

ANGULAR DEPENDENCE OF MAGNETIC PROPERTIES IN Co NANOWIRE ARRAYS

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ABSTRACT

The Co nanowire arrays were fabricated by electrodeposition method by using the porous polycarbonate template. Study on crystallographic structure, micro structure, and the element composition confirmed the quality of the fabricated Co nanowires. SEM image shows the wires with an average diameter of 200 nm and the average length of 9 μm . The magnetic properties, measured at room temperature using vibrating sample magnetometry (VSM), displays that the nanowires have anisotropic property. The angular dependence of coercivity of Co nanowires has been studied. The decrease of the coercivity, when the angular changed from 0 ° to 90 °, will be discussed.

Keywords: PC template, Co nanowires, magnetic properties and angular.

1. INTRODUCTION

In the last few years, the fabrication and characterization of magnetic one dimensional nanostructures have been drawn much attention because of their potential applications in the high density magnetic recording media, magnetic sensors, cell separation and magnetic labeling in biomedicine [1, 2, 3]. The magnetic nanowires have quasi-one dimensional (1D) anisotropic structures along the wire axis and the magnetic properties of the nanowires are related to many parameters such as diameter, length, and composition [3, 4, 5]. Therefore, the coercivity, remanent magnetization and saturation magnetization are dependent on the direction of an externally applied field. The coercivity is one of the most important properties of magnetic materials for many present and future applications of nanowires. Furthermore, the use of a nanoporous membrane is believed to increase the coercivity of the nanowires as compared to the thin film or the bulk material of the same composition [5, 6].

In this paper, we investigated angular dependence of magnetic properties in Co nanowires arrays, which were electrodeposited into polycarbonate templates. We found that the decrease of the coercivity, when the angular changed from 0° to 90° . These findings are of practical importance in exploiting ordered Co nanowire arrays for use in magneto-electronic devices.

2. MATERIALS AND METHODS

In this work, porous polycarbonate templates with the pore diameters of 200 and the thickness of 10 μm were used. Before electrodeposition, a copper (Cu) layer of the thickness of 300 nm was sputtered onto one side of the polycarbonate template and used as the working electrode to fabricate magnetic nanowires. Afterward, the polycarbonate template was placed in an electrolytic bath. Electrodeposition is a process in which an electrical current passes through an electrolyte of cobalt ions. As shown in Figure.1 [7], electrodeposition of nanowires is usually done in a three-electrode arrangement, consisting of An Ag/AgCl electrode was used as the reference electrode (*RE*), the counter electrode was a platinum mesh (*CE*), and the working electrode (*WE*).

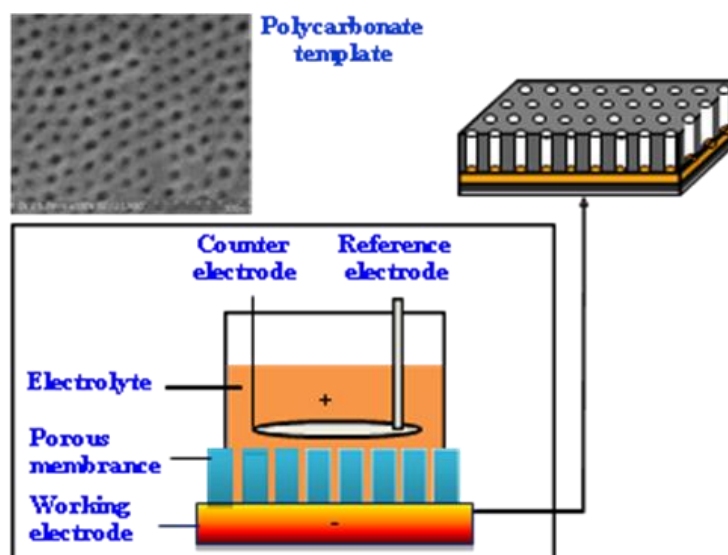


Figure 1. Schematic representation of the electrodeposition process.

The electrolyte consisted of 0.22M $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$, 0.7M H_3BO_3 , 0.001M Sarcosine. The deposition potential was - 0.85 V, while the pH value of the electrolyte bath was 5.0. The electrodeposition process was performed at room temperature. The morphology of the Co nanowires was investigated by scanning electron microscopy (SEM, JSM-5410LV, JEOL, Tokyo, Japan). The nominal composition of the nanowires was determined by energy dispersive spectroscopy (EDS, ISIS 300, Oxford, England). The crystal structure was analyzed by X-ray diffraction (XRD, Advance D8, Bruker, Germany). Magnetic hysteresis loops were recorded at room temperature as a function of the angle between the applied field and the nanowires axis using a vibrating sample magnetometer (VSM 7404, Lake Shore, OH, USA) in fields up to 8 kOe.

