Proceedings of the European Conference "Physics of Magnetism 96", Poznań 1996

PULSED LASER DEPOSITION OF AMORPHOUS Co–Fe–Ni–Si–B THIN FILMS

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Soft magnetic multicomponent Co–Fe–Ni–Si–B thin films have been grown by pulsed laser deposition onto single-crystal sapphire and silicon substrates. The static hysteresis measurements for different substrate temperatures are presented. Thin films with a coercive force smaller than 1 Oe were grown at substrate temperatures from 250°C to 350°C. X-ray diffraction measurements proved that the structure of films is amorphous. The surface morphology of grown thin films was observed by scanning electron microscopy. The chemical composition of deposited films corresponds to the composition of bulk alloy.

PACS numbers: 75.70.Ak, 75.50.Kj

1. Introduction

Amorphous Co-based multicomponent soft magnetic thin films are promising materials for magnetic head cores in high density recording [1]. A sufficient saturation field, high permeability and a low coercive force of these materials are obtained by the variation of their structure and composition. These materials are characterized by a low value of magnetocrystal anisotropy [2]. Consequently, magnetic characteristics of soft magnetic materials are sensitive to the small changes of stoichiometry during the deposition process. Thus, a special care must be taken to control composition during the deposition of these materials. In our experiments we used the method of pulsed laser deposition (PLD) [3]. This method offers major advantages over other methods of thin film growth. It is necessary to stress that the method of PLD enables a stoichiometric material transfer from a target to substrate. Actually, an interaction of laser beam with the target leads to simultaneous blow up heating of material components to temperatures sufficiently higher than the vaporization temperature. As a result, the ablated plasma composition corresponds to the composition of laser ablated material. The laser produced plasma consists of ionic, atomic components and droplets. Time-of-flight measurements [4] have shown that high energy ions reach the substrate surface earlier than the major part of ablated material. Thus, the specific target surface cleaning from impurities is caused by high energy ions and improves deposited films adhesiveness. Finally, the amorphous thin films can be easily grown by the method of PLD.

2. Experimental

The experimental set up for film preparation consisted of a pulsed nanosecond KrF excimer laser (wavelength $\lambda = 248$ nm, 150 mJ/pulse, 20 ns pulse width and duty cycle 10 Hz). The output beam was passed through an aperture and focused onto a rotating target, at an angle of incidence of 45°. The substrate–target distance was 65 mm. The pulsed energy fluence at the target was 1.5 J/cm^2, which is sufficient to diminish the droplet formation. For each temperature of substrate the total number of laser pulses was kept constant at 20000. The thickness of produced films was between 250–300 nm. The deposition temperatures were varied from room temperature to 500°C, where the substrate temperature was measured from a thermocouple and checked with an optical pyrometer. The deposition was carried out in vacuum $P \approx 10^{-6}$ torr. The multicomponent $Co_{64}Fe_5Ni_5Si_{13}B_{13}$ alloy was deposited onto sapphire and silicon polished single crystal substrates placed parallel to the target. Two targets of the same composition with different structures were used for PLD. The first target consisted of a set of ten 20 mm long and 10 mm wide pressed amorphous ribbons. The amorphous ribbon had a thickness of 20 μ and a coercive force smaller than 0.1 Oe. The round bulk alloy target of the same material with 20 mm diameter had a coercive force of 50 Oe. The measurements of static hysteresis loops and the coercive force were performed by a vibrating sample magnetometer in plane of the substrate. The thin films thickness was measured by a step profiler. Surface morphology of the grown films was observed by the digital scanning microscope DSM-960, equipped with a microanalyzer Microspec-2A. X-ray diffraction was used for the structural characterization of material.

