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Corrosion Behavior of Amorphous Fe-Cr-Zr Alloys†

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KEY WORDS: (Corrosion) (Passivation) (Amorphous Alloys) (Iron) (Chromium)

In the last several years, amorphous metals produced by rapid quenching methods have generated both fundamental and practical interest because of their attractive character in mechanical, chemical and magnetic properties. Many kinds of amorphous alloys containing chromium and phosphorus reveal an extremely high corrosion resistance in acid and neutral solutions^{1), 2)}. The high corrosion resistance of amorphous alloys is attributable to the chemical homogeneity and the rapid formation of chromium-enriched passive film³⁾. In order to clarify the role of phosphorus the corrosion behavior of amorphous alloys composed of only metallic elements should be

investigated. The present paper examines the corrosion resistance of amorphous Fe-Cr-Zr alloys.

Melt-spinning method was applied to the preparation of amorphous $Fe_{90-x}Cr_xZr_{10}$ ($X = 0 \sim 25$) alloys by rapid quenching from the liquid state. The number attached to respective element denotes the nominal content in atomic percent. The amorphous ribbons prepared were about 2 mm wide and 30 μm thick. The formation of amorphous structure was confirmed by X-ray diffraction.

Corrosion test and electrochemical measurements were carried out in 1N HCl, 1N H_2SO_4 and 1N HNO_3 solutions,

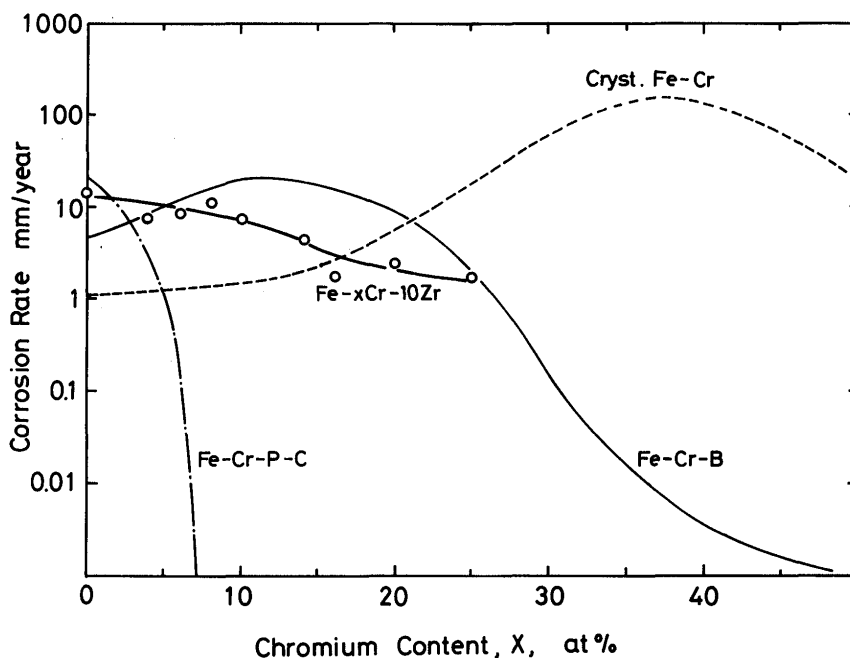


Fig. 1 Corrosion rates of amorphous $Fe_{90-x}Cr_xZr_{10}$, $Fe_{80-x}Cr_xP_{13}C_7$ and $Fe_{80-x}Cr_xB_{20}$ alloys in 1N HCl at 303 K.

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which were open to air. The preparation of acids were carried out using reagent grade chemicals and deionized water. Corrosion rates were estimated from weight losses after immersion in the acids at 303 K. Polarization measurements were made by the potentiation-dynamic method with a potential sweep rate of $2.5 \times 10^{-3} \text{ V s}^{-1}$, starting from the corrosion potential at room temperature.

