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Effects of irradiation on the electrochemical behavior of the alloy $Ti_{60}Ni_{40}$

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ABSTRACT

The electrochemical studies were carried out on specimens of amorphous $Ti_{60}Ni_{40}$ both before and after irradiation with Ni^{11+} 150 MeV ions at fluence of 1×10^{13} ions/cm^2 using potentiodynamic polarization method in 1 M HNO_3 aqueous medium. The corrosion behavior of the virgin and irradiated specimens of $Ti_{60}Ni_{40}$ was also compared with that of the nanocrystalline specimen of the same alloy. It was observed that the irradiated amorphous specimen exhibits superior corrosion resistance than that of the amorphous specimen. However, the value of corrosion current density (I_{corr}) for irradiated specimen was found to be comparable with that for the nanocrystalline specimen. The better corrosion resistance of the irradiated amorphous specimen can be understood in terms of the evolution of Ti_2Ni nanocrystalline phase after irradiation with heavy ions.

1. Introduction

Metallic glasses share the properties of both metals as well as glasses and exhibit superior mechanical and chemical properties. They can be produced at a rapid cooling rate of 10^5–10^6 K/s in conventional ribbon form while the formation of bulk metallic glasses require a much smaller cooling rate of 10–100 K/s [1]. In recent years nanocrystalline materials having grain size less than 100 nm have attracted attention as advanced materials worldwide. It is possible to obtain nanocrystalline alloys by thermal annealing of amorphous alloys under controlled conditions [2]. It gives us a possibility to compare the properties of amorphous alloys with their nanocrystalline forms of same composition under identical experimental conditions. Several investigations have been reported on magnetic, elastic and mechanical properties of nanocrystalline alloys [3–10], but a limited number of investigations are available on electrochemical properties of the nanocrystalline alloys [11–15]. Nanocrystalline alloys obtained by annealing of their corresponding amorphous alloy forms have been shown to possess better corrosion resistance than their amorphous and stable crystalline forms [11–15]. Irradiation of amorphous alloys with heavy ions is known to induce nanocrystalline phases [16]. This motivated us to carry out the electrochemical studies on amorphous specimens of the alloy $Ti_{60}Ni_{40}$ in 1 M HNO_3 aqueous medium both before and after irradiation and compare the results with those obtained in a previous investigation [14] for the nanocrystalline specimen of the same alloy.

2. Experimental

The $Ti_{60}Ni_{40}$ amorphous ribbon was obtained by melt-spinning technique. The amorphous specimens (1 cm × 1 cm × 30 μm) of $Ti_{60}Ni_{40}$ were irradiated by Ni^{11+} 150 MeV ions at a fluence of 1×10^{13} ions/cm^2. The irradiation was carried out at the Inter-University Accelerator Centre (IUAC), New Delhi. Potentiodynamic polarization studies were carried out on the amorphous specimen before and after irradiation and on the nanocrystalline specimen of the alloy $Ti_{60}Ni_{40}$ in 1 M HNO_3 aqueous medium at room temperature. The details about the experimental procedure and calculation of the corrosion current density can be found in another paper [17]. The electrochemical behavior of the virgin specimen of the nanocrystalline form of the same alloy in 1 M HNO_3 has earlier been reported in another investigation [14].

3. Results

The X-ray diffraction (XRD) patterns of the amorphous specimen before and after irradiation and the nanocrystalline specimen of the alloy $Ti_{60}Ni_{40}$ were recorded using CuK_α radiation at room temperature and are shown in Fig. 1. It was observed that nanocrystalline phase (Ti_2Ni) appeared after irradiation of the amorphous specimen with a crystallite size of about 4–5 nm. The crystallite size of 10–12 nm was found in the case of nanocrystalline specimen [14]. The crystallite size was obtained by using the Debye Scherrer formula [18].

Fig. 2 shows the potentiodynamic polarization plots of amorphous specimen before and after irradiation and nanocrystalline specimen of the alloy $Ti_{60}Ni_{40}$ in 1 M HNO_3 aqueous medium at room temperature. The corresponding values of corrosion current density are given in Table 1. The values of the corrosion current

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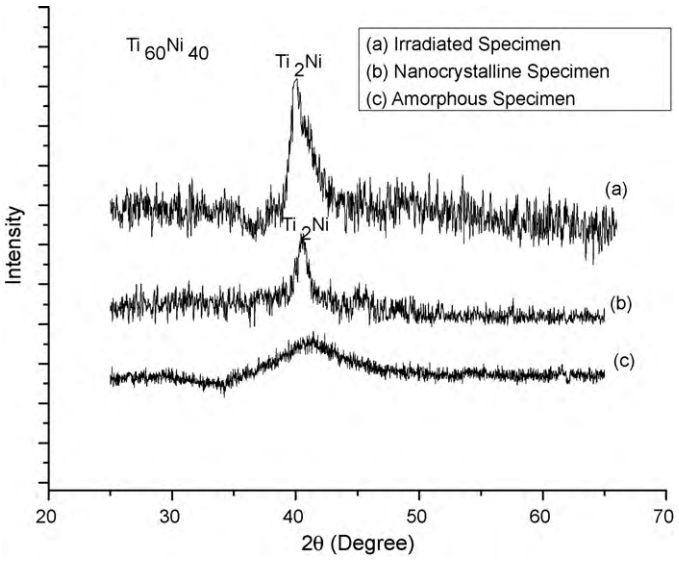

