Growth and Magnetic Properties of Co thin Films Deposited on Anodic Porous Alumina

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1. Introduction

Nanopatterned and nanostructured magnetic systems are expected to broaden our understanding of magnetic materials in deep-submicron and to promise the advances of the direct technological applications based on the novel magnetic properties. Here we have deposited thin Co films on anodic porous alumina and investigated the surface morphology as well as the magnetic properties of the resulting nanostructured Co films.

2. Experimental details

For the substrate used in the Co deposition, we have prepared anodic alumina with an array of uniform pores by two-step anodization method. On top of the prepared anodic porous alumina substrate, 50 nm thick Co films have been deposited by pulsed laser deposition(PLD). Also, to see the effect of the substrate temperature on the film growth, the film depositions were carried out at room temperature and 500 °C. For comparison, we have also prepared 40 nm thick Co films on non-porous SiO2 substrate deposited both at room temperature and 500 °C. The surface morphologies of the deposited films were studied with field-emission scanning electron microscope and atomic force microscope, and their magnetic properties were measured by vibrating sample magnetometer.

3. Results and discussions

The scanning electron micrographs of the Co films deposited on both anodic porous alumina and non-porous SiO_2 substrates at room temperature reveal the growth of uniform thin films, while the film on the anodic porous alumina reproduces the honey-comb structure of porous alumina underneath. When the film deposition has been carried out at 500 °C, the resulting films show the formation of grains. Even though in both films the grains are formed by the thermally-driven coalescence process, the detailed growth of these grains in the films highly depends on the substrates underneath. While the film PLD deposited on the SiO_2 substrate at 500 °C shows the formation of grains with various shapes and sizes ranging roughly from 20 to 150 nm along in their longest axis, the film on the anodic porous alumina consists of similarly-sized, almost-spherical grains with an average diameter of about 20 nm, formed around the pores on the surface. The fact that the grains avoid the pores on the surface suggests that a grain over a pore would be in the higher free energy state than one on the alumina surface would. We expect that on the non-porous substrate, upon deposition fine grains are widely dispersed over the substrate surface, and they diffuse and merge with other small grains nearby. This random coalescence process leads to the increase in the grain size and especially results in the wide size distribution. On the contrary, on the porous substrate, the presence of the ordered pores might limit the continuous random-growth of the gains due to the surface energy difference and lead to the more uniform grain size distribution. However, one might not completely rule out the difference in the nature of the substrates used here.

The M-H curves, normalized with the substrate area, of the PLD deposited Co films show that all the films exhibit the similar values of the saturation (M_s) about 10^{-5} emu/mm^2. The small difference in M_s might be due to the thickness variation or the formation of CuO layer on the film surface. However, the values of the coercivity(H_c) of these films change significantly with the underlying substrate and the substrate temperature during the deposition process, which can not be simply accounted for by the above. The Co films on the anodic porous alumina show H_c of 120 G for room temperature deposition and 260 G for 500 °C, while for the films on SiO_2, the values are 50 G for room temperature and 580 G for 500 °C. We have also considered the squareness of the hysteresis curves, defined as the ratio between the remanence(M_r) and the saturation(M_s). While the films on the SiO_2 substrate show the squareness ratio of 92% for room temperature deposition and 68 % for 500 °C, the films on the porous alumina substrate exhibit the hysteresis curves with the corresponding ratio of 29 % for room temperature and 45 % at 500 °C. We expect that the detailed surface morphology of the nanostructured Co films prepared with the porous substrate affects their magnetic properties in addition to other factors such as the deposition condition.