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# Synthesis and Characterization of $Co_{1-x}Sn_x$ Magnetic Nanowires

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High-density and uniform-sized $Co_{1-x}Sn_x$ alloy nanowires have been prepared electrochemically in anodic aluminum oxide (AAO) templates. This highly ordered arrays of nanowires have magnetic properties that affect by several agents including Sn concentration in structure of nanowires and annealing process. The morphologies of the nanowires were obtained by using the scanning electron microscope (SEM). The measurement of magnetic properties was made using the alternating gradient fors magnetometer (AGFM). The composition of the $Co_{1-x}Sn_x$ nanowires was analyzed by EDX. It has been observed that these properties were changed significantly with increasing of Sn content in nanowires. Also the affect of annealing temperature, up to 575˚C, on the magnetic properties and microstructure of as-prepared nanowires have been investigated.

**Keywords:** Nanowire, AAO template, Magnetic property, Annealing process.

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## 1. INTRODUCTION

Recently, one-dimensional and quasi-one-dimensional nanos- tructured materials have attracted considerable interest because of their applications in optics and high-density perpendicular magnetic recording media and much effort has been expended on the synthesis of these materials. The fabrication of magnetic nanowire arrays has received much attention due to their potential utilization in high-density magnetic recording media. Anodized aluminum oxide (AAO) has been extensively used in the past few years as an easy way to prepare nanowire by electrodeposition [1]. Anodic oxidation process was happened via the high-purity aluminum foil, through process treatment in acid solution prepared in condition including low pH value and temperature of electrolyte solution.

Templates contain a hexagonally packed two-dimensional (2D) array of cylindrical pores with a uniform size that was very suitable template for fabricating nanowires [2].

Recently, ferromagnetic-nonmagnetic alloy systems have attracted much attention in order to improve the magnetic properties of nanowires. Alloy nanowires were normally electrodeposited via AC electerodeposition which requires a less complex sample preparation process. In present work, the $Co_{1-x}Sn_x$ alloy nanowires have been fabricated in AAO template by AC electrodeposition. The magnetic properties of Co nanowires that affect by addition of Sn concentration and annealing process up to 575˚C have been investigated [2, 3].

## 2. EXPERIMENTAL

Ordered AAO templates were prepared via a two-step anodization process in sulfuric acid solution which has been reported in detail in other works [2]. On next stage, the nanochannels were filled with alloys of $Co_{1-x}Sn_x$ electrodeposited from an aqueous electrolyte (pH in range 4-4.3) consist of $CoSO_4.7H_2O$, $SnSO_4$ and $NaC_6H_{11}O_7$. The Sn content of the nanowires was adjusted by varying ions concentration in the electrolyte solution. The co-electrodeposition of $Co^{2+}$ and $Sn^{2+}$ ions in the AAO template was performed by using a standard double electrode bath and AC sine wave ($V_{P-P}$ = 30V) at room temperature. Varying ion concentrations in the solution were utilized for producing alloy nanowires with different concentration of Sn in their structures. Samples were made including pure Co nanowires and $Co_{0.99}Sn_{0.01}$, $Co_{0.98}Sn_{0.02}$, $Co_{0.97}Sn_{0.03}$, $Co_{0.96}Sn_{0.04}$, $Co_{0.95}Sn_{0.05}$, $Co_{0.85}Sn_{0.15}$ alloy nanowires. After producing alloy nanowires via co-electrodeposition, these samples were annealed at different temperature (200, 300, 400, 450, 500, 550 and 575˚C)

## 3. RESULTS AND DISCUSSION

### 3.1 Co and Sn Content

A typical top view SEM micrograph of a pore structure after preparation via two step anodization was shown in Fig. 1. The SEM image of $Co_{0.95}Sn_{0.05}$ alloy nanowires is shown in Fig. 2 after removal AAO template with NaOH solution.

