Angular dependence of high-field microwave absorption in Nano-FePt films

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Abstract

Electron Spin resonance (ESR) measurements at room temperature and X-band microwave frequency were performed on highly crystalline Fe-Pt system thin films. Fairly high DC static magnetic field absorption of about 280 mT was observed in these films. We attribute the high field absorption to ferromagnetic resonance (FMR). No detectable spin waves modes were identified. This signifies magnetic stability in our films. We qualitatively attribute such magnetic stability in our films as a self-assembly of these Fe-Pt system nanoparticles. The angular dependence of microwave absorption in ferromagnetic resonance (FMR) is investigated. These measurements showed an increase in the resonance field as a function of the angle, which can be explained in terms of a contribution of shape anisotropy field (SAF).

Keywords: SAF; FMR; Spin Waves; Laser solution photolysis, MA

1. Introduction

Magnetic recording media plays an important role in the development of non-volatile data storage technologies. Particularly, magnetic hard disk drives are important parts in many devices such as video cameras, computers etc. The year 1956 marked the first magnetic hard disk with recording density of 2 kb/in^2 that was successfully built by IBM **[1]**. Since then, the areal density (the number of bits /unit area on a disk surface) has successively increased **[2]**. Nowadays, products with an areal density of more than 700 Gb/in^2 are commercially available **[3].** The increase in the areal density needs to be continued due to the future demand for information storage. Areal density in a level of 1 Tb/in^2 or more would be unavoidable. Iron platinum (FePt) nano-particles (NPs) are actively being pursued as a potential candidate for larger storage capacities on hard-disk drives than any other materials due to its high magneto-crystalline anisotropy (MA) **[4]**. MA is when the atomic structure of a crystal of a certain material introduces preferential direction of magnetisation. This phenomenon is mostly common in ferromagnetic materials. Traditional magnetic recording materials such as Co/Cr have limitations since their magnetic direction of each recording bit would become unstable at room temperature due to thermal fluctuation **[5]**. FePt possesses bot h higher magnetic anisotropy and better thermal stability **[6, 7]**. This however makes it a better candidate for magnetic recording unlike other materials.

Ferromagnetic materials normally exhibit ferromagnetic resonance (FMR) when exposed to microwaves and appropriate magnetic fields that satisfy resonance conditions. This phenomenon is

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due to absorption in the full saturation state and is a direct signature of ferromagnetic state of a material. FePt possesses FMR at room temperature as illustrated in figure 1; this implies that FePt is ferromagnetic. Ferromagnetic materials have a strong attraction to applied magnetic fields and are able to retain their magnetic properties even after the field has been removed. They have a large and positive susceptibility. This observable fact is responsible in data mass storage materials. However, FMR arises mostly with spin waves. Spin waves are propagating disturbances in the ordering of magnetic materials and are sometimes called magnons. These intrinsic excitations in magnetic materials reduce the FMR phenomenon and are triggered by thermal effects. In this report, we present the FMR study for potential high-density magnetic recording and thermal stability of Fe-Pt system. In addition, the study of the angular dependence of the high field absorption by FePt gives enough evidence of magnetic anisotropy present in these films.

1. Experimental section

The Fe-Pt NPs were prepared using a method previously described by Mwakikunga et al. **[8]**. Precursor for this Fe-Pt system comprised a CH_3OH (Sigma-Aldrich, St Louis, MO) solution in which Fe(III) acetyacetonate [Fe(III)($C_5H_7O_2$)$_3$, 99.9+%, Sigma-Aldrich], denoted by Fe(III) (acac)$_3$, and Pt(II) acetyacetonate [Pt(II) ($C_5H_7O_2$)$_2$, Sigma-Aldrich 97%] solution, denoted by Pt(II) (acac)$_2$ were completely dissolved. The concentration of Fe(III) (acac)$_3$ and Pt(II) (acac)$_2$, was 2.4 and 0.6 mM, respectively. Four samples were irradiated at different incident laser fluence settings. Soon after irradiation, black precipitates formed and were washed with hexane to remove impurities. These precipitates were Fe-Pt NPs and were allowed to dry on Si(111) substrates for scanning electron microscopy (SEM), transmission electron microscope (TEM) and x-ray diffraction (XRD) studies. Some of these results were presented elsewhere **[9]**.

