JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 9, No. 5, May 2007, p. 1462 - 1464

Microstructure and magnetic properties of the Ni-Zn thin films electrodeposited in ultrasound field

C. PIRGHIE[*], N. SULITANU[a], V. NICA[a]
Faculty of Mechanical Engineering, "Stefan cel Mare" University, 720225 Suceava, Romania
[a]*Faculty of Physics, "Al.I.Cuza" University, 700506 Iasi, Romania*

This work is focussed on the microstructure and the magnetic properties of Ni-Zn thin films electrodeposited in an ultrasound field. There were used frequencies of 20 kHz and 1 MHz for different power of the ultrasound wave applied to the electrolytic bath. The crystal structure of films was investigated by XRD. The surface microstructure was evidenced with an atomic force microscope (AFM) and a metallographic microscope. There was determined the RMS roughness for different thin films electrodeposited without ultrasounds and with ultrasound for different power and for different time of deposition. We noticed that roughness decreases with the increase of ultrasound power for 1 and 2 minute time of deposition and increases with the increasing of the ultrasound power for 5 minutes time of deposition. The structure alteration of thin films deposited in the ultrasound field determines changes of magnetic properties. By changing the frequency and power of applied ultrasound on the electrolytic it is possible to control the microstructure of the films, and so we can control the magnetic properties. In order to get the magnetic properties we used vibrating sample magnetometer (VSM). The coercitivity, the remanence, the saturation magnetization and the magnetic anisotropy were studied for different conditions of deposition and for different parameters of ultrasounds. The power of ultrasounds was varied from 0 to 10 kW/m^2.

(Received November 14, 2006; accepted April 12, 2007)

Keywords: Microstructure, Electrodeposition, Ultrasounds, Ni – Zn thin films

1. Introduction

Th microstructure influences the magnetic properties because it has an important effect on the density of domain walls and on the pinning and unpinning of domain walls. These domain walls attributes ultimately are responsible for the hysteretic behaviour of magnetic properties.

Two important features of the microstructure that affects magnetic hysteresis are grain size and dislocation density. As grain size decreases, the total length of grain boundary increases. Since the grain boundary is often associated with the pinning of domain walls, it follows that with decreasing grain size, the pinning of domain wall motion increases. Since the coercitivity H_c reflects the amount and strength of pinning, we expect H_c to increase when d decreases. Similarly, as dislocation density increases, dislocations begin to get entangled, forming strong pinning centers for domains walls, so preventing domain wall motion [1, 2].

The magnetic Ni-Zn alloys such as Ni-Zn and Zn spinel ferrites are commercially important materials because of their excellent electrical and soft magnetic properties [3, 4]. There is a particular application of Ni-Zn ferrites requiring low porosity and controlled microstructure in the magnetic cores of read-write heads for high-speed digital tape or disk recording [6, 7]. For this purpose we have to understand the relationship between microstructure and magnetic properties in dense ferrite thin films [5].

2. Experimental details

Ni-Zn thin films were prepared by the electrodeposition method. The electrolyte was a mixed bath made of $NiSO_4$, 250g/l, $ZnSO_4$, 50g/l, H_2BO_3, 20g/l and lauryl sulphate, 0.5g/l. The pH value was adjusted to 4.0 by a small addition of sulphuric acid. During the alloy formation, the cell system was kept at a constant temperature of T = 298 K. The time of deposition was modified from 1 min. to 5 min. Copper substrate was used. Thin films were electrodeposed with ultrasounds of 1MHz frequency applied perpendicular to the deposition direction. Ultrasound generator was applied to the cathode. Power of ultrasounds was modified between 1 kW/m^2 and 10 kW/m^2. For obtaining ultrasounds of 1 MHz frequency it was used a piezoelectric transducer. The microstructure of the thin films was characterized by AFM and XRD analysis. The magnetic properties were inferred from VSM measurements.

3. Results and discussion

It was studied the influence of ultrasound and deposition time on magnetic properties of Ni-Zn thin films electrodeposited with ultrasound 1 MHz frequency. Figs. 1, 2 and 3 shows the dependence of coercitivity and magnetic flux density on the ultrasound power for deposition time by 1, 3 and 5 minutes.