Fig. 1. X-ray diffraction (XRD) patterns of amorphous specimen before and after irradiation and nanocrystalline specimen of the alloy $Ti_{60}Ni_{40}$.

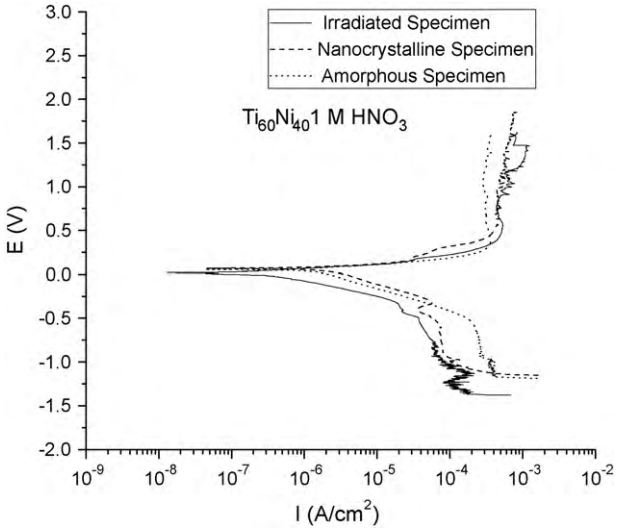

Fig. 2. Potentiodynamic polarization plots obtained from the amorphous specimen before and after irradiation and nanocrystalline specimen of the alloy $Ti_{60}Ni_{40}$ in 1 M HNO_3 aqueous medium.

Table 1
Potentiodynamic polarization results obtained from the amorphous specimen before and after irradiation and nanocrystalline specimen [14] of the alloy $Ti_{60}Ni_{40}$ in 1 M HNO_3 aqueous medium at room temperature.

$Ti_{60}Ni_{40}$	1 M HNO_3 I_{corr} (A/cm^2)
Irradiated specimen	2.0×10^{-7}
Nanocrystalline specimen	2.6×10^{-7}
Amorphous specimen	1.7×10^{-6}

density (I_{corr}) for these states were obtained under identical experimental conditions in several experimental runs with a deviation of about ±10%.

4. Discussion

It is observed from Table 1 that the irradiated amorphous specimen exhibits superior corrosion resistance than the amorphous specimen in 1 M HNO_3 aqueous medium. In this context it is worth noting from Fig. 1 that the irradiation by Ni^{11+} 150 MeV ions on the amorphous specimen causes the evolution of nanocrystalline Ti_2Ni phase having crystallite size of 4–5 nm. The presence of the nanocrystalline phase (Ti_2Ni) seems to improve the corrosion resistance of the alloy $Ti_{60}Ni_{40}$ after irradiation. It is further observed from Table 1 that the irradiated amorphous specimen exhibits comparable corrosion current density as that of the nanocrystalline specimen [14]. It was reported that the presence of single phase Ti_2Ni nanocrystallites of about 10–12 nm in the nanocrystalline specimen was responsible for its superior corrosion resistance [14]. Therefore, in both the irradiated amorphous specimen and nanocrystalline specimen the nanocrystalline Ti_2Ni phase results in the improvement of corrosion behavior.

Similar observations have also been reported by other investigators [11–13]. Mondal et al. [11] investigated the corrosion behavior of Zr-based amorphous alloys while Pardo et al. [12–13] studied corrosion of $Fe_{73}Si_{13.5}B_9Nb_3Cu_1$ in several aqueous media. In their investigations it was suggested that the evolution of nanocrystalline phase in investigated amorphous alloys results in an improvement in corrosion resistance. Hence in the present study superior corrosion resistance observed for the irradiated amorphous specimen and the nanocrystalline specimen of the alloy $Ti_{60}Ni_{40}$ than that for the amorphous specimen of the same alloy can be attributed to the presence of nanocrystalline Ti_2Ni phase.

5. Conclusions

1. The amorphous alloy $Ti_{60}Ni_{40}$ exhibits superior corrosion resistance after irradiation with 150 MeV Ni^{11+} ions as compared to the amorphous specimen of the alloy $Ti_{60}Ni_{40}$ in 1 M HNO_3 aqueous medium.
2. The superior corrosion resistance of $Ti_{60}Ni_{40}$ after irradiation is attributed to the evolution of Ti_2Ni nanocrystalline phase.

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