The FMR data were taken at room temperature using a commercial electron spin resonance spectrometer (JEOL-JES-FAS 200) operating at the X-band microwave frequency, with sample located at the center of a standard TE_{102} microwave resonant cavity and fixed to a goniometer, allowing the study of in-plane and out-of-plane angular dependence of the absorption field and line-width. The FMR spectra were taken using standard phase-sensitive detection techniques, applying modulation fields up to 1.0 mT, modulation frequency of 100 kHz, and microwave power of up to 10mW. The microwave resonance frequency at $\theta_H = 0^\circ$ for all the samples was 8988.9158 ± 0.8960 MHz.

2. Results and Discussions

In this report, measurements were conducted in the usual electron spin resonance (ESR) geometry, the DC static magnetic-field was parallel to film surface i.e. ($\theta_H = 0^\circ$) and the AC magnetic field was always maintained parallel to the film. FMR was observed at fairly high DC static magnetic field of about 280 mT, the FMR spectra were almost symmetric. This FMR signal is due to absorption in the full saturation state. The compositional study of the FePt system on the ESR is reported elsewhere **[10]**. Further, the role of anisotropy on the FMR feature was studied by a variation of angular dependence. The microwave field was always parallel to the film. Figure 1 depicts of the derivative of microwave absorption with angle $\theta = 0^\circ$ to $\theta = 75^\circ$ for the thin film of FePt. Measurements were carried out at room temperature and microwave power P=10mW. At 0˚ the intensity of the FMR signal is quite significant and may be due to the induced anisotropy field (IAF) since magnetization remains within the plane. IAF corresponds to the energy needed to orientate the magnetic moments in the easiest direction. When the DC static field is parallel to the film surface it coincides with the easy magnetization axis. A considerable difference in the intensity of the FMR signal is observed from 0˚ to 55˚due to shape anisotropy field effect (SAF). This effect starts to dominate since the magnetization starts to be out of plane. However at 0˚ it is minimum since magnetization remains within the plane.**[11]**. SAF corresponds to the energy required to orientate the magnetic moment in the hardest direction. This indicates that magnetic moments are aligning in the hard axis. Unexpected anisotropy behaviour was observed at angle from 55˚ to 75˚.