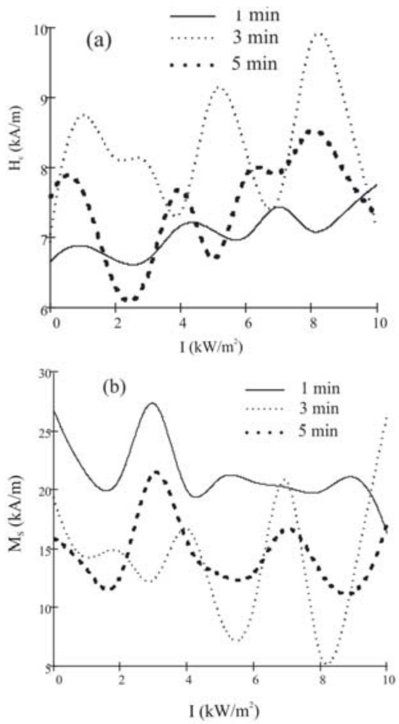

Fig. 1. Dependence of coercitivity (a), on magnetic flux density (b) on ultrasounds power.

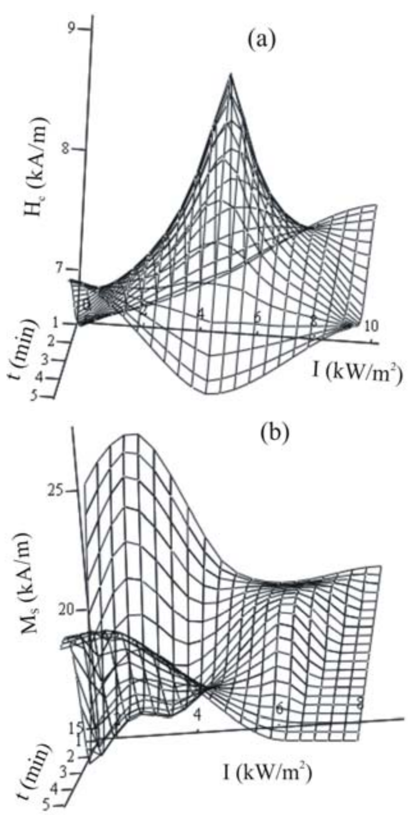

Fig. 2. 3D plot for variation coercitivity, magnetic flux density with ultrasound power and time.

We notice that the dependence of coercitivity, magnetic remanence and magnetic flux density are periodic functions of ultrasound power. This behaviour is caused by different grain size obtained for different ultrasound power. Fig. 2 show 3D plot for variation coercitivity and magnetic saturation with power of ultrasounds and time. We notice that coercitivity increases with ultrasound power and with deposition time.

We notice that coercitivity increases with ultrasounds power increasing but there is a value for ultrasounds power at which coercitivity reaches a minim value. Figure 3 show 3D plot for variation of average aria (S_m) of grain with ultrasounds power and deposition time. We can see that for 3 minutes deposition time and for 5 kW/m^2 ultrasound power, coercitivity, magnetic remanence and magnetic flux density reaches a minimum. We can notice that in Fig. 3 (a) average aria of grain has a minimum for 3 minutes deposition time and at ultrasounds power of 4 kW/m^2. In Fig. 3 (b) we can observe that coercitivity reaches a maximum value for 3 minutes deposition time and for a 5 kW/m^2 ultrasound power. For different ultrasound power have been got thin films with different values for coercitivity, magnetic remanence and magnetic flux density.

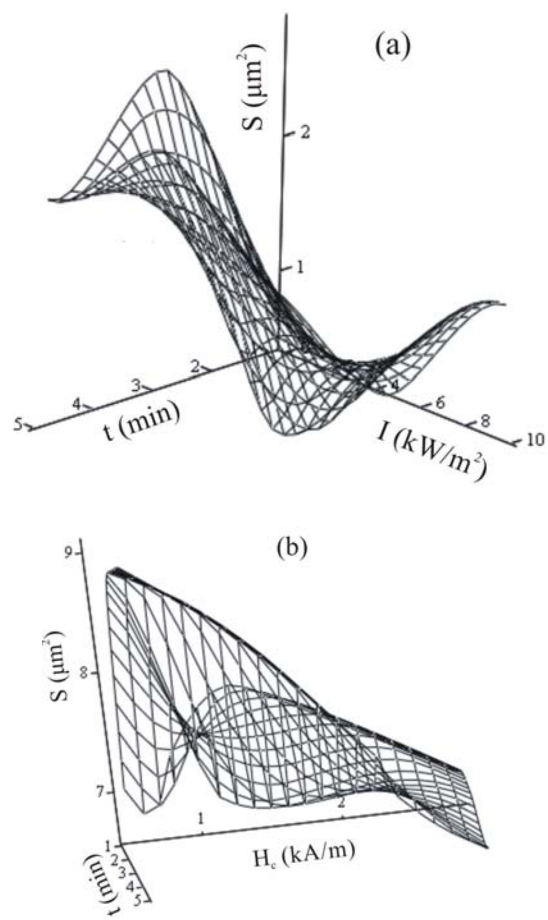

Fig. 3. 3D plot for variation of grain average aria (S_m) versus ultrasound power and time (a), and coercitivity (H_c) (b), respectively.

