Enhancement in Perpendicular Anisotropy of Co/Cu Multilayer Nanowires via Phase Doping Transformation

P.-Y. Chen (陳柏源)[1], R.-S. Liu (劉如熹)[2],
S.-F. Hu (胡淑芬)[3], and C.-Y. Huang (黃昭淵)[3]

[1]Institute of Electro-optical Science and Technology,
National Taiwan Normal University, Taipei, Taiwan
[2]Department of Chemistry, National Taiwan University, Taipei, Taiwan
[3]Department of Physics, National Taiwan Normal University, Taipei, Taiwan

Electrochemical templates synthesis is a versatile technique for producing single component and multisegment nanowires and nanorods. Ferromagnetic nanowires of materials such as Fe, Co and Ni, ferromagnetic alloys such as CoPt, FePt and FeCo and multilayer nanowires such as NiFe/Cu, Ni/Cu, Co/Cu and CoPt/Pt, have been fabricated using this technique. Herein, we report the fabrication of Co/Cu magnetic multilayer nanowires through the electrodeposition process in porous alumina templates and a novel method to achieve enhancement in perpendicular anisotropy by doping nano grains of fcc phase into hcp phase in Co segment of multilayer nanowires.

Anodic aluminum oxide (AAO) is chosen as the template because AAO has an isolating, non-connecting, and parallel pore structure with tuneable pore diameters. The AAO templates used in our experiments was prepared via anodic oxidation of Al foil (99%, 0.25 mm thick). The Al foil was first electropolished in sulfuric acid / phosphoric acid mixed solution and then the Al foil was anodized in 0.3 M oxalic acid at 10 ºC for few hours to form nano-size channel template. The voltage of the anodization was kept at 30 V to keep the constant pore diameter and interpore distance of AAO template. The template was dipped into saturated $HgCl_2$ solution to remove the remaining aluminum, and then dipped in 5 wt% H_3PO_4 to dissolve the barrier layer.

Electrodeposition in single solution containing both Co^{2+} and Cu^{2+} ions was used for the synthesis of Co/Cu nanowires. First, a silver film of 5000 Å thick was thermal evaporated onto one side of AAO to serve as the back electrode. The electrodeposition was performed via a 3-electrode method, the counter electrode was Pt wire and the Ag/AgCl electrode serves as the reference electrode. The deposition solution contain 2 M $CoSO_4$, 0.02 M $CuSO_4$ and 0.6 M H_3BO_3 and the concentration ratio of Co^{2+}/Cu^{2+} is 200/1 to avoid the Copper impurities in Cobalt segment during the electrodeposition. In order to achieve multilayer nanowires structure, the reduction voltage was set at -1 V for Co^{2+} ions and -0.16 V for Cu^{2+} ions. The time duration of each pulse can be changed to tune the thickness of each layer. After the nanowires were formed, the silver electrode was removed by 1 M HNO_3 and then the AAO was dissolved in 1 M NaOH to obtain Co/Cu nanowires.

The XRD profile of a specimen with 1 μm and d = 50 nm Co/Cu multilayer nanowires is shown in Fig. 1. All the observed peaks can be fitted with the fcc phase and hcp face of standard Cobalt. It is known that at room temperature the stable phase for bulk (or bulklike) Co is only hcp, whilein nanostructure or very thin film of Co, the fcc phase can also appear. Analysis indicates that the fcc and hcp phases dominate over the cobalt layer and fcc phase for copper layer. The result is similar to hcp phase in Cobalt nanowires published by Zuwei and Fashen which the preferential texture is (100) plane and the hexagonal c axis lies perpendicular to the long axis of nanowires, however the preferential texture from (100) to (101) plane was observed significantly in our results, the probably mechanism is that (101) plane of Cobalt hcp phase induced by (111) plane of Cobalt and Copper fcc phases and this makes a contribution of magnetocrystalline perpendicular anisotropy. Rietveld refinement was performed using the general structure analysis system (GSAS) program to obtain the phase ratio between fcc and hcp in crystal structure and the results show that the ratio between fcc and hcp phase is almost 1:1. For fcc phase of cobalt, the magnetocrystalline anisotropy energy density ($K_1 = 6.3 \times 10^5$ erg cm^{-3}) can be ignored in comparison with the shape anisotropy energy density ($K_1 = 6 \times 10^6$ erg cm^{-3}) and the effective anisotropy of the Cobalt segment can be enhanced by doping fcc phase of Cobalt nano grains with increasing the aspect ratio of Cobale segment. The grain size, as determined from the full width at half-maximum of the fcc-Co (111) and hcp-Co (101) peaks are all about 30 nm.

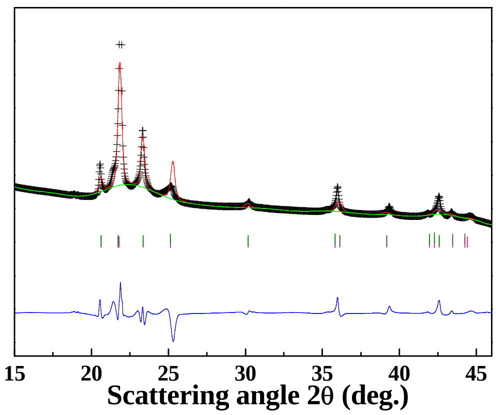

Fig. 1: X-ray diffraction patterns for 50 nm diameter Co/Cu multilayer nanowires with mixture phase of hcp and fcc crystal structure in Co segment.