

Electron Energy-loss Magnetic Circular Dichroism of L1₀ FePt Nanograins

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Heat-assisted magnetic recording (HAMR) is a promising technology that further increases the areal density in magnetic hard disk drives. Highly ordered L1₀ FePt nano-granular films with high perpendicular magnetic anisotropy are considered the key media materials for HAMR [1]. To better understand the performance of the HAMR media, it is critical to know the microstructure and magnetic properties at the grain level. Although extensive microstructural analysis has been conducted [2], measuring magnetic properties locally is still a challenge. Electron energy-loss magnetic circular dichroism (EMCD) has been explored to study magnetic properties inside TEM at nanoscale [3, 4]. EMCD could provide magnetic orbital and spin moment by sum rules [4], similar to X-ray magnetic circular dichroism (XMCD).

To date, most of the EMCD work was conducted on soft magnetic materials, such as Fe and Co [3, 5]. However, there is no report of EMCD study on L1₀ FePt due to the nature of its hard magnetic properties. The EMCD signals of FePt are notoriously low compared to Fe. The two-beam condition, necessary for getting the EMCD signals, is hard to achieve on grains as small as 50 nm.

In this work, 50 nm thick L1₀ FePt granular film was DC sputtered from an alloy target onto a [001]-oriented MgO seed layer. The magnetic easy axis (*c*-direction of the L1₀ FePt) is normal to the film surface. EMCD studies were conducted in plan-view TEM samples on a FEI Tecnai F20 microscope with a Gatan GIF Tridium, operating at 200 kV with an energy resolution of about 1.2 eV. The specimen was tilted in a two-beam condition such that only the transmitted spot (000) and a specific g_{hkl} (i.e. $hkl=200$) appeared in the diffraction pattern. Two Fe L_{2,3} edge spectra were collected in the + and – position on the Thales circle by shifting the diffraction pattern to the entrance aperture of the GIF.

Figure 1a and 1b are the TEM BF and STEM HAADF images, respectively, from the same area of the plan-view sample. FePt grains, ranging from 50-100 nm diameter, are in contact. Figure 2a shows the two beam diffraction pattern from the grain in the inset of Fig.1a. The specimen was tilted in such a way for EMCD acquisition [3, 4]. Nano-beam diffraction of the grain confirmed that it has a L1₀ structure. The spectra of Fe L_{2,3} edge collected from the + and – positions are shown in Fig. 2b. The pre-edge background was subtracted by a power-law in Digital Micrograph software. The x-ray spikes were removed. No other treatment like normalization or smooth was applied on the data. EMCD signal, difference of the two spectra of the opposite chirality, was also shown in Fig.2b. The EMCD spectrum showed sufficient intensity with no further data treatment (e.g., smoothing) necessary. We will present details of the experimental setup, signal optimization, and influence of the sample thickness and diffraction condition on the EMCD signals [6].

References:

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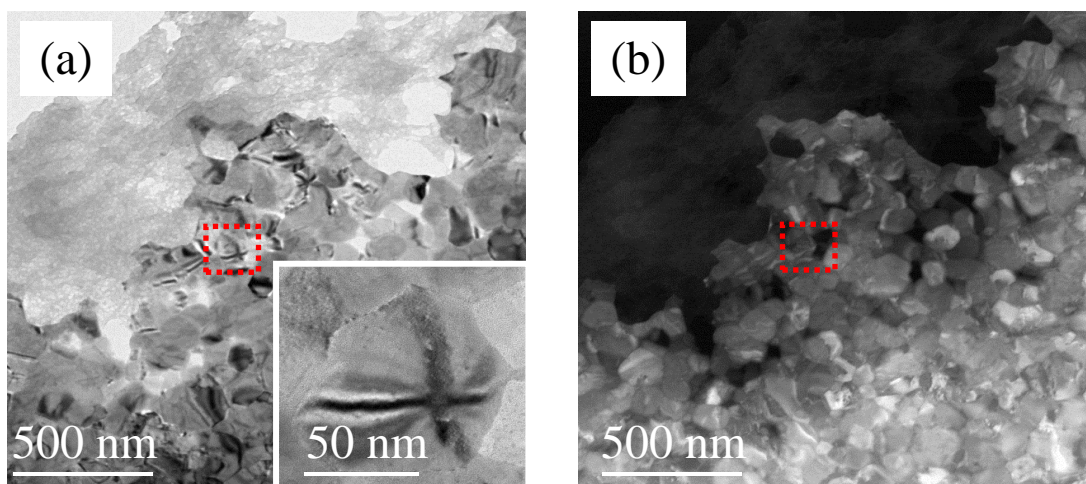


Figure 1. 1a, 1b. TEM BF and STEM HAADF images of L_{10} FePt nanograins of the same region. The EMCD was conducted on the grain shown in the inset from the squared area.

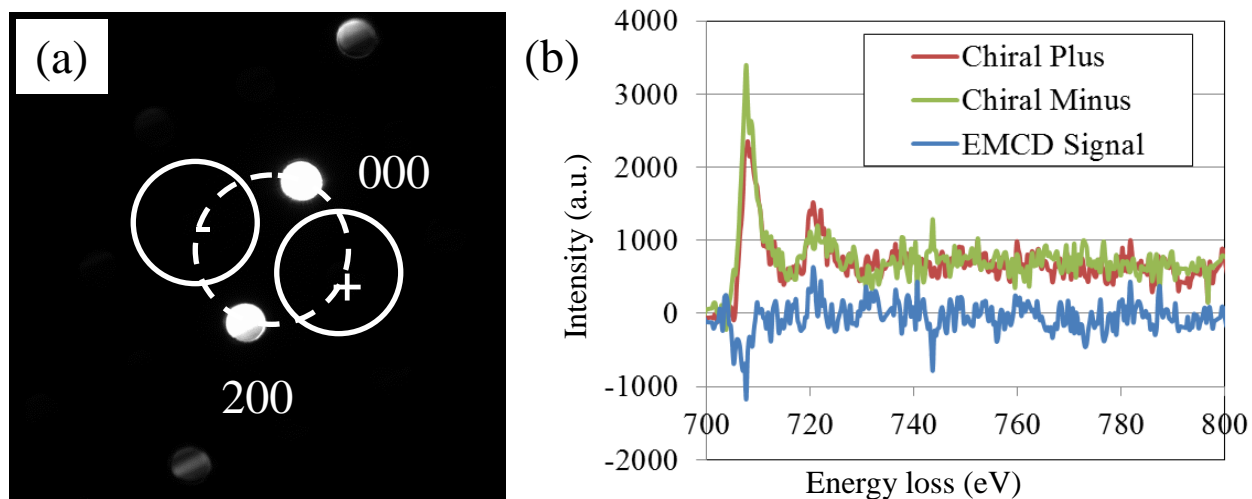


Figure 2. (a) Nano-beam electron diffraction pattern from the grain shown in the inset of Fig. 1. The grain was tilted to get a two beam condition for the EMCD signal acquisition. The solid line