3. RESULTS AND DISCUSSION

Figure 2 shows the SEM image of Co nanowire arrays after removal of the polycarbonate template. It is obvious that these Co nanowires were grown uniformly when compared to the template thickness and pore diameter. From SEM image show that these magnetic Co nanowires have the diameter of 200 nm and length about 9 μm . The aspect ratio (length/diameter) of Co nanowires is about 50.

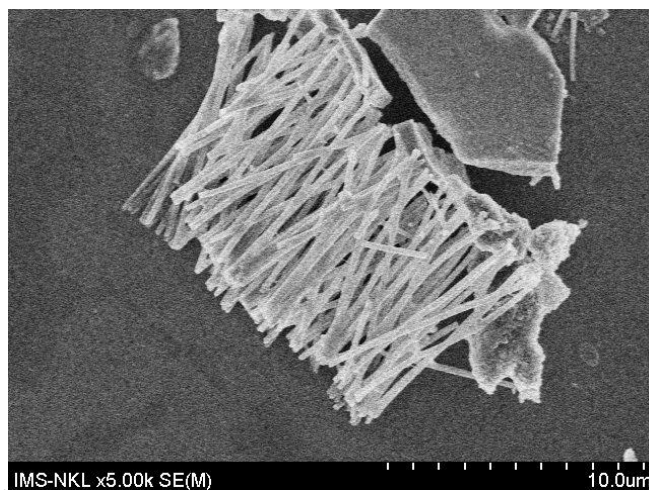


Figure 2. SEM image of the Co nanowires.

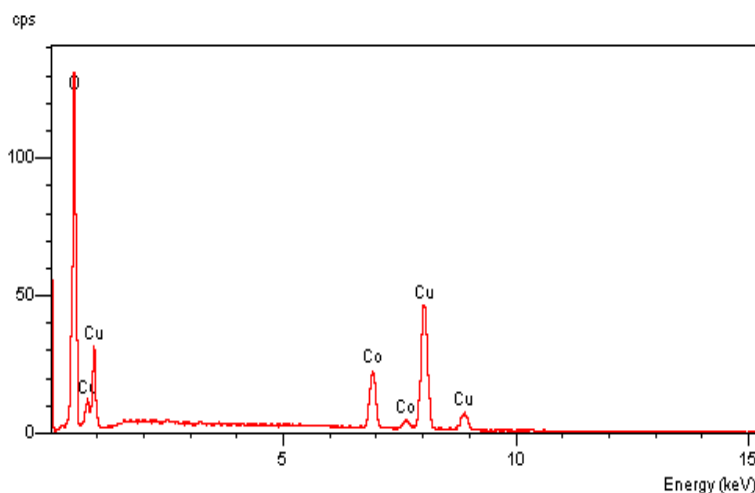


Figure 3. EDX spectrum analysis of Co nanowires.

The elemental compositions of the Co nanowire arrays were measured by energy dispersive analysis by X-rays. Figure 3 shows an EDS spectrum of the 200 nm Co nanowires. It is observed that the Co nanowires contained only Co, Cu, O elements. The presence of Cu peaks is due to the copper film sputtered on the surface of the sample and O peak is native oxide surface formation on Co nanowires.

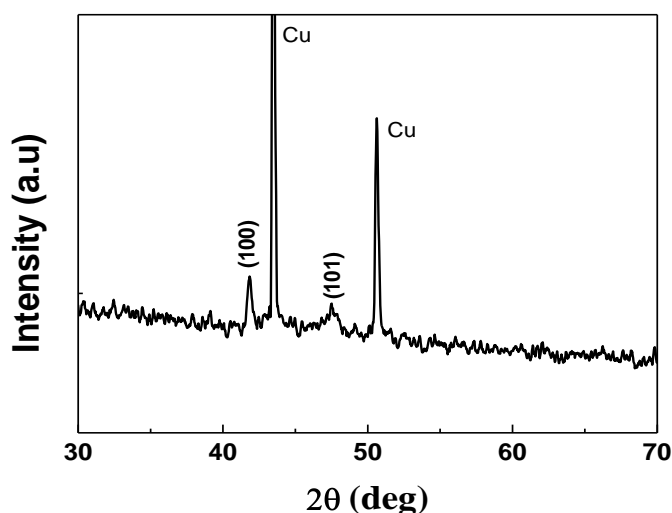


Figure 4. XRD pattern of the Co nanowires.