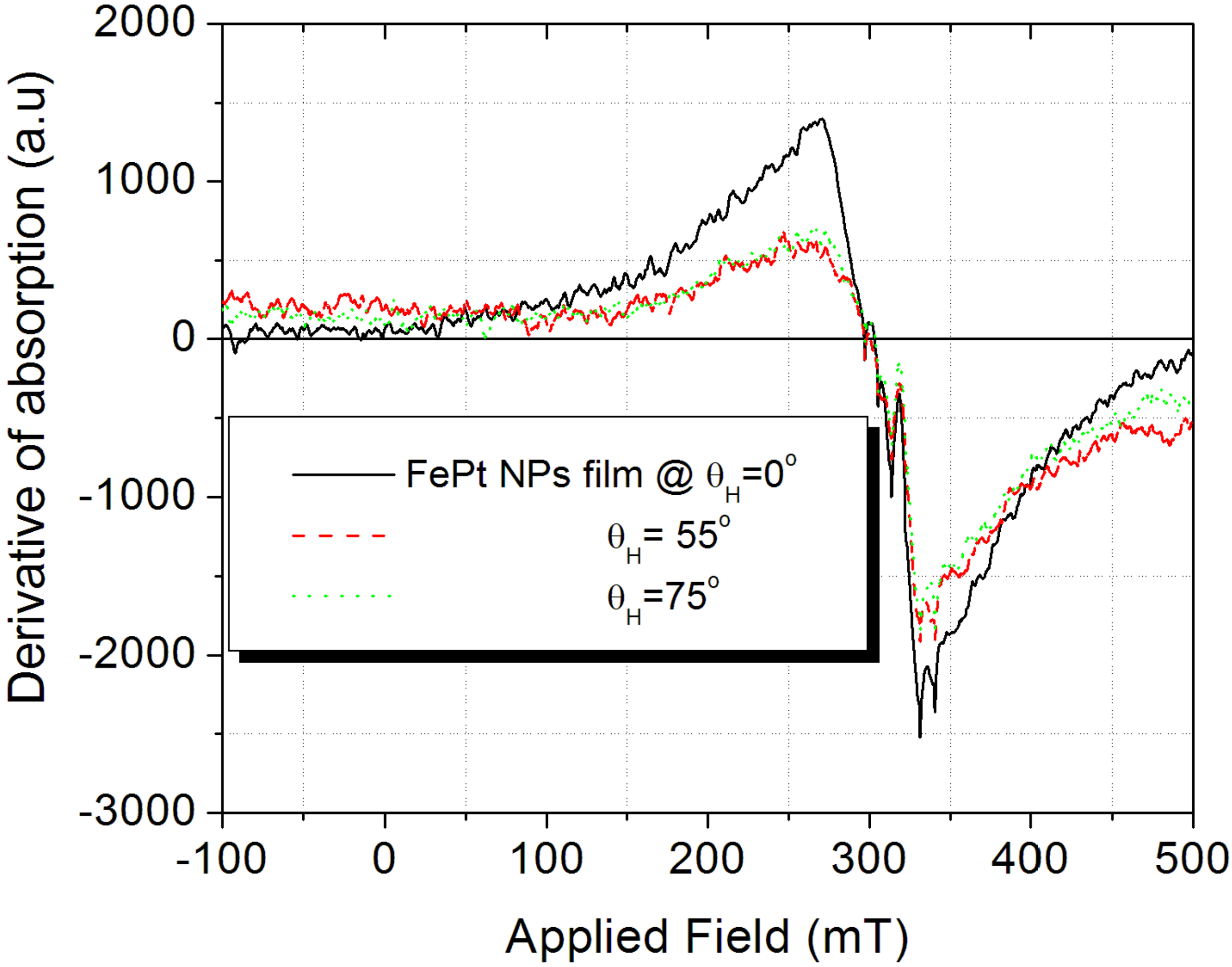

Figure 1: (a) FMR spectrum of FePt/Si (111). The angle θ_H gives the direction of the applied field H with respect to the film normal.

One would expect that by further increasing the angle, the energy corresponding to SAF will increase. SAF is minimized but eliminated. This can be explained by the SAF and IAF contribution to the total anisotropy field (TAF) **[5, 12]**. These latter two FMR spectra intensities remain almost the same. Moreover, FMR spectra observed at high field by Martin et al. (2007) **[13]** includes spin waves at lower angles giving evidence that FMR can originate with spin waves. The absence of spin waves in our films could already be suppressed by patterned media **[6, 7, 14, 15]**. This consists of a regular array of magnetic dots, each of which has uniaxial magnetic anisotropy. This qualifies the laser solution photolysis technique and the way in which these films were prepared as a self-assembly. Self-assembly is highly regarded as an alternative solution to overcome thermal fluctuation **[6, 7].** Thermal fluctuation triggers these spin waves which makes magnetic films unstable at room temperature.

3. Conclusions

A high microwave absorption field was observed. This was due to ferromagnetic resonance (FMR) in our films. The angular dependence of the magnetic anisotropy field can be correlated with the angular dependence of the FMR signal. FMR experiments are proposed as sensitive methods to determine different contribution to the total anisotropy field in FePt films.

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