DEUTERIUM RETENTION IN MAGNESIUM, $Mg_{72}Mm_8Ni_{20}$ ALLOY AND IN TWO-LAYER $Mg_{72}Mm_8Ni_{20}$–Pd SYSTEM

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Introduction

In years to come, hydrogen can play the key role as a source of ecologically clean and renewable energy. Among the main candidates for retaining hydrogen in a bound state, consideration is given to magnesium-base alloys, which meet the present-day requirements imposed on metal-hydride systems in regard to hydrogen content (over 5 % wt. hydrogen). The main obstacle in the use of magnesium as a working material in metal-hydride generators of hydrogen is a high temperature of H_2 evolution and absorption. The promising way of improving the kinetic properties of magnesium lies in the use of magnesium-base alloys doped with intermetallic compounds consisting of a hydride-forming metal and the components that reduce the temperature of hydride decomposition. An important factor that can exert a significant effect on the kinetic properties of alloys is their structural-phase state. In this connection, of particular interest are the materials, which possess unique structures (nanocrystalline, amorphous) for hydrogen sorption and, owing to this, may have potentially high concentrations of retained hydrogen.

This paper describes the results of studies aimed at investigating the temperature ranges of deuterium retention in Mg, the $Mg_{72}Mm_8Ni_{20}$ alloy and in the $Mg_{72}Mm_8Ni_{20}$–Pd system.

Experimental procedure

A quenched $Mg_{72}Mm_8Ni_{20}$ alloy was produced in a form of a strap, ~2.5 mm in width and ~70 μm in thickness, by melt flow turning in a purified argon atmosphere. The rate of quenching the alloy stock was about 10^5 K/s.

A polycrystalline state of the alloy was attained by annealing the sample at a temperature of ~640 K for five minutes. The annealing conditions were determined on the basis of data obtained from the measurements of electrical resistance variations of the sample with temperature (see Fig. 1).

It can be seen in the figure that the annealing curve has a step structure typical for the cases, where the processes of annealing are accompanied by phase transitions. Here the horizontal parts on the curve correspond to stable states of phases, and the steeply falling off parts correspond to the phase transition region. As it is obvious from the figure, the $Mg_{72}Mm_8Ni_{20}$ alloy is characterized by two phase transitions at temperatures of ~470 K and ~570 K. At a temperature over ~620 K, the $Mg_{72}Mm_8Ni_{20}$ alloy goes into the polycrystalline state.

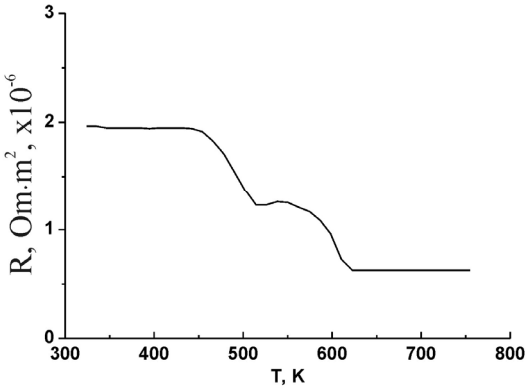

Fig. 1. Temperature dependence of electrical resistance of the quenched $Mg_{72}Mm_8Ni_{20}$ alloy.

The samples were saturated with deuterium by implanting D_2^+ ions of energy 24 keV at temperatures of ~110 K and ~300 K. In the process of ion implantation, the nuclear reaction technique was used to determine the deuterium concentration Y/ΔD in the sample through the measurement of the number of particles of given species (Y). The particles are the d-d fusion reaction products, which have emitted from the target surface during irradiation and were detected by the surface-barrier detector within the same time of dose increase ΔD [1]. The dependence of the Y/ΔD ratio on the implantation dose D shows the process of deuterium content increase in the implantation layer and the attainment of saturation, while the saturation level represents the peak concentration of deuterium that can be accumulated/retained in the material at the given temperature of the sample.

To reduce the temperature of hydrogen desorption from the magnesium alloy $Mg_{72}Mm_8Ni_{20}$, a palladium film of thickness δ ~200 nm was sputtered onto the alloy samples, and in this way a two-layer diffuse system $Mg_{72}Mm_8Ni_{20}$-Pd was obtained.

The thermodesorption spectroscopy technique was used to determine the temperature ranges of deuterium desorption from Mg, as well as from the $Mg_{72}Mm_8Ni_{20}$ ternary eutectic alloy and the two-layer $Mg_{72}Mm_8Ni_{20}$–Pd system.

Results and their discussion

Figure 2 shows the yield of charged particles T (tritium) as a function of the exposure dose for a quenched nanocrystalline magnesium alloy $Mg_{72}Mm_8Ni_{20}$. It can be seen from the figure that the deuterium concentration grows with an increase in the implantation dose by approximately the linear law and attains saturation at Y/ΔD ~13. A similar function was obtained for the $Mg_{72}Mm_8Ni_{20}$ alloy in a polycrystalline state. In this case the Y/ΔD ratio was equal to ~11. For comparison, and hence, for calibration similar studies were performed with magnesium. The deuterium concentration for the magnesium sample attains saturation at Y/ΔD ~11, this practically being in coincidence with the Y/ΔD value for the $Mg_{72}Mm_8Ni_{20}$ alloy in a polycrystalline state.