Fig. 3 is an EDX pattern that demonstrates the elemental composition of a typical nanowire system. The inset is the curve that compares between Sn concentration in nanowire structures and $SN^{2+}$ concentration in electrolyte solution. As seen the Sn content in the nanowires have a nonlinear relation to the ionic concentration of Sn in the electrolyte. The amount of Sn in the nanowires significantly rises with increasing the $Sn^{2+}$ concentration in the electrolyte, revealing that Sn is deposit much faster than Co. Therefore co-electrodeposition of this alloy nanowires are an unnormal electrodeposi-

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tion. On the other sight, due to non-magnetic of Sn, the magnetic properties of nanowires have downward trend with increasing the amount of Sn.

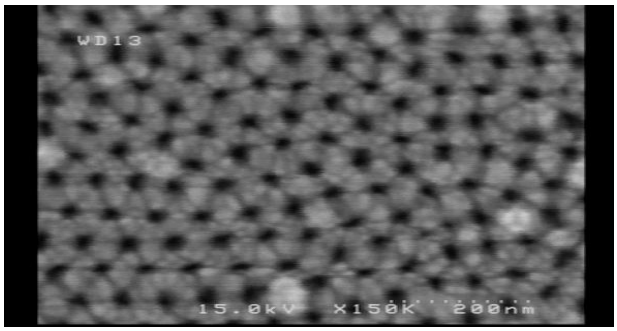

**Fig. 1** – A typical top view SEM micrograph of AAO template preparing with high-density array of nanopores

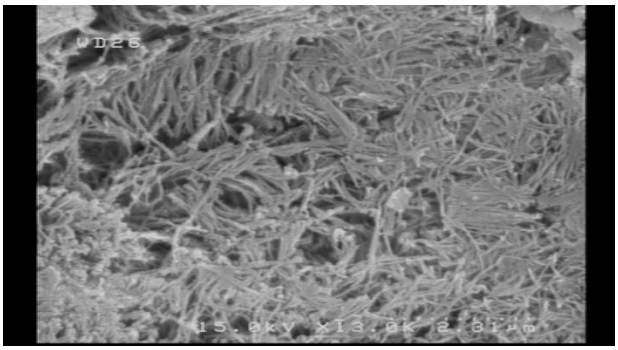

**Fig. 2** – SEM image of the $Co_{0.95}Sn_{0.05}$ nanowires were released from the AAO template

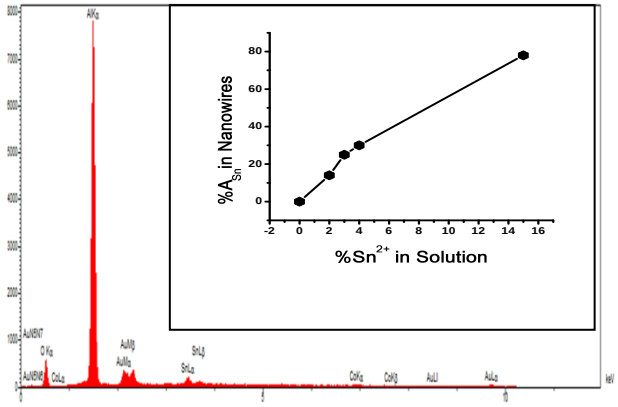


**Fig. 3** – A typical EDX result of $Co_{0.85}Sn_{0.15}$ nanowires. Inset show the variation of Sn content in the content of alloy nanowires versus ionic concentration of Sn in the electrolyte solution measuring by EDX.

