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## Effect of Chromium Addition on Corrosion Resistance of Amorphous Co-Zr Alloys<sup>†</sup>

Masaaki NAKA\*, Masauki MIYAKE\*\*, Michimasa MAEDA\*\*\*\*, Ikuo OKAMOTO\*\* and Yoshiaki ARATA\*\*

ARATA\*\*

**KEY WORDS;** (Corrosion), (Amorphous Alloy), (Chromium), (Cobalt), (Passivity)

In the past few years the field of liquid quenching has been seen hundreds of publications on techniques of quenching, property measurements, and industrial applications. A number of metal alloy systems have been formed in amorphous condition through rapid solidification. The amorphous alloys are also applicable to brazing filler metals<sup>1)</sup>. One of the outstanding characteristics in the field is the high corrosion resistance of some amorphous alloys. Naka et al.<sup>2)</sup>, in reporting the first observation of corrosion behavior of amorphous alloys, have stated that amorphous FeCrP<sub>13</sub>C<sub>7</sub> and FeCrNiP<sub>13</sub>C<sub>7</sub> alloys containing 8 at. % or more chromium show an extremely high corrosion resistance in various environments, especially to pitting in acid and neutral solutions containing chloride. The studies of corrosion behavior of amorphous alloys have so far been focused on the metal-metalloids systems. On the other hand, Nose and Masumoto<sup>3)</sup> have recently to prepare amorphous Co-rich Zr alloys without metalloids. These alloys possess excellent magnetic properties. Therefore, the corrosion properties of these alloys are worth examining. The present paper aims to clarify corrosion behavior of amorphous Co-Zr alloys.

Amorphous Co<sub>90-x</sub>Cr<sub>x</sub>Zr<sub>10</sub> (x = 0~30) alloys of 1mm in width and 25  $\mu$ m in thickness were prepared by a melt-spinning method. This technique consists of impinging a jet of molten alloy on the outer surface of a rapidly rotating cylinder. The formation of amorphous structure was confirmed by X-ray diffraction. The number attached to respective element denotes the nominal content in atomic percent.

Corrosion tests and electrochemical measurements were carried out in 1N HCl, 3%NaCl, 1N H<sub>2</sub>SO<sub>4</sub>, 1N

HNO<sub>3</sub> solutions, which were open to air. The solutions were prepared by using reagent grade chemicals and deionized water. A corrosion rate was estimated from measurements of the weight loss after immersion in the solutions at 303 K. Polarization curves were estimated by potentiodynamic method with a potential sweep rate of  $2.5 \times 10^{-3}$  Vs<sup>-1</sup>, starting from the corrosion potential at room temperature.

**Figure 1** shows the change in corrosion rate of amorphous Co<sub>90-x</sub>Cr<sub>x</sub>Zr<sub>10</sub> alloys in 1N HCl as a function of chromium content.

Included for comparison in the figure are corrosion rates of amorphous Co<sub>80-x</sub>Cr<sub>x</sub>B<sub>20</sub> and Co<sub>80-x</sub>Cr<sub>x</sub>P<sub>13</sub>C<sub>7</sub> alloys. The corrosion rates of amorphous alloys containing phosphorus as a major metalloid element decrease effectively with an increase in chromium content. Immunity to corrosion in 1N HCl is attained at 10 at. % chromium for Co<sub>80-x</sub>Cr<sub>x</sub>P<sub>13</sub>C<sub>7</sub> alloys. When boron is added as a metalloid, alloying with chromium up to about 20 at.% is ineffective in increasing the corrosion resistance. With further increase in chromium content the corrosion rate of Co<sub>80-x</sub>Cr<sub>x</sub>B<sub>20</sub> alloys decreases and becomes undetectable at 50 at.% chromium.

With an increase in chromium content the corrosion rates of amorphous Co<sub>90-x</sub>Cr<sub>x</sub>Zr<sub>10</sub> alloys which compose of only metallic elements decrease gradually. In contrast to amorphous alloys containing phosphorus as major metalloid, addition of chromium is not effective in increasing the corrosion resistance.

Further examination of corrosion behavior was performed by potentiodynamic polarization measurements. **Figs. 2 and 3** show anodic polarization curves of Co<sub>90-x</sub>Cr<sub>x</sub>Zr<sub>10</sub> alloys in 1N HCl and 3% NaCl,

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\* Associate Professor

\*\* Professor

\*\*\* Associate Professor, University of Osaka Prefecture, Osaka

\*\*\*\* Associate Professor, Department of Traffic Mechanical Engineering, Faculty of Engineering, Osaka Industrial University, Osaka

