Effects of constant, pulse and pulse-reverse current modes on the electrodeposition of NiFe films

A.N. Kotelnikova [1]*, T.I. Zubar [1], T.I. Usovich [1], M.I. Panasyuk [1], V.A. Fedkin [1], O.D. Kanafyev [1], A.V. Trukhanov [1]

[1] SSPA "Scientific and practical materials research center of NAS of Belarus"

*** corresponding author e-mail:: anna.kotelnikova.98@mail.ru**

Electrodeposited NiFe alloys are widely used in microelectronics due to their magnetic softness. In particular, they are used in production of magnetic recording heads, magnetic field detectors and as electromagnetic shields.

Pulse plating techniques have been known to improve some deposit physical properties such as hardness, adhesion, surface topography, brightness, and internal stress for both single-metal and alloy deposition

The effect of current modes on composition, crystal structure and microstructure was investigated in this work. For this purpose, NiFe coatings were obtained using stationary, pulsed and pulse-reversed electrodeposition. The coatings composition, crystal structure and surface microstructure were studied.

Chemical Composition

According to the EDX spectroscopy DC film has less Fe content (36.40 at.%) then PC film (42.15%). It is caused by increased anomalous character of deposition in pulse mode, which is cyclic repetition of DC deposition initial stage.

There is a decrease in the Fe content during the transition to pulse-reversed mode (27.5%). This is due to the difference in the dissolution rates of nickel and iron during anodic pulses. Iron has a lower electrode potential (-0.44 V) than nickel (-0.24 V), which means iron is more prone to oxidation and dissolves faster.

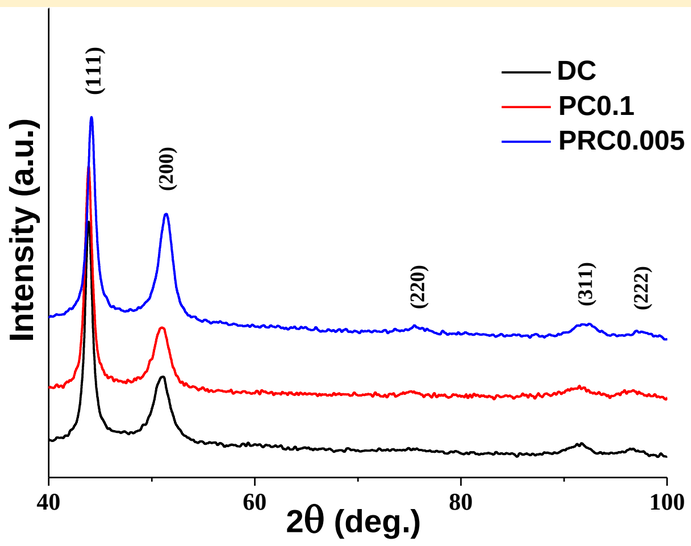

Figure 1. X-ray diffraction data of NiFe films

Crystal Structure

The most intense and characteristic peaks on the XRD patterns (Figure 1) are 42-43 deg. (corresponding to the Ni atomic plane (111) and 50-51 deg. (corresponding the Ni atomic plane (200). This indicates that these alloys have a face-centered cubic lattice.

Broadened peaks in the diffraction patterns indicate a small grain size and high internal stresses in the lattice. A decrease in the intensity and increase in the width at the half-height of the (111) peak was observed for PRC sample, while there are no significant differences for DC and PRC samples. Increase in the intensity of the (200) peak was observed for PRC sample.

Width at the half- height of the (200) peak decreases from DC through PC to PRC sample. CSR was 6-7 nm for all samples. Crystal lattice parameters a and V are almost the same for all films.

Surface Microstructure

There is bright and rough surface with a lot of pores at the sample DC. Surface of the sample PC is also bright and rough and has much less pores. This is result of the lateral growth of the grains in presence of saccharine. We expected that in the pulse-reversed mode, an even smoother coating would be obtained due to the etching of irregularities during the anode pulses. But the opposite was founded, the surface of the sample was covered with bulk microstructures.

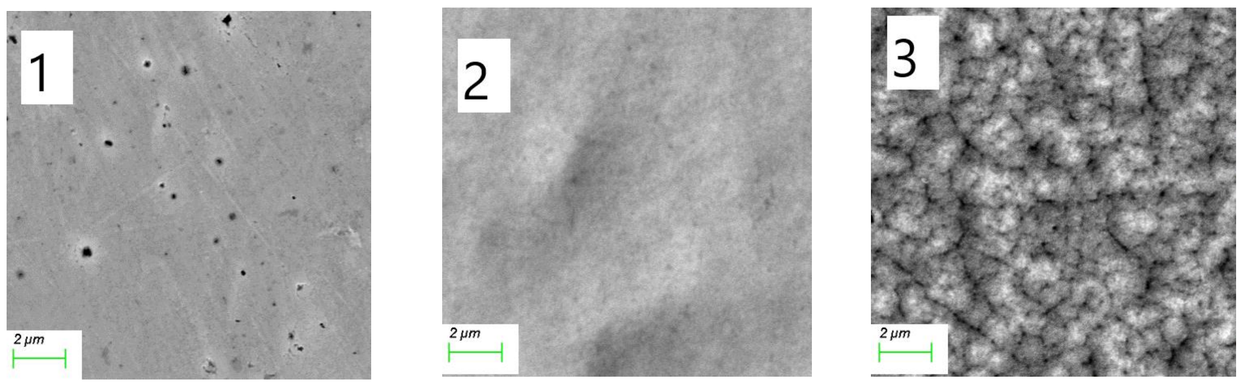

Figure 2. Microstructure of the surface of NiFe deposits, investigated using SEM: 1-DC, 2-PC0.1, 3-PRC0.005

Conclusion

Effect of of current modes on the NiFe deposits composition, crystal structure and microstructure was investigated. Increase of Fe content for PC film and decrease of Fe content for PRS film in contrast to DS film were observed.

All samples have fcc Ni lattice according to the XRD patterns. And there is no significant effect of current modes on CSR and lattice parameters.

PC mode application results to more flat and less porous film. Meanwhile PRS mode use leads to rough surface covered by volumetric microstructures.

Such a radical change in the surface is caused by a several reasons. First of all, passivation of the anode (sample) might occur during the anodic pulses.

Pulse-reverse modes known to have lees overpotential. Decreasing the value of overpotential leads to reducing of the nucleation rate and formation of bigger grains.

The greatest influence on the surface microstructure was exerted by the adsorption of saccharin. Saccharin is widely used as the brightener at the nickel plating and electrodeposition of NiFe alloys, as it inhibits vertical grain growth leading to smooth and shiny deposits formation. But it's adsorption on the sample surface is too reduced in PRC mode, due it' dissolution during anodic pulses. Consequently, vertical grain growth was increased and volumetric structures were formed.