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Effect of Current Frequency and Annealing on Magnetic Properties of $[Co_{70}Fe_{30}]_{97}Sn_3$ Nanowire Arrays

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$[Co_{70}Fe_{30}]_{97}Sn_3$ alloy nanowire arrays have been fabricated by alternative current (ac) electrodeposition of Co^{2+}, Fe^{2+} and Sn^{2+} into anodic aluminum oxide (AAO) templates. The samples were deposited at current frequency 50, 100, 200, 300, 400, 500, 800 and 1000 Hz, respectively. The structure and magnetic properties of $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowire arrays dependence on different current frequency were analyzed by XRD and alternating gradient field magnetometer (AGFM). The X-ray diffraction patterns are shown an amorphous structure of the$[Co_{70}Fe_{30}]_{97}Sn_3$ nanowires.

Keywords: Nanowire, Coercivity, Ac electrodeposition, Hysteresis loops, Squareness.

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1. INTRODUCTION

Metallic nanowires have attracted much attention because of their attractive electrical, optical, catalytic and magnetic properties, with potential applications in nanoscale electronics, sensing and magnetic devices and information storage systems [1–6]. Highly ordered nanostructured material arrays with controlled diameter and composition have attracted much attention [7] in recent years due to their unique properties and potential applications in optoelectronics electronics, photonics, and magnetics. Creations of well ordered metallic nanowire arrays have become important aspects to realize their promise in ultrahigh-density perpendicular magnetic recording media. Since the magnetic properties are related to their element component, morphology, and microstructure [8], alloy nanowires are expected to exhibit the perpendicular anisotropy. Among these materials, Co-Fe alloy nanowires, especially chemically ordered Fe_3Co_7 with body-centered cubic (bcc) structure have been the focus of extensive research activities due to their large uniaxial magnetocrystalline anisotropy and good chemical stability [9]. In contrast to Fe, Co or Ni, Co_xFe_{1-x} alloy has high saturation magnetization and low magnetic crystalline anisotropy i.e. K_1 (the first magnetic crystalline anisotropy constant). In the range of $0.3 < x < 0.7$, Fe_xCo_{1-x} alloys in bulk material or thin film undergo a phase transformation from a disordered bcc structure to the ordered CsCl structure below 730 °C. The ordered alloy shows excellent soft magnetic properties with negligible magnetocrystalline anisotropy K1 [10]. So the magnetic properties of $Fe_xCo_{1\_x}$ nanowire arrays are mainly predominated by shape anisotropy of the nanowires. In this Letter, we report our work on fabrication and current frequency effects on magnetic characterization of $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowire arrays.

2. EXPERIMENTAL

Aluminum foil (99.99 %)with a thickness of 100 was used as the starting material. These specimens were degreased ultrasonically with acetone for 5 min and annealed in 450 °C for 20 min in the inert argon atmosphere to prevent surface oxidation. Oxide formation can cause further residual stress in the surface of plate, which can hinder order formation in the anodic aluminum oxide struture. A mirror surface was achieved by electropolishing in a 1:4 solutions of $HClO_4$ and alcohol ethylic. To obtain AAO (anodic alumina oxide) templates with highly ordered pores, a new sulfuric-acid based anodization process (hard anodization) was employed. An annealed Al (99.99 %) sheet was anodized by two step at 25 V in 0.3 M H_2SO_4 for 7 h to get a porous anodic aluminum oxide (AAO) template. The Co-Fe-Sn alloy nanowires was then deposited into the pores by AC electrolysis in an electrolyte consisting of $[Co_{70}Fe_{30}]_{97}Sn_3$ ratio of $CoSO_4.7H_2O$, $FeSO_4.7H_2O$, $SnSO_4.7H_2O$.To make a buffer electrolyte used sodium gluconate and ascorbic acid (0.25 g/l) at a pH = 3.0. The electrodeposition was conducted at room temperature. To investigate the effect of current frequency on the magnetic properties of $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowire arrays, the samples were deposited at different frequencies:50, 100, 200, 300, 400, 500, 800 and 1000 Hz and 30 V ac for 5 min using Pt as the counter-electrode. The magnetic properties were studied at room temperature by alternating gradient field magnetometer (AGFM) with an applied field of 5 KOe. where the applied field is parallel (//) to the nanowire's axis. The effect of annealing on magnetic properites of nanowires investigated by annealing nanowires in Ar atmosphereat different temperature from 200 °C to 575 °C. The AAO templates filled with nanowires were removed from the Al substrates using $HgCl_2$ aqueous solution. The structure of the deposited nanowires was investigated by X-ray diffraction (XRD).

