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Effect of Electrodeposition Frequency on Magnetic Properties of $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ Nanowires

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The magnetic properties of $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ nanowires electrodeposited at different frequency of 50-1000 Hz were studied. This nanowires were prepared by alternative current electrodeposition using porous anodic aluminum oxide as template. The results show that coercivity of samples slightly increased with increasing the frequency. Comparing the M–H hysteresis loops in different frequency shows that saturation magnetization (M_s) per unit area decreases with increasing the frequency. Magnetic properties were also investigated after annealing at 575 C. After annealing, a clear increase in coercivity was observed.

Keywords: Nanowire, Magnetic properties, Electrodeposition, Frequency, Anodic aluminum oxide membrane (AAO).

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1. INTRODUCTION

Metal nanostructures continue to attract considerable attention because of their size and shape-dependent catalytic, electronic, optical, and magnetic properties [1]. To date, various mesoporous materials such as polycarbonate membranes [2], anodic oxide films of aluminum [3], carbon nanotubes [4], and organic molecule networks [5] have been employed as templates for the fabrication of arrays of various materials by means of electroless, sol-gel, hydrothermal, solvothermal, chemical vapor, and electrodeposition approaches. Using AAO films, the electrochemical deposition process is an attractive synthesis route for 1D nanostructures, providing a controllable and inexpensive method for the preparation of metallic nanowires with well-defined geometry[6]. In the present paper, we systematically investigate the effects of electrodeposition frequency and annealing on magnetic properties of $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ nanowires.

2. EXPERIMENTAL

Anodic aluminum oxide membrane template were prepared by using a two-step anodization procedure. In the first anodization step, the polished Al foils were dc anodized in 0.3M oxalic acid at 40V for 15 h. Then, the formed oxide layer was removed by wet chemical etching in a mixed solution of phosphoric acid and chromic acid. The sample was re-anodized for 1 h using the same parameters as in the first step. After tendering the barrier layer by reduce voltage systematically, electrodeposition was started. Porous aluminum oxide on the aluminum base was used as working electrode and platinum plate used as counter electrode. The Co-Al-Fe alloys were electrodeposited in the pores of the alumina templates at a constant potential. The peak to peak voltage and frequencies of the sine waveform used in ac electrodeposition were 30V and 50, 200, 400, 600, 800, and 1000 Hz, respectively. The electrolyte used to electrodeposit $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ nanowires had the following composition: (190.9g/l of $CoSO_4.7H_2O$, 7.0g/l of $Al_2(SO_4)_3.18H_2O$, 83.4g/l of $FeSO_4.7H_2O$ a 45 g/l boric acid and 1 g/l ascorbic acid), with pH value about 3.

To study the effect of annealing on the crystallinity, the as-deposited samples were annealed in argon atmosphere. It is noticeable that the optimum temperature and time were found to be 575°C and 30 min, respectively.Magnetic properties of the samples were measured using alternating gradient force magnetometer (AGFM).

3. RESULTS AND DISCUSSION

In a systematical investigation, the effects of different frequency of the ac electrodeposition as well as annealing on the magnetic properties of $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ nanowires were studied.

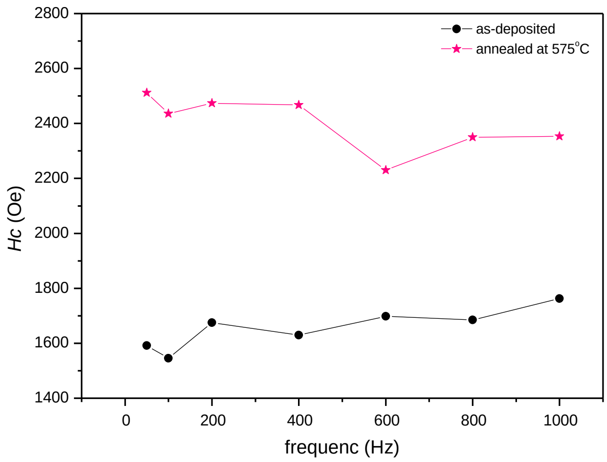

Fig. 1 – Coercivity and squareness of $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ nanowires deposited as a function ofelectrodeposition frequency and annealing

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As shown in Fig. 1, the coercivity slightly increases with increase in frequency from 50 Hz to 1000 Hz. The increase in coercivity after annealing is probably related to the change microstructure of samples during the annealing process. There is a sort of internal stress in the as-deposited samples induced by rapid electrodeposition of ions. Thermal annealing relieves the internal stress. A higher degree of crystallinity is also obtained by annealing. So the Hc of annealed sample is higher for annealed sample than that for as-deposited.

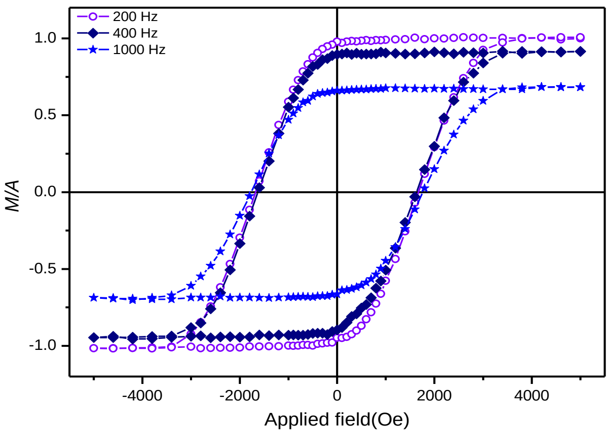

Fig. 2 – Hysteresis loops of $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ samples synthesized at 200, 400, 1000 Hz with sine waveform. Hysteresis loops were measured with the magnetic field appliedperpendicular (out of plane) to template surface

Comparing the hysteresis loop of samples synthesized at 200, 400, and 1000 Hz shows that saturation magnetization (Ms) per unit area with lower frequency is higher than those with higher frequency (Fig. 2). It is because the tunneling current decreased by increasing the frequency and then the amount of electrodeposited material is decreased. Root mean square of electrodeposition current (I_{rms}) during the $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ nanowires electrodeposition process increases by frequency but deposited material that depended to tunneling current (unsymmetrical part of negative current) decreases by frequency.

4. CONCLUSIONS:

The influences of ac electrodeposition frequency and annealing on the magnetic properties of high aspect ratio $(Co_{0.97}Al_{0.03})_{0.7}Fe_{0.3}$ nanowires deposited into the alumina nanopores were investigated. This study enables us to arrive at the following conclusion:

1. It was seen that increasing the frequency increased the coercivity and decreased the among of deposited material.
2. The high coercivity was obtained for samples preparedat 50Hz after annealing at 575°C in argon atmosphere for 30 min.

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