at 973 K in the simulated condensate and a phosphate buffer solution at 363 K.

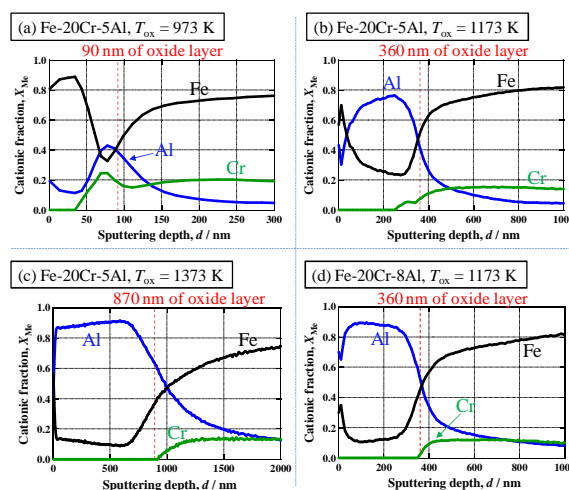


Fig. 3 Depth profiles of cation fractions for the oxide scales of (a) Fe-20Cr-5Al oxidized at 973 K, (b) 1173 K, and (c) 1373 K, and (d) Fe-20Cr-8Al oxidized at 1173 K.

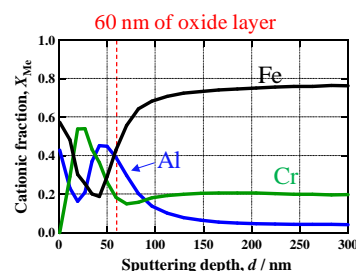


Fig. 4 Depth profiles of cation fractions for the oxide scales of Fe-20Cr-5Al oxidized at 973 K after the potentiostatic polarization at -0.1 V for 50 min.