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ARTICLE

Influence of Remelting Treatment on Corrosion Behavior of Amorphous Alloys

Liu Jingtao[1,2], Hou Jixin[3], Zhang Xiaorong[1,2], Guo Jing[1,2], Xu Lingfeng[1,2], Fan Guiju[1,2]

[1] Shandong Agricultural University, Taian 271018, China; [2] Shandong Provincial Key Laboratory of Horticultural Machineries and Equipments, Taian 271018, China; [3] Soochow University, Suzhou 215021, China

Abstract: The corrosion behavior of $Gd_{56}Al_{26}Co_{18}$ and $Sm_{56}Al_{26}Co_{18}$ amorphous alloys in 0.01 mol/L NaOH solution has been researched by polarization curves, EIS technique, XRD and SEM. The free volume was also investigated by DSC technique. We find that the corrosion resistance of amorphous alloys in 0.01 mol/L NaOH solution increases after remelting. The corrosion resistance of Gd-based amorphous ribbons is better than that of the Sm-based amorphous ribbons in 0.01 mol/L NaOH solution. In addition, the amount of free volume of remelting amorphous ribbons is less than that of first-time melting amorphous ribbons.

Key words: corrosion behavior; amorphous alloys; electrochemical impedance spectroscopy (EIS); free volume

Over the past decade, amorphous alloys have been extensively investigated because of their superior properties, such as high strength [1], and excellent corrosion resistance [2]. Liu et al. found that compression has an important effect on the corrosion resistance of $Al_{86}Ni_9La_5$ amorphous alloy[3]. The thermally induced relaxation can also enhance the corrosion resistance of amorphous $Al_{87}Co_7Ce_6$ alloy[4]. Ye et al. found that remelting treatment can improve the glass-forming ability of $Fe_{78}Si_9B_{13}$ amorphous alloy[5]. Our previous work also showed that remelting treatment could enhance the glass-forming ability and thermal stability of $Gd_{56}Al_{26}Co_{18}$ and $Sm_{56}Al_{26}Co_{18}$ bulk metallic glasses (BMG)[6]. Therefore, it is valuable to study the influence of remelting treatment on corrosion resistance of amorphous ribbons.

In general, the amorphous ribbons are prepared by rapid cooling of metal liquids, so the liquids have significant effects on the formation and the properties of amorphous ribbons[7]. The heredity theory of liquids and solids has been widely investigated[8]. It is necessary to carry out extensive research on the effects of remelting treatment and structure heredity of amorphous ribbons.

A free volume model was proposed by Morrel H. Cohen and David Turnbull[9], and then developed by Cohen and Spaepen [10,11]. Beukel et al. found that the change of enthalpy had a positive relation with the change of free volume[12]:

$$\Delta H=\beta\Delta x \tag{1}$$

where, ΔH is the change of enthalpy, β is a constant and Δx is the change of free volume per atomic volume. According to this equation, the method of differential scanning calorimetry had been widely used to study the free volume of amorphous alloys [13, 14].

In the present paper, the influence of remelting treatment on corrosion resistance of $Gd_{56}Al_{26}Co_{18}$ and $Sm_{56}Al_{26}Co_{18}$ amorphous alloys were investigated by polarization curves and electrochemical impedance spectroscopy (EIS). In addition, the free volume change was also analyzed by DSC.

1 Experiment

The $Gd_{56}Al_{26}Co_{18}$ and $Sm_{56}Al_{26}Co_{18}$ master alloys with

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Corresponding author: Guo Jing, Associate Professor, College of Mechanical and Electronic Engineering, Shandong Agricultural University, Taian 271018, P. R. China, Tel: 0086-538-8246822, E-mail: gjcp1980@hotmail.com

nominal composition were made by alloying high-purity elements (99.9% at least) in an arc furnace under argon atmosphere, which were remelted three times to guarantee the homogeneity. The first-time melting alloys $Gd_{56}Al_{26}Co_{18}$ (1) and $Sm_{56}Al_{26}Co_{18}$ (1) were prepared by single roller spinning apparatus. Then, the first-time melting alloys as master alloy were remelted to prepare the remelting alloys $Gd_{56}Al_{26}Co_{18}$ (2) and $Sm_{56}Al_{26}Co_{18}$ (2). The amorphous structure was studied by X-ray diffractometry (XRD) with CuKα radiation. The surface morphologies of the ribbons after electrochemical tests were examined using scanning electron microscope (SEM, Ultra-55). Differential scanning calorimetry (DSC) was detected at a constant heating rate of 10 K/min under a flow of argon.

Prior to the electrochemical measurement, the exposed surface area of all as-quenched samples was polished with 1200# emery paper. In addition, electrochemical measurement was carried out using a typical three-electrode system: work electrode, platinum counter electrode and reference electrode. The polarization curves in 0.01 mol/L NaOH solution were obtained using LK2010 advanced electrochemical workstation with a scan rate of 5 mV/s. Then, EIS was performed in the frequency range from 10^6 to 0.1 Hz, with a sinusoidal wave perturbation of 5 mV in 0.01 mol/L NaOH solution.