By means of AFM we studied roughness modification with deposition time and ultrasound power. Fig. 4 shows AFM micrographs of Ni-Zn films with different average roughness (R_{ave}) and root mean square (R_{rms}) function of film deposition parameters.

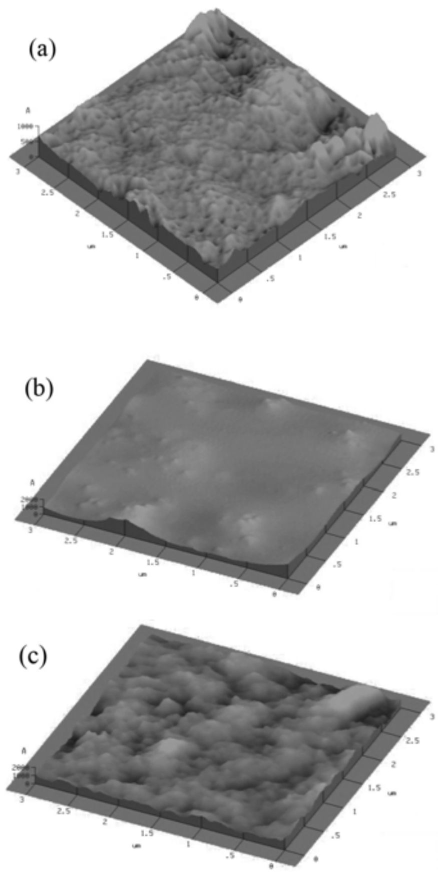

Fig. 4. AFM images for Ni-Zn thin films electrodeposited for different time and different ultrasounds power (a) R_{ave} = 8.334 nm and R_{rms} = 11.122 nm, (b) R_{ave} = 18.205 nm and R_{rms} = 23.176 nm, (c) R_{ave} = 19.091nm and R_{rms} = 14.558 nm.

In Fig. 4a and 4c we can observe that roughness have different values for sample obtained at 3 minutes deposition time and 5 kW/m^2 ultrasound power. Fig. 4b indicates that roughness reaches greater value than samples obtained for 1 minute and, respectively, 5 minutes deposition time at the same ultrasound power. These observations prove the existence a relationship between magnetic properties and microstructure of thin films. As grain size decreases, the total length of grain boundary increases. Since coercitivity is often associated with the pinning of domain walls, it follows that with decreasing of grain size, the pinning of domain wall motion increases [1].

4. Conclusions

Using electrodeposition method we obtained Ni-Zn thin films at different ultrasounds power. By AFM and VSM investigation we observed dependence between grain size and magnetic properties. By controlling ultrasounds power for different deposition time we can obtain Ni-Zn thin films with certain coercitivity values. By applying ultrasounds with certain intensities, during deposition, one gets thin films with small grain size and high coercitivity compared with thin films deposited without ultrasounds.

References

[1] M. J. Sablik, J. Appl. Phys. **89**, 5610 (2001).
[2] M. J. Sablik, D. Stegemann, and A. Krys, J. Appl. Phys. **89**, 7254 (2001).
[3] L. Wang, F. S. Li, J. Magn. Magn. Mater. **223**, 237 (2001).
[4] A. M. El-Sayed, Ceram. Int. **28**, 651 (2002).
[5] Monica Sorescu, L. Diamandescu, R. Swaminathan, M. E. McHenry, M. Feder, J. Appl. Phys. **97**, 10G105 (2005).
[6] A. Lisfi, M. Guyot, R. Krishnan, M. Porte, P. Rougier, V. Cagan, J. Magn. Magn. Mater. **157-158**, 258 (1996).
[7] O. F. Caltun, J. Optoelectron. Adv. Mater., **7**(2), 739 (2005).

*Corresponding author: parghie@fim.usv.ro