Figure 1 shows the change in corrosion rate of amorphous $\text{Fe}_{90-x}\text{Cr}_x\text{Zr}_{10}$ in 1N HCl as a function of chromium content. Included for comparison in the figure are corrosion rates of amorphous $\text{Fe}_{80-x}\text{Cr}_x\text{P}_{13}\text{C}_7$ and $\text{Fe}_{80-x}\text{Cr}_x\text{B}_{20}$ alloys and crystalline $\text{Fe}_{100-x}\text{Cr}_x$ alloys. The addition of chromium to crystalline iron reduces the corrosion resistance in 1N HCl. On the other hand, the corrosion rates of amorphous alloys containing phosphorus as a major metalloid element decrease effectively with an increase in chromium content. Amorphous $\text{Fe}_{80-x}\text{Cr}_x\text{P}_{13}\text{C}_7$ alloys containing 8 at.% chromium or more are immune in 1N HCl. An increase in chromium content up to 20 at.% is ineffective in increasing the corrosion resistance of $\text{Fe}_{80-x}\text{Cr}_x\text{B}_{20}$. With further increase in chromium content the corrosion rate decreases and becomes undetectable at 50 at.% chromium.

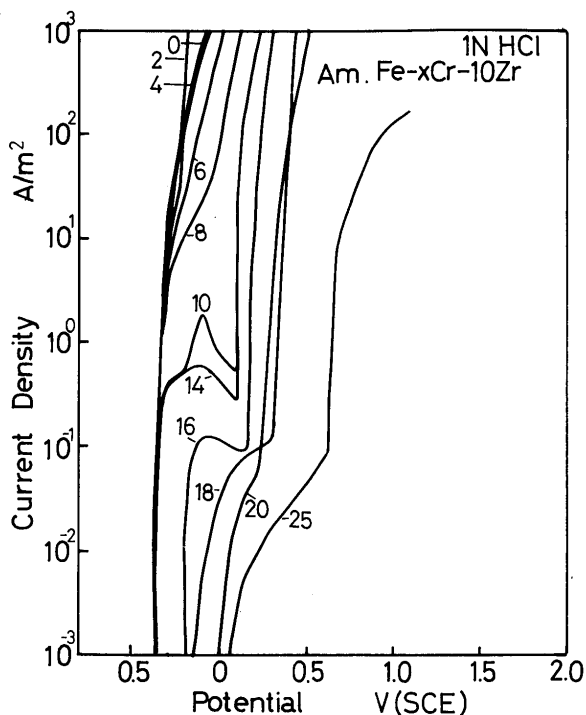


Fig. 2 Anodic polarization curves of amorphous $\text{Fe}_{90-x}\text{Cr}_x\text{Zr}_{10}$ in 1N HCl.

The corrosion rates of amorphous $\text{Fe}_{90-x}\text{Cr}_x\text{Zr}_{10}$ alloys which compose of only metallic elements decrease gradually with an increase in chromium content. In contrast to amorphous alloys containing phosphorus

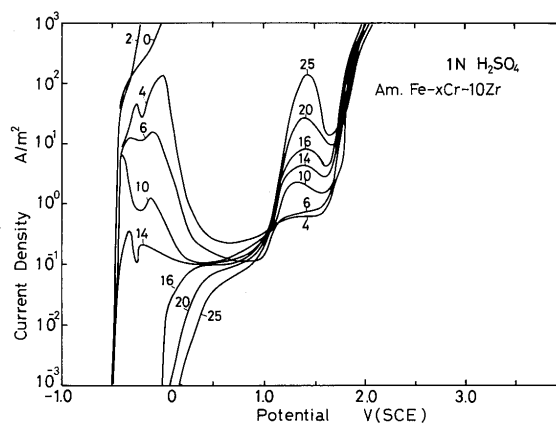


Fig. 3 Anodic polarization curves of amorphous $\text{Fe}_{90-x}\text{Cr}_x\text{Zr}_{10}$ in 1N H_2SO_4 .

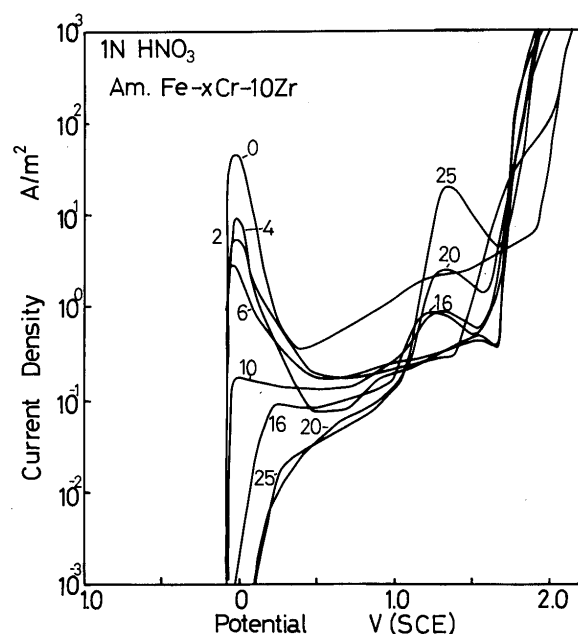


Fig. 4 Anodic polarization curves of amorphous $\text{Fe}_{90-x}\text{Cr}_x\text{Zr}_{10}$ in 1N HNO_3 .

as major metalloid, the addition of chromium is not effective in increasing the corrosion resistance.