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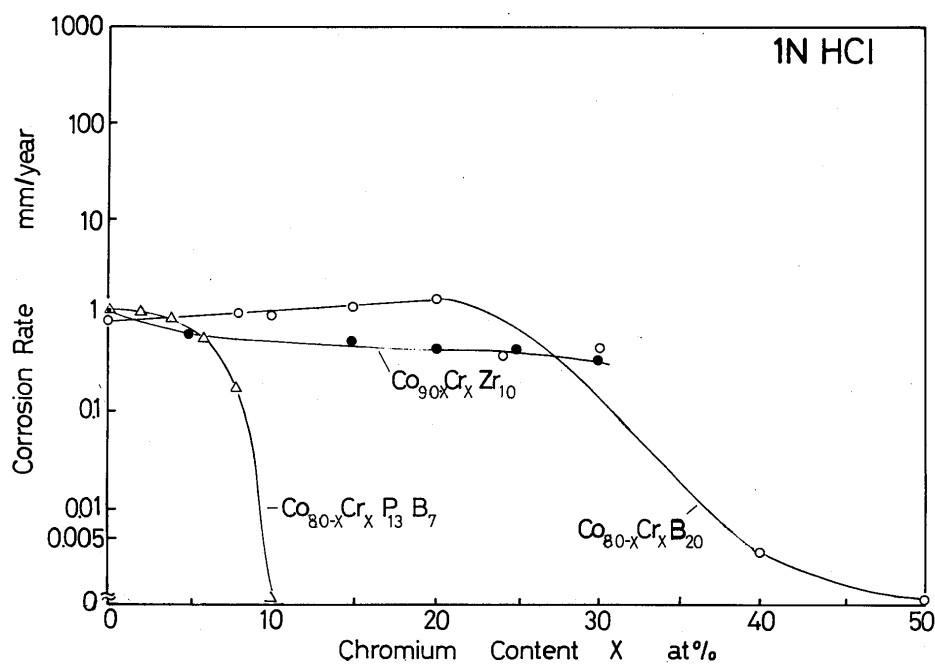


Fig. 1 Corrosion rates of amorphous  $\text{Co}_{90-x}\text{Cr}_x\text{Zr}_{10}$ ,  $\text{Co}_{80-x}\text{Cr}_x\text{P}_{13}\text{B}_7$  and  $\text{Co}_{80-x}\text{Cr}_x\text{B}_{20}$  alloys in 1N HCl at 303 K.

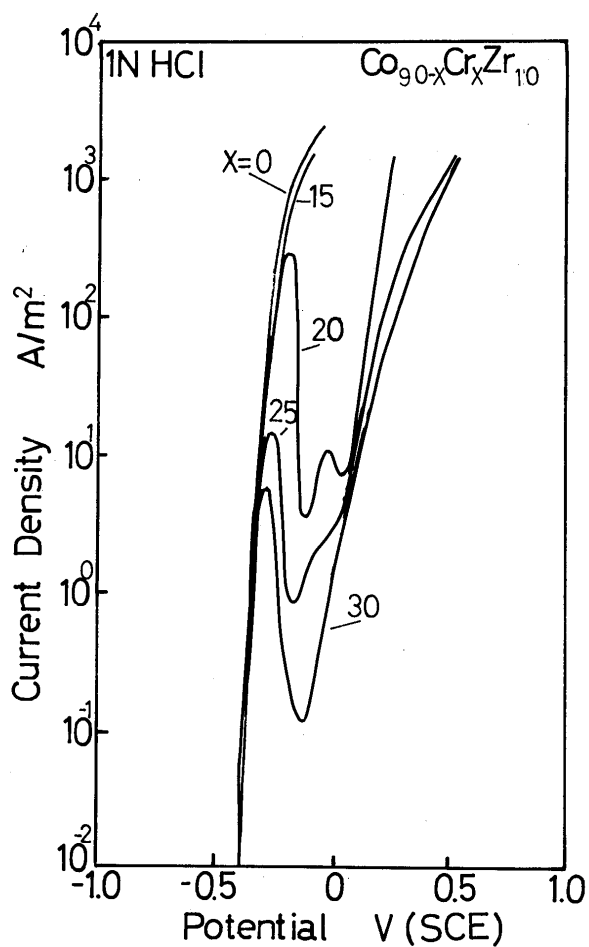


Fig. 2 Anodic polarization curves of amorphous  $\text{Co}_{90-x}\text{Cr}_x\text{Zr}_{10}$  in 1N HCl.