3. Results and discussion

Figure 1 demonstrates the dependence of coercive force on substrate temperature. It is seen that the coercive force of deposited thin films does not depend significantly on the type of substrate (sapphire or silicon) and corresponds to the bulk alloy coercive force value at a temperature of 20°C. The essential difference in the value of coercive force is observed at temperature 20°C and at higher substrate temperatures. At substrate temperatures from 200°C to 400°C the coercive force value is weakly depending on temperature. The hysteresis loops for different sapphire substrate temperatures are shown in Fig. 2. It is seen from Figs. 1, 2 that coercive forces smaller than 1 Oe and of the highest permeability are obtained for substrate temperatures from 250°C to 350°C. The optimal temperature for

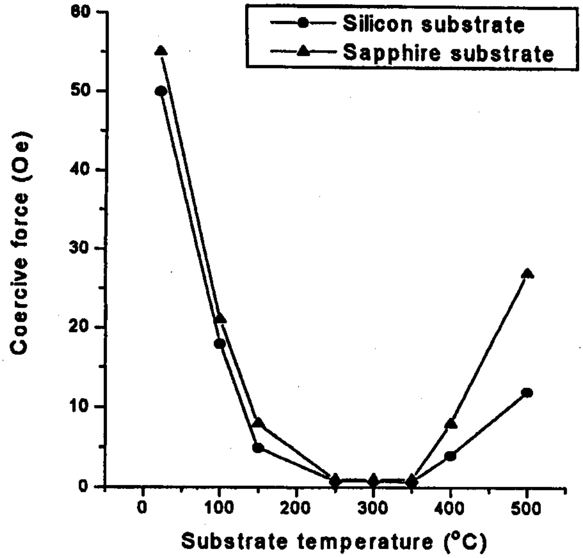

Fig. 1. Coercive force of Co–Fe–Ni–Si–B thin films as a function of substrate temperature.

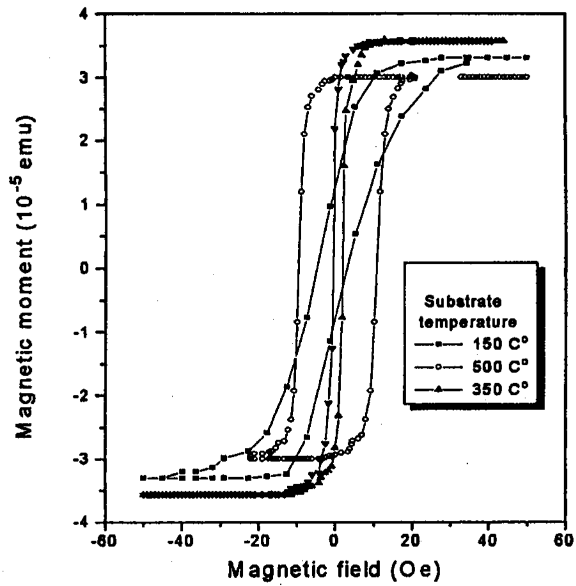

Fig. 2. Hysteresis loops of Co–Fe–Ni–Si–B thin films deposited onto silicon substrate at different substrate temperatures.

PLD of amorphous soft magnetic films is 350°C. The coercive force value at this temperature is 0.7 Oe. At temperatures higher than 400°C the gradual increase in coercive force is observed. It should be noted that the form of hysteresis loops and the value of coercive force appeared to be independent on the target structure. The same hysteresis loops were obtained both for the amorphous ribbon and bulk alloy targets. This experimental fact is connected with peculiarities of the PLD method. Actually, as the result of blow up heating of material, the initial structure of target material becomes not essential during the PLD process. It is clear from our experiments that the magnetic characteristics of multicomponent Co-based laser deposited thin films are extremely sensitive to the substrate temperature. The surface morphology, checked by scanning microscope, showed that at temperatures below 150°C the striped film surface is observed. For substrate temperatures from 200°C to 400°C the film surface is covered by spots of several microns size. For temperatures higher than 400°C a surface roughness increase is observed. The deposited films and droplets composition, determined by the microanalyzer, in the error 1%, corresponds to the composition of the bulk material. X-ray diffraction measurements proved that for temperatures higher than 200°C the material is amorphous. At temperatures higher than 400°C the recrystallization process evidently begins. Only several ring micron size droplets were observed by the electron microscope on 0.05 mm^2 area that demonstrates sufficiently good conditions for PLD.

4. Conclusion

We report the growth of low coercivity amorphous films of Co–Fe–Ni–Si–B alloy by the PLD method. The important role of the substrate temperature for the PLD of amorphous soft Co-based magnetic films is demonstrated. The further improvement of magnetic films characteristics by optimization of laser ablation conditions is in progress.

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