The change in corrosion behavior by alloying can be seen from anodic polarization curves measured in 1N HCl, 1N H_2SO_4 and 1N HNO_3 . An abrupt increase in anodic current density due to pitting corrosion takes place although amorphous Fe-Zr alloys containing 10 at.% chromium or more passivate in 1N HCl and the anodic current densities decrease with an increase in chromium content as shown in Fig. 2. In acids such as 1N HNO_3 and 1N H_2SO_4 without chloride the passivation takes place and the anodic current densities decrease with an increase in chromium content as shown in Figs. 3 and 4. The corrosion resistance of amorphous Fe-Cr-Zr alloys is lower than that of amorphous Fe-Cr alloys containing phos-

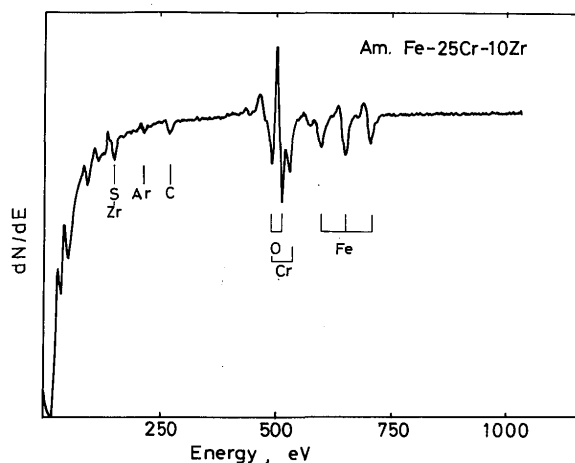


Fig. 5 Auger spectrum of amorphous $\text{Fe}_{65}\text{Cr}_{25}\text{Zr}_{10}$ alloy after 30 min immersion in 1N HCl.

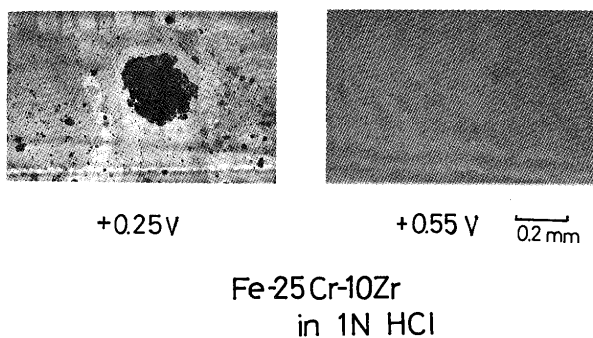


Fig. 6 Microphotographs of amorphous $\text{Fe}_{65}\text{Cr}_{25}\text{Zr}_{10}$ (a) held at 0.25 V (SCE) for 5 min (b) held at 0.55 V (SCE) for 5 min.

phorus in 1N HCl.

Figure 5 shows the Auger spectrum of film of amorphous $\text{Fe}_{65}\text{Cr}_{25}\text{Zr}_{10}$ alloy prepared in 1N HCl during immersion. In contrast to the film formed on amorphous Fe-Cr alloys which is composed of exclusively chromium oxyhydroxide³⁾, iron and zirconium remain in the film on the surface of specimen during immersion in 1N HCl. This leads to lower the chromium content in the film, and decreases the corrosion resistance of the Fe-Cr-Zr alloys. The film formed during polarization is not so strong to suppress the occurrence of pitting corrosion in solutions containing chloride. As shown in Fig. 6 pitting corrosion of amorphous $\text{Fe}_{65}\text{Cr}_{25}\text{Zr}_{10}$ alloy takes place potentiodynamically at 0.55 V for 5 min in 1N HCl. This result indicates that pitting corrosion may occur from the fluctuation of ions in chloride solutions even if the film of amorphous alloys formed during immersion is uniform and homogeneous.

Aknowlwgement

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