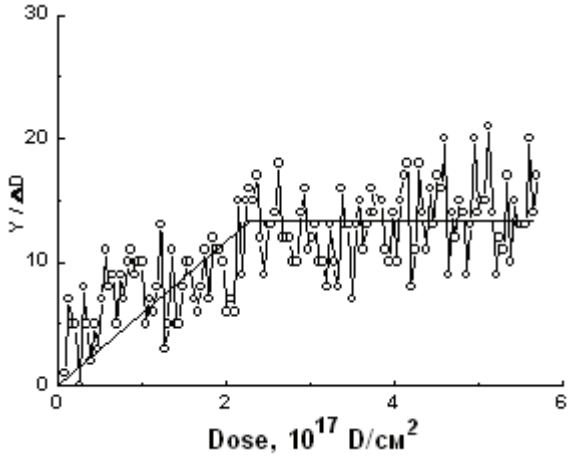

Fig. 2. The yield Y/ΔD versus exposure dose for the quenched $Mg_{72}Mm_8Ni_{20}$ alloy.

From the present data it follows that the $Mg_{72}Mm_8Ni_{20}$ alloy in a quenched condition retains hydrogen by ~10% more than in a polycrystalline state.

The spectrum of deuterium thermodesorption (TD) from the two-layer system $Mg_{72}Mm_8Ni_{20}$–Pd (see Fig. 3) exhibits a single peak with a maximum temperature of ~750 K. The TD spectra of deuterium from Md and the $Mg_{72}Mm_8Ni_{20}$ alloy are similar in appearance.

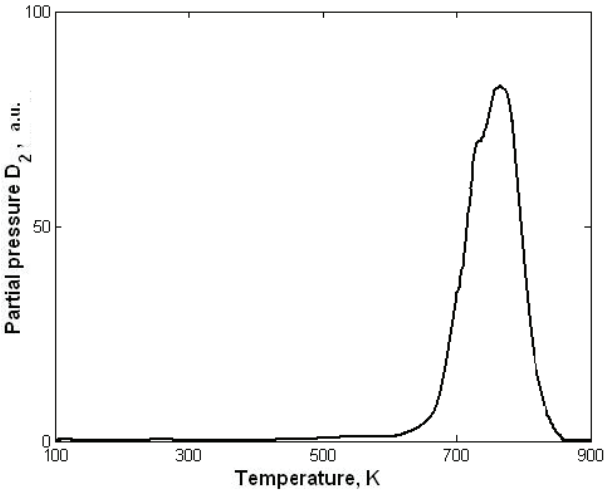

Fig. 3. Thermodesorption spectrum of ion-implanted deuterium from the two-layer $Mg_{72}Mm_8Ni_{20}$–Pd system without preliminary heating. Dose: ~$1.4\cdot\times10^{17}$ D/cm^2, T_{irr}~110 K.

The annealing temperature has been found, at which the interface of the two-layer $Mg_{72}Mm_8Ni_{20}$–Pd system would become transparent for hydrogen diffusion. It has been established that the annealing at T ~600 K for 2 to 5 minutes changes the temperature range of deuterium desorption (Fig. 4).

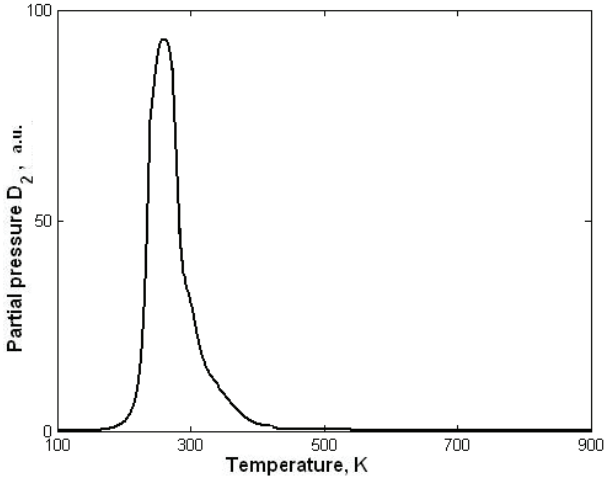

Fig. 4. TD spectrum of ion-implanted deuterium from the two-layer $Mg_{72}Mm_8Ni_{20}$–Pd system preheated up to T~600 K. Dose:$1\times4\cdot10^{17}$ D/cm^2, T_{irr}~110 K.

References

1. Neklyudov I.M., Morozov A.N., Zhurba V.I., Azhazha V.M., Andreyev A.A., Piatenko E.V., Kulish V.G. Levels of Ion-Implanted Deuterium Retention in Zr and in the Two-Layer Zr-Pd System. In: Carbon Nanomaterials in Clean Energy Hydrogen Systems. NATO Science for Peace and Security. Series C: Environmental Security. Springer, Netherlands, 2009, p. 503-508.