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Magnetic properties of (1 1 0)- and (2 0 0)-oriented Fe-nanowire arrays

H.N. Hu*, H.Y. Chen, J.L. Chen, G.H. Wu*

Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100080, China

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Abstract

Fe-nanowire arrays with (1 1 0) and (2 0 0) orientation have been fabricated through controlling the pH values in electrodeposition. Fe-nanowire arrays 30 and 60 nm in diameter were obtained. With the magnetic field applied parallel to the wire, 60 nm diameter Fe nanowires with preferred (2 0 0) orientation show an improved squareness and an easier magnetization than the nanowires with preferred (1 1 0) orientation. For 30 nm diameter Fe nanowires, (2 0 0)-oriented nanowires show an improved squareness and coercivity compared with (1 1 0)-oriented nanowires.
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1. Introduction

One-dimensional nanostructures are of great interest because of their potential application in many areas, such as high-density perpendicular-magnetic-recording media and nanosensors [1,2]. The synthesis and precise control of such a magnetic nanostructure on a large scale is a challenging issue in material science. One strategy is to electrodeposit magnetic nanowires into nanochannels of porous anodic aluminum oxide (AAO) templates, which have been utilized by many groups to prepare magnetic metals, such as Ni, Co, and Fe. Among earlier works, most of the Fe nanowires deposited are (1 1 0) oriented or polycrystalline [3–7]. It is well-known that (1 1 0) is the hard axis of the magnetization of Fe. Most of the earlier work was focused on ultra-thin Fe-nanowire arrays with diameters of about 5–35 nm [4–6], using the shape anisotropy to suppress the crystalline anisotropy. In the present paper, we report a unique dynamically controlled growth method to prepare Fe nanowire with preferred (2 0 0) orientation along the wire. In contrast, (1 1 0)-oriented Fe nanowires have also been deposited. Fe nanowires 60 and 30 nm diameter

*Corresponding authors. Tel.: +86 10 8264 9247; fax: +86 10 8264 9485.
E-mail addresses: hnhu@aphy.iphy.ac.cn, userm201@aphy.iphy.ac.cn (H.N. Hu).

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with both orientations were fabricated. The magnetic properties were measured in a superconducting quantum interference device (SQUID) magnetometer. When the magnetic field is applied parallel to the wire, the 60 nm diameter Fe nanowires with (2 0 0) orientation show a higher aspect ratio and easier magnetization than the (1 1 0)-oriented Fe nanowires. As to the 30 nm Fe nanowire, (2 0 0)-oriented nanowires show a much improved coercivity (about 30%) than (1 1 0)-oriented nanowires.

2. Experimental procedures

Porous AAO template was prepared by a two-step anodizing process on aluminum foils with a high purity of 99.999% [8,9]. Where AAO template with 60 nm diameter was anodized in 0.3 M oxalic acid solution under a constant voltage of 40 V at 12 °C, 30 nm diameter AAO template was anodized in 0.3 M sulfuric acid at 26 V and 1 °C. Both kinds of AAO templates were anodized for about 12 h. The 30 and 60 nm diameter templates have a thickness of about 50 and 70 μm, respectively. Both templates have a high aspect ratio of more than 1000. After anodization, the remaining aluminium substrate and its barrier layer at the bottom of the AAO template were removed. Then, a 300 nm Cu layer was sputter-deposited on one side of the AAO template to serve as the working electrode during the electrodeposition. An aqueous bath containing Fe^{2+} was used to deposit Fe nanowires at room temperature. Both kinds of Fe nanowires were electrodeposited using the potentiostatic method with a three-electrode arrangement with a saturated calomel reference electrode (SCE) and a graphite rod as counter electrode at a constant potential of −1.1 V. X-ray diffraction (XRD) with Cu Kα radiation was used to characterize the structure of the wires. Magnetic measurements were performed using a SQUID magnetometer.

The electrodeposition was carried out as follows: (1) Fe-1 (60 nm diameter) and Fe-3 (30 nm diameter) were deposited in a solution containing 0.2 M $FeCl_2$ with pH = 2.6 (adjusted by an appropriate amount of dilute HCl). Then deposition was performed at a constant potential of −1.1 V relative to the SCE in a three-electrode system. (2) Fe-2 (60 nm diameter) and Fe-4 (30 nm diameter) were deposited in a solution containing 0.2 M $FeCl_2$ with the same deposition potential of −1.1 V relative to SCE as Fe-1 and Fe-3. At the very beginning of the deposition procedure at pH = 3.7, within 2 min the pH value was adjusted to 2.6 by adding an appropriate amount of dilute HCl; then the deposition was continued till Fe nanowire filled the whole AAO template. For this kind of sample, it was found that only changing of the pH value during the deposition procedure can result in a change of preferred orientation.

3. Results and discussion

Fig. 1 shows the XRD spectra of Fe nanowire arrays with (1 1 0) (a) and (2 0 0) (b) orientation, embedded in the AAO template. Both samples show (1 1 0) and (2 0 0) reflections of cubic Fe. In Fig. 1(a) a very strong (1 1 0) reflection can be seen which is accompanied by two weak (2 0 0) and (2 1 1) reflections, indicating that the Fe-1 and Fe-3 nanowires have a strong preferred (1 1 0) orientation. Fig. 1(b) shows a very strong (2 0 0) reflection accompanied by a weak (1 1 0) reflection, indicat-

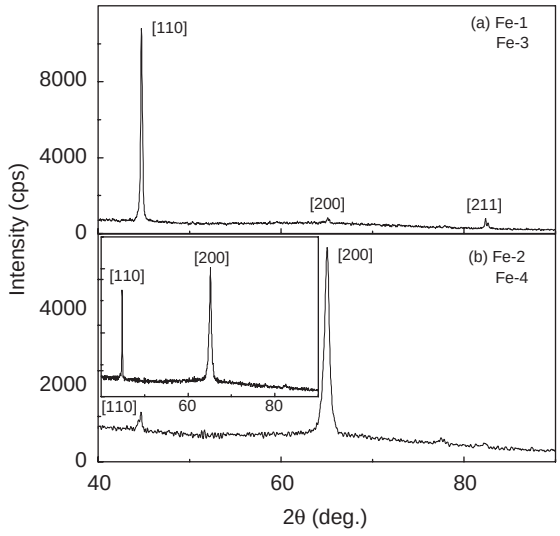

Fig. 1. XRD of Fe nanowires electrodeposited under different conditions: (a) Fe-1 and Fe-3, (b) Fe-2 and Fe-4 (inside was XRD of the beginning growth side of the nanowire).

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