2 Results and Discussion

Fig.1 shows the X-ray diffraction patterns of the first-time melting $Gd_{56}Al_{26}Co_{18}$ (1) and remelting $Gd_{56}Al_{26}Co_{18}$ (2) amorphous ribbons, which displays only a diffraction peak of both alloys corresponding to a fully amorphous structure, denoting the homogeneous amorphous structures. The result accords with our previous works, which showed the first-time melting $Sm_{56}Al_{26}Co_{18}$ (1) and remelting $Sm_{56}Al_{26}Co_{18}$ (2) were all amorphous structure [15].

The polarization curves of corrosion behavior of first-time melting and remelting amorphous alloys $Gd_{56}Al_{26}Co_{18}$ and $Sm_{56}Al_{26}Co_{18}$ in 0.01 mol/L NaOH solution are shown in Fig.2. In addition, the corresponding corrosion potential and corrosion current density are listed in Table 1. As shown in Table 1, the corrosion potential of remelting amorphous ribbons is higher than that of first-time amorphous ribbons for the two alloys, and the corrosion current density decreases after the remelting process. In other words, remelting treatment improves the corrosion resistance of $Gd_{56}Al_{26}Co_{18}$ and $Sm_{56}Al_{26}Co_{18}$ amorphous alloys. In addition, Qin et al found that the different corrosion behavior of bulk metallic glass (BMG) $Zr_{55}Al_{10}Cu_{30}Ni_{5-x}Pd_x$ (x=0, 5, at%) was attributed to glass forming ability (GFA)[16].

What's more, it is obvious that corrosion current density of Gd-based amorphous ribbons is smaller than that of the Sm-based ones in NaOH solution. When the Gd-based

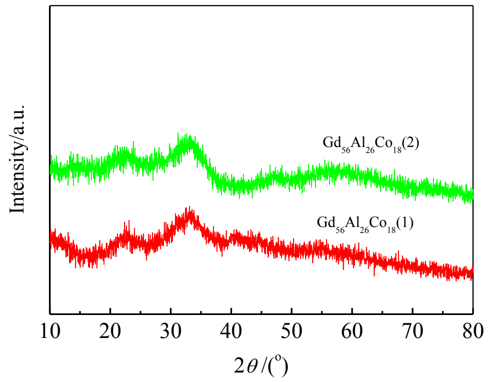

Fig.1 XRD patterns of the amorphous ribbons prepared by first-time melting $Gd_{56}Al_{26}Co_{18}$ (1) and remelting $Gd_{56}Al_{26}Co_{18}$ (2)

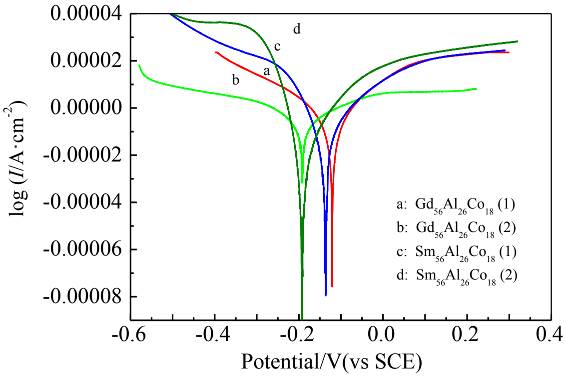

Fig.2 Polarization curves of Sm-based and Gd-based amorphous ribbons in 0.01 mol/L NaOH solution

Table 1 Corrosion potential E_{corr} and corrosion current density I_{corr} of Sm-based and Gd-based amorphous ribbons in 0.01 mol/L NaOH solution

Amorphous ribbon	E_{corr}/mV	I_{corr}/×10^{-4} A·cm^{-2}
$Gd_{56}Al_{26}Co_{18}$ (1)	-120.6	0.2029
$Gd_{56}Al_{26}Co_{18}$ (2)	-113.6	0.1173
$Sm_{56}Al_{26}Co_{18}$ (1)	-121.0	0.7436
$Sm_{56}Al_{26}Co_{18}$ (2)	-112.4	0.6531

amorphous ribbons are put into the NaOH solution, Gd→Gd^{3+}+3e, Al→Al^{3+}+3e, Co→Co^{2+}+2e are considered as the anodic reactions, and for Sm-based amorphous ribbons, Sm→Sm^{3+}+3e, Al→Al^{3+}+3e, Co→Co^{2+}+2e as the anodic reactions; the oxygen reduction and hydrogen evolution are the cathodic reactions for two kinds of amorphous ribbons[17,18]. Afterwards, hydrated oxides such as $Gd(OH)_3$, $Co(OH)_2$, $Sm(OH)_3$, are precipitated to form a surface protection film[19]. In the two corrosion reactions, Gd and Sm are the only different elements for two nominal compositions. As we all know, the effectiveness of the Gd element on the corrosion is better than that of Sm element.