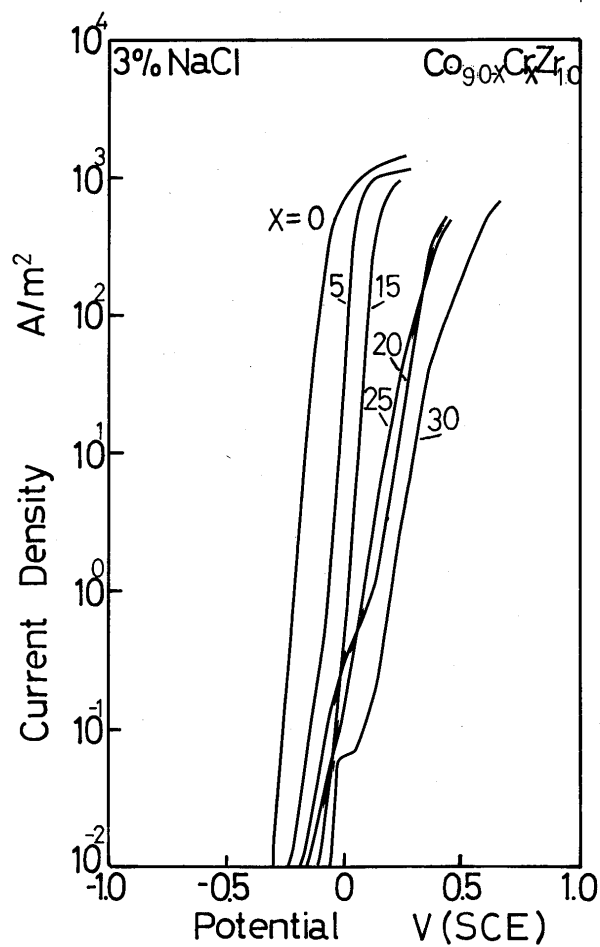


Fig. 3 Anodic polarization curves of amorphous  $\text{Co}_{90-x}\text{Cr}_x\text{Zr}_{10}$  in 3% NaCl.

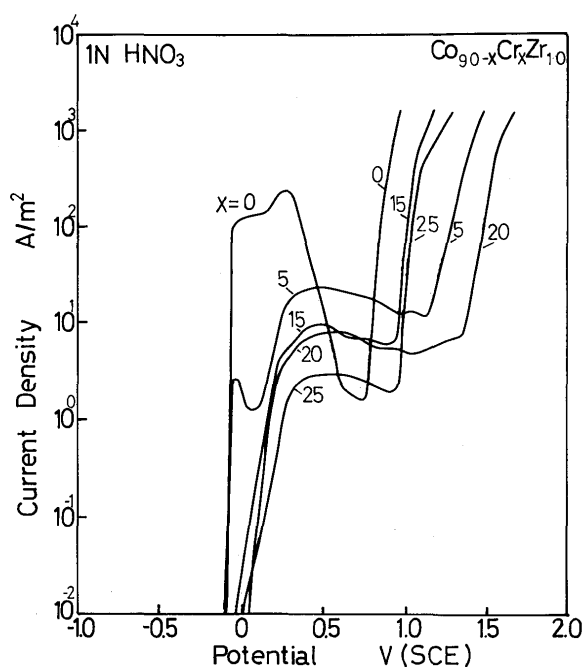


Fig. 4 Anodic polarization of amorphous  $\text{Co}_{90-x}\text{Cr}_x\text{Zr}_{10}$  in 1N  $\text{HNO}_3$ .

respectively. Though the passivation of amorphous Co-Zr alloys containing 20 at.% chromium in 1N HCl takes place and the anodic current densities decrease with an increase in chromium content, an abrupt increase in anodic current density due to pitting corrosion occurs as shown in Fig. 2. The corrosion potentials and anodic current densities without the passivation decrease gradually with an increase in chromium content in 3% NaCl as shown in Fig. 3. In acids such as 1N  $\text{HNO}_3$  and 1N  $\text{H}_2\text{SO}_4$  without chloride the passivation takes place and the anodic current densities decrease with an increase in chromium content as shown in Figs. 4 and 5.

The amorphous structure and the presence of zirconium is attributable to the improvement of amorphous  $\text{Co}_{90-x}\text{Cr}_x\text{Zr}_{10}$  alloys. However, the corrosion rate of amorphous Co-Cr-Zr alloys is higher than that of amorphous Co-Cr alloys containing

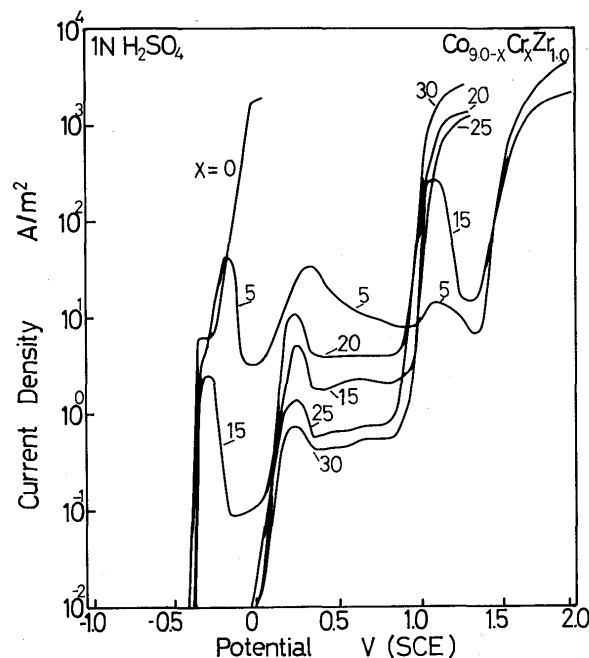


Fig. 5 Anodic polarization curves of amorphous  $\text{Co}_{90-x}\text{Cr}_x\text{Zr}_{10}$  in 1N  $\text{H}_2\text{SO}_4$ .

phosphorus. This arises from that the active dissolution to passivation of amorphous Co-Cr-Zr alloys is not enough to enrich the chromium in the surface of the alloys during immersion.

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