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THE INFLUENCE OF VELOCITY GROWTH ON THE Si-CONTENT AND COERCIVITY OF NiFe-Si FILMS

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Abstract. The *rf*-sputtered NiFe-Si alloy thin films were investigated. The thickness of the films was around 110 nm, the velocity of deposition was changed from 0.11 nm·s^{-1} to 0.92 nm·s^{-1}. The coercive force H_c was examined by galvanomagnetic measurements. It was found that H_c decreases and the content of Si increases when the growth velocity increases. The magnetic behaviour was explained by structural effects during the film growth.

Резюме. Исследованы пленки NiFe-Si, полученные методом радиочастотного распыления. Толщина пленок — около 110 nm, а скорость напыления изменялась от 0,11 nm·s^{-1} до 0,92 nm·s^{-1}. Методом эффекта Холла определена коэрцитивная сила H_c образцов. С ростом скорости напыления H_c уменьшивается, а содержание Si растет. Магнитное поведение пленки связано с структурными особенностями процесса напыления.

1. Introduction

The alloy films of the transition metals Ni and Fe are well investigated as a soft magnetic material and they are usually prepared by a vacuum evaporated technique [1].The metal-metalloid alloys of Ni and Fe with Si, Ge, B, C, P, of a different quantity allow to be produced as magnetic materials with a variety of properties and structures. The sputtering vacuum film deposition could give an opportunity to prepare films with new properties.

In this paper the coercivity of NiFe–Si films was investigated by galvanomagnetic measurements. The films were prepared by *rf*-magnetron sputtering method. The coercivity H_c of the films was measured as a function of the velocity of deposition. The important influence of this technological parameter of the magnetic properties of the films was shown.

2. Experimental

The alloy $(Ni_{80}Fe_{20})_{100-x}Si_x$ films were prepared by *rf*-magnetron sputtering of NiFeSi alloy target by a Z-400 Leybold-Heraeus system in Ar-plasma at pressure 10^{-1}–10^{-2} mbar. The *rf*-sputtering parameters were: cathode voltage U_{rf} = 1–2 kV, *rf*-generator's current I_{rf} = 120–170 mA, *rf*-power applied to the target $P_{rf} = 2$–$8\,W{\cdot}cm^{-2}$.

The films were deposited onto glass substrates and onto thermally oxidized Si-wafers with a thickness of the oxide around 500 nm. The substrates were cleaned chemically and just prior to the deposition an ion bombardment was used for final cleaning. No intentional heating was applied to the substrate during the deposition, but due to the substrate contact with the plasma components, the substrate temperature increased to a value of < 100°C. The thickness of the samples was about 110 nm. The obtained layers had random orientation of the easy axis of magnetization. The samples were annealed after deposition. The annealing procedure consisted of two steps:

(*i*) annealing of samples in H_2-atmosphere at 450° for 15 min in order to reduce the number of defects arised durung the deposition;

(*ii*) cooling the samples in H_2-atmosphere at an external homogeneous magnetic field $8\,kA{\cdot}m^{-1}$ applied in the plane of the films [2].

The aim of this work was to find out the influence of the velocity growth v_g on the chemical content and the coercivity force of the film samples. The velocity growth was changed from $0.11\,nm{\cdot}s^{-1}$ to $0.92\,nm{\cdot}s^{-1}$. The samples were prepared with rectangular geometry by means of photolithography. After that the electrodes of copper with thickness of 60 nm were evaporated. This configuration was convenient for the galvanomagnetic measurements. The chemical composition of the samples was determined by the electron microscope "Philips 515". Their crystal structure was observed by an electron diffraction using Carl Zeiss elecron microscope EF-IV.