### 3.2 Effect of the Sn Content and Annealing

Fig. 4 brightly illustrated how Sn concentration and annealing process up to 575°C can affect on magnetic coercivity of alloy nanowires. With surveying this curve, decreasing in $H_c$ values because of increasing in Sn concentration is seen. On the other hand annealing process rise the Hc value of alloy nanowires especially for sample of $Co_{0.99}Sn_{0.01}$ Co nanowires do not have considerable increasing after per stag of annealing process but all alloy nanowires steadily rise is shown. To further investigate about the effect of the Sn content on the structure of nanowire, the crystal structure of samples was studied. The XRD pattern of nanowire arrays are shown in Fig. 5. As seen, the as deposit $Co_{0.99}Sn_{0.01}$ and $Co_{0.97}Sn_{0.03}$ alloy nanowires revealing an amorphous shape which annealing up to 575°C does not varied the crystal structure of alloy nanowires. As a result, the shape anisotropy is a more important agent in determining of the magnetic properties of nanowires. While annealing process was done the Sn melted due to low melting temperature of this metal (about 231.93°C). Finally in the next step nanowires cooled slowly improving the tension in structure of alloy nanowires. So shape anisotropy of these nanowires were improved [2, 4].

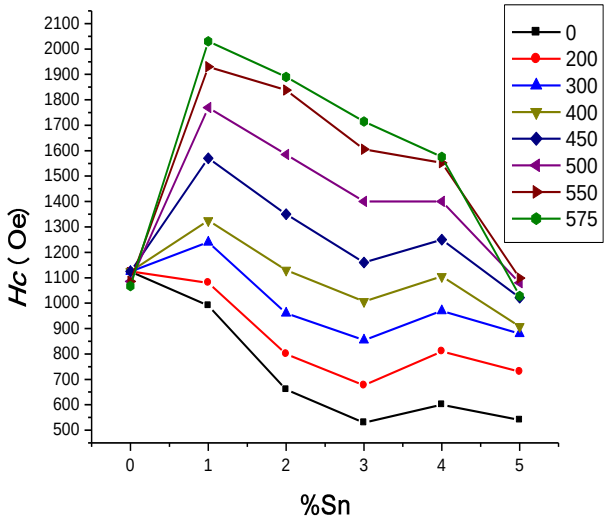


**Fig. 4** – The effect of annealing temperature on the $H_c$ value of $Co_{1-x}Sn_x$ of nanowires for x= 0, 0.1, 0.2, 0.3, 0.4, and 0.05

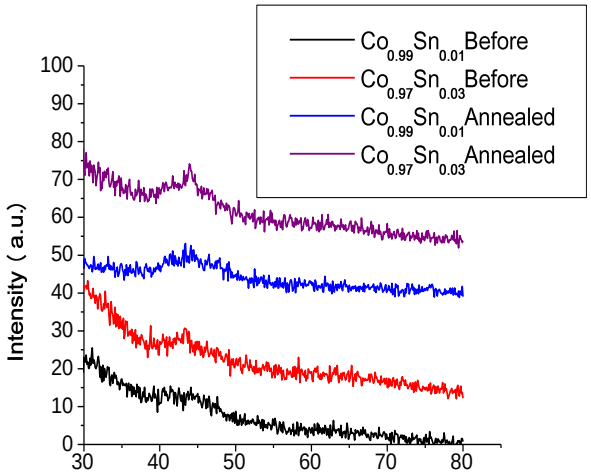


**Fig. 5** – The XRD patterns of the as $Co_{0.99}Sn_{0.01}$ and $Co_{0.97}Sn_{0.03}$ samples before annealing and after annealing up to 575°C

## 4. CONCLUSION

To summarise, highly ordered nanowire arrays of $Co_{1-x}Sn_x$ with high aspect ratio were fabricated by co-electrodeposition of Co and Sn in to pores of AAO templates. Furthermore electrodeposition of $Co^{2+}$ and $Sn^{2+}$ in structure of alloy nanowires is an unnormal co-electrodeposition. The effect of Sn concentration in the content of array nanowires and annealing process on the

magnetic properties of the deposited nanowires was investigated. It is found that $H_c$ values of alloy nanowires are dropped with addition Sn in structure of nanowire. Amount of alloy nanowires coercivity risen after annealing process via improving shape anisotropy.

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