Letters to the Editor

CONTRIBUTION TO THE STUDY OF THE EFFECT OF HEAT TREATMENT ON THE COERCIVE FORCE OF THIN PERMALLOY FILMS

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The magnetic properties of thin magnetic films, above all their coercive force, may be appreciably influenced by heat treatment. The mechanism of how this influence is realized is — in view of the possible overlapping of several effects — rather complex. The heat treatment causes changes of internal stresses in the film as well as various structural changes in it, etc. When the film is annealed together with the substrate, the effects of the structural changes of the substrate, the diffusion and other effects are also taking place.

The changes of the crystallite size belong to the most apparent structural changes taking place in the process of the heat teatment of the film. Opinions of various workers differ when assessing the effect of the crystallite size on the coercive force: some of them [1, 2, 3] relate the increase of the coercive force to the increase of the crystallite size, others [4] with the decrease, and still others [5] deny this effect. However, when evaluting these different opinions, the various conditions at which the particular experiments were realized must be taken into account.

Our work, in which we by means of electron microscope studies of the structural changes investigated the effect of heat treatment of thin electrodeposited permalloy films on the coercive force, is meant as a contribution to the experimental data on electrodeposited films.

For the experiment a heating attachment was used, which could be positioned into the electron microscope *JSM-U3* and which made it possible to heat the sample up to the temperature of 450° C in a vacuum of $5 \cdot 10^{-5}$ torr. The polycrystalline copper substrates prepared from rolledin sheet were ground on emery paper. Onto the so prepared substrates the permalloy films were deposited, with a composition of 80 % Ni — 20 % Fe and with a thicknesses of 1000 A and 2000 A, respectively. The annealing in the temperature range of 100—450° C was performed in the tubus of the electron microscope. The usual method of annealing was used and the time of annealing was 10 minutes and 1 hour, respectively.

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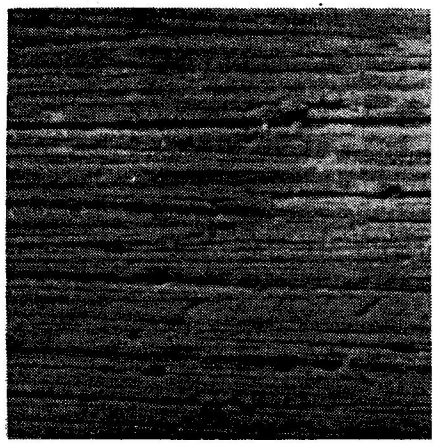

Fig. 1. The surface structure of the film annealed at a temperature of 300°C for 10 minutes. Magnification 1000×.

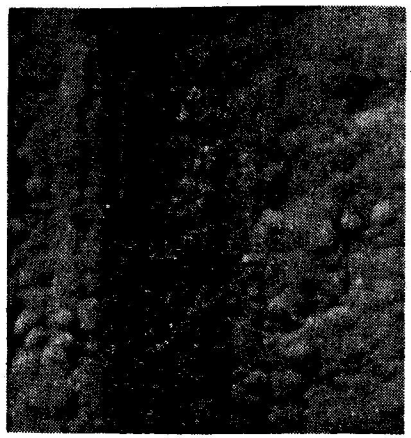

Fig. 2. The surface structure of the film annealed at a temperature of 450° C for 10 minutes. Magnification 3000×.

The observations in the electron microscope showed apparent changes in the sample structure after annealing. A film, which has not been heat-treated, shows a relatively smooth surface. At an annealing temperature of 300° C (for 10 minutes) the surface becomes rougher and a vacuum etching of the film begins to take place (Fig. 1). At a temperature of 450° C the growth of crystallites is already apparent (Fig. 2). These structural changes become still more apparent when the time of annealing is prolonged to one hour.

Fig. 3 shows the dependence of the sample coercive force upon the annealing temperature; in the range of relatively lower temperatures (up to 150° C) the coercive force

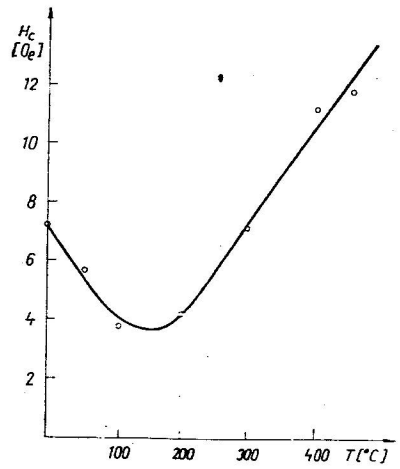

Fig. 3. Dependence of the coercive force of PY 80 (d = 2000 Å) on the annealing temperature.

decreases with an increasing temperature and at a temperature of about 150° C reaches the minimal value. A further increase of the temperature leads to an increase of the coecive force.

Electrodeposited thin films exhibit relatively strong internal stresses [6]; however, they may be removed by short annealing at relatively low temperatures, in our case up to 150° C, which leads to a decrease of the coercive force. In the process of a further increase of the annealing temperature the effect of the structural changes in the sample begins to take place. These changes are clearly evidenced on our micrographs from the electron microscope: the crystallite size is increasing with a simultaneous increase of roughness, of irregularities and defect on the surface of the film. These changes lead then to an increase of the coercive force, as evidenced also by works of other authors, realized at different experimental coditions [7]. Of course, on the basis of our measurements it cannot be unambiguously decided, which of the factors considered above participates in the increase of the coercive force. It is really very difficult to separate the crystallite size effects from other effects such as irregularities and defects on the surface and possibly effects connected with the structural changes of the substrate taking place during the heat treatment.

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