Available online at www.sciencedirect.com
SCIENCE DIRECT
Journal of Magnetism and Magnetic Materials 286 (2005) 113–118
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

# Magnetoresistance of FePt nanograins embedded in carbon matrix

Y.H. Lee[a,*], M.S. Guo[a], C.S. Wur[a], P.C. Lin[b], W.-H. Li[b]

[a]*Department of Physics, National Cheng Kung University, #1, Tashuei Rd, Tainan 70101, Taiwan, ROC*
[b]*Department of Physics, National Central University, #300, Jungda Rd, Jhongli 32054, Taiwan, ROC*

Available online 22 October 2004

**Abstract**

We studied the magneotransport properties of granular films of FePt/C which were fabricated by using DC magnetron co-sputtering technique. Films were made at the sputtering pressures of 30 and 15 mTorr, and with sputtering powers of 80 and 60 W for each pressure. A large magnetoresistance of 6% at 2 K was observed only for the film made at 80 W and 15 mTorr. Other magnetoresistance values were all below 1%. We also discussed the influence of carbon matrix on the giant magnetoresistance.


*PACS:* 75.47.−m; 72.15.Gd; 75.70.Cn

*Keywords:* GMR; Granular films; FePt; Carbon films; Superparamagnetism

## 1. Introduction

Giant magnetoresistance (GMR) was first discovered in the Fe–Cr [1] multilayer system. Later it was also observed in granular films [2–8]. GMR of the granular films is not only an interesting subject of theoretical investigation, but it also initiates a new generation of applications in magnetic sensors and recording devices. Magnetic grains of the granular film can be embedded in either metallic or insulating matrix. The magnetoresistance of the former situation is due to the spin-dependent scattering of conduction electrons, and the later to the spin-dependent scattering of tunnel electrons. The magnetic grains are usually made of transition metals (Fe, Co or Ni) or their alloys. The materials of the film matrix, regardless of whether they are electrically conductive or insulating, are immiscible with the transition metals. Usually noble metals such as copper [2,3], silver [4], are taken as the materials for the conductive matrix and insulators such as quartz [5] or sapphire [6–8] are adopted for the insulation matrix. The FePt alloy was known to have a very large uniaxial magneto-crystalline anisotropy constant [9] $K_a =$

*Corresponding author. Tel.: +011 886 6 2757575x65238; fax: +011 886 6 2747995.
*E-mail address:* yuhua@phys.ncku.edu.tw (Y.H. Lee).

0304-8853/$ - see front matter 
doi:10.1016/j.jmmm.2004.09.049

$7 \times 10^7$ erg/cm$^3$ when it is in an ordered $L1_0$ phase with the face-center-tetragonal (fct) structure. It thus received a lot of interest, for example, in the research of the anisotropies of the magnetic properties [10] or GMR [11] of FePt thin films. There are also many studies of granular FePt films, for example, of the GMR of FePt grains embedded in Ag films [12]. The largest GMR of 0.7% at room temperature was found for the multilayer films of FePt/Ag with thin FePt (0.2 nm) and Ag (0.4 nm) layers annealed at 500 °C for 5 min. The magnitude of GMR is sensitive to sample parameters such as particle size, inter-particle distance, magnetization, etc., which are in turn dependent on the deposition parameters and annealing treatments. Using carbon as an insulation matrix in the granular films is also of interest to many scientists. For example, Delaunay et al. [13] have focused on the magnetic properties of CoPt grains embedded in carbon films. We investigate the GMR of FePt grains embedded in amorphous carbon matrix. In our previous work [14] on the structure and magnetic properties of FePt/C granular films, the transmission electron microscope (TEM) images of the carbon matrices were very different for varying deposition parameters. The carbon matrices looked grayish, except for the white one obtained at 80 W and 15 mTorr. But the grain sizes were similar for different deposition parameters. The post-deposition annealing improved only the crystal structure of the grain, and had little effect on both the grain size of FePt alloy and the structure of carbon matrix. In this study, we focused on the magnetoresistances of the granular film of FePt/C, and found both the GMR and the temperature-dependent resistances showed little changes before and after annealing. At 2 K the GMR larger than 1% is obtained only in the film of 80 W and 15 mTorr. It appears that the properties of the carbon matrix influence the magnitude of GMR in our films. We also discuss the relation between the nature of carbon matrix and the GMR.

## 2. Experiment

The DC magnetron sputtering technique was adopted in preparing the films. We used a single composite target, which is a 2-in-diam plate of graphite plus two pellets each of iron and platinum on top. In order to reach a one-to-one atomic ratio in the fct structure of FePt alloy in the grains obtained during the deposition process, equal amounts of Fe and Pt were used. But the sputtering yield of Pt is about 1.8 times larger than that of Fe. The Fe and the Pt pellets were of different sizes (2-mm-diam $\times$ 3 mm and 2-mm-diam $\times$ 2 mm, respectively). No intentional heating was applied to the quartz ($SiO_2$) substrate. Both pressures of 15 and 30 mTorr were adopted for the sputtering at the power of 80 and 60 W, respectively. The post-deposition annealing was carried out in a quartz tube evacuated by using a rotary pump. Films were annealed at a temperature of 400 °C for 1 h. Higher temperature or longer period will blacken the film. We adopted the conventional four-point method, which uses four pins in a straight line, in measuring the resistance of the sample which is cut in a size of about $5 \times 2.5$ mm. For magnetoresistance measurements, the magnetic field was applied parallel to the film surface and normal to the current. The resistances were first measured at zero field ($H = 0$ T) while lowering the temperature from 300 to 2 K, and then at 9 T with temperature rising from 2 to 300 K. The magnetoresistances were also measured at 2 K with the field increasing from zero to $+9$ T then decreasing to $-9$ T and back to $+9$ T again. Magnetoresistances measured by applying the field parallel to the current was also checked on one sample. There is no difference between the results of the field in the film plane parallel or perpendicular to the current. This is not surprising because of the random distribution of the magnetic moments of the grains. We thus present only the results for the field applied in the film plane and perpendicular to the current.

## 3. Results and discussion

### 3.1. Experimental results

The temperature-dependent resistivities measured at $H = 0$ T of the as-deposited films made at the conditions of 80 and 60 W and 15 and