The magmetic properties of investigated NiFe-Si films were determined by two galvanomagnetic dependences of the planar Hall effect. The first one was the field dependence $U(H)_{\theta=const}$ where U is the planar Hall voltage at different values of external magnetic field H, applied in the film plane at different field directions θ with respect to the long side of the sample. The second one was the angular dependence $U(\theta)_{\theta=const}$ where U was the Hall voltage at fixed value of the planar magnetic field H, applied in different angles θ. The measurements were carried out in the homogeneous magnetic field $H \leq 7.1$ kA m^{-1} produced by Helmholtz coils. The angular rotation of the sample towards the magnetic field direction was controlled within an accuracy 20′.

The stabilized current source ensured a constant current density through the sample. The changes of the Hall voltage were registred by X–Y plotter [3].

3. Conclusions

The chemical composition measurements determined that the silicon content in the films depend essentially on the velocity of the film growth. The Si-content increased from 3 to 29 at.% when the velocity of deposition v_g increased as stated above (Fig. 1). The small silicon content in the film at a low sputtering velocity

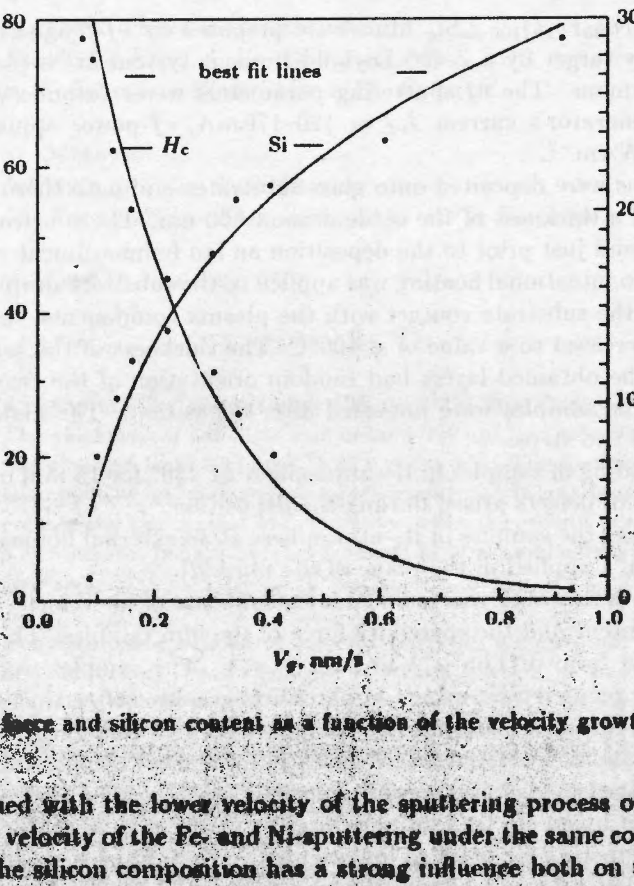

Fig. 1. Coercive force and silicon content as a function of the velocity growth of NiFe–Si films

could be explained with the lower velocity of the sputtering process of the silicon compared to the velocity of the Fe- and Ni-sputtering under the same conditions [4]. The change of the silicon composition has a strong influence both on the electron structure and on the domain walls which reflects on the H_c-value.

The crystal structure of the $(NiFe)_{100-x}Si_x$ samples was examined by elecron diffraction patterns in the range of x as previously mentioned. The polycrystalline structure was observed in the films with a silicon content of 3 or 7.5 at.%. The samples were amorphous when the silicon content was more than 20 at.%. The adhesion between the films and the different substrates was good. The value of coercivity H_c determined by the Hall measurements decreased with the increase of the velocity growth (Fig. 1.).

The behaviour of H_c could be connected with structural effects. The films grown at lower sputtering velocity formed a coarse-grained polycrystalline structure determining a higher value of the coercivity H_c. The magnitude of H_c decreases gradually with the increase of the velocity of the film growth. This is presumably connected both with a decrease of the size of the grains and with begining of the amorphous structure due to the higher silicon content. They both facilitate the domain wall motion in the films.

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