In order to study the structure of the Co nanowires, before X-ray measurements, a layer of copper (Cu) film and the polycarbonate template were removed by using aqueous solution of chloroform. Figure 4 shows the XRD patterns of Co nanowire arrays with the average diameter is about 200 nm. The XRD patterns, clearly indicate that two diffraction peaks corresponding to the (100) and (101) are in the hexagonal close packed (hcp) phase. The peaks at 41.8° and 47.4° correspond to the hcp (100) and hcp (101) phases, respectively. The copper (Cu) peaks are due to the uncaredful washing process, so on the surface of the nanowires there still exist Cu impurities.

Comparing to the standard powder diffraction of the hexagonal close packed structured Co crystal phase, which is consistent with the standard card JCPDS no. 05-0727. (JCPDS no. 05-0727 with the standard peaks indicating the formation of these phases can be seen 41.72° , 44.73° , 47.63° and 76° corresponding to crystal planes of (100), (002), (101) and (110), respectively) [8].

In order to study the magnetic properties of the Co nanowires, hysteresis loops of the Co nanowires measured using vibrating sample magnetometer (VSM) with the range of $0^\circ < \theta < 90^\circ$, where θ is the angle between applied field and nanowires axis. The hysteresis loops obtained at $\theta = 0, 30, 60$ and 90° are displayed in Figure 5. The clear hysteresis loops obtained indicated that the different shapes of (M-H) curve provided that the Co nanowires exhibited the anisotropy when magnetic field was applied change the direction to the nanowire axis. This behavior allows us to conclude that shape anisotropy of nanowires may induce a hard axis of magnetization when $\theta = 90^\circ$.

The magnetic anisotropy change simultaneously with the direction of the applied magnetic field. From the in-plane hysteresis loop, we can determine the anisotropy field H_A [9]. The anisotropy field of the nanowires increases from 2342 Oe to 4530 Oe correspondingly with $\theta = 0^\circ$ (the applied field parallel to wire) and $\theta = 90^\circ$ (applied field perpendicular to wire).

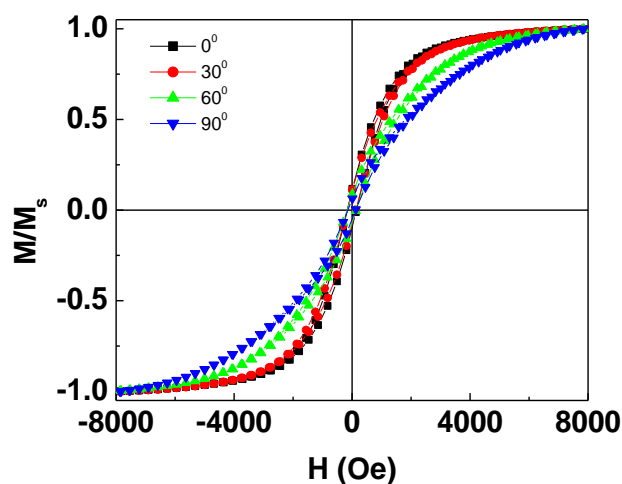


Figure 5. Angular dependence of the hysteresis loops Co nanowires.

Table 1. Values of coercivity and squareness of Co nanowires at different angles.

θ ($^{\circ}$)	H_c (Oe)	M_r/M_s
0	160	0.11
30	147	0.10
60	130	0.08
90	120	0.06

Values of coercivity and squareness (M_r/M_s) of Co nanowires at different angles are shown in Table 1. As seen from Table 1, the coercivity and squareness decreases when the angle changes from 0° to 90° .

4. CONCLUSIONS

In summary, we have successfully prepared Co nanowires with the average diameter of about 200 nm and length of 9 μm by the electrodeposition method in polycarbonate template. The Co nanowires were observed by XRD to have hcp structure with preferred orientation of (100) and (101). The results of magnetic measurements show that the anisotropy of the Co nanowires change with the direction of the applied magnetic field. The decrease of the coercivity, when the angular changed from 0° to 90° .

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