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3. RESULTS AND DISCUSSION

3.1 Magnetic properties

Magnetic properties of the Co-Fe-Sn nanowires were investigated at room temperature using an alternating gradient field magnetometer (AGFM) with an applied field of 5 KOe. Fig. 1 shows the magnetic hysteresis loops of $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowire arrays as-deposited at different frequency for 5 min, where the applied field is parallel (//) to the nanowire's axis. In Fig. 2 and Fig. 3 was shown the coercivity (H_c) and squareness (Mr/Ms) as a function of current

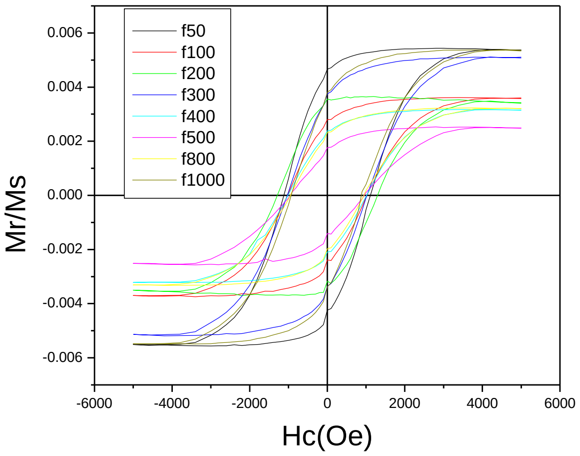

Fig. 1 – Typical hysteresis loops of the samples measured in a magnetic field parallel to the long axes of $[Co_{70}Fe_{30}]_{100-x}Sn_x$ nanowires

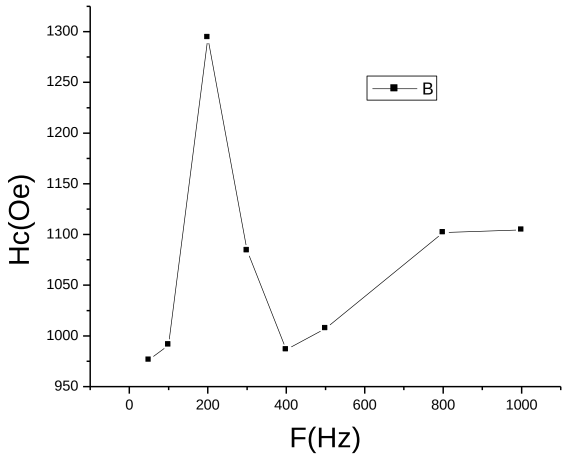

Fig.2 – Composition dependence of coercivity in parallel to the $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowires

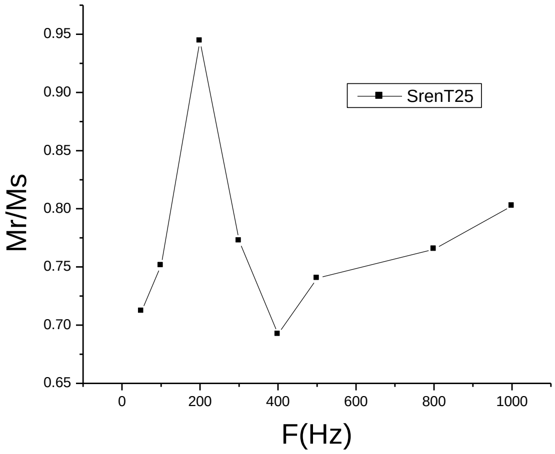

Fig. 3 – Composition dependence of squareness in parallel to the $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowires.

frequency. The coercivity and remanence ration Mr/Ms are about 1300 Oe and 0.949 in optimum frequency (200 Hz) in $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowire, respectively.It is seem electrodeposition in frequency of 200 Hz can be restored more CoFe in nanowire's structure. Fig. 4 was shown coercivity of nanowires after annealing at several temperatures.

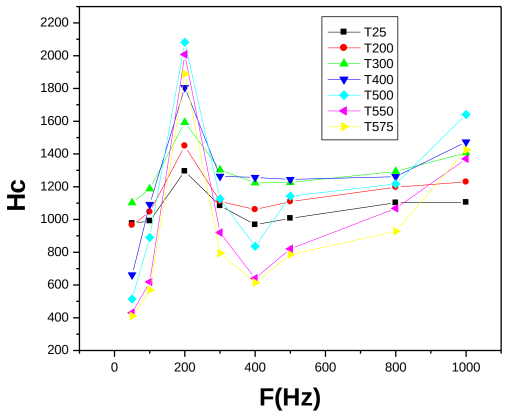

Fig. 4 – The influence of annealing treatment on coercivity of $[Co_{70}Fe_{30}]_{97}Sn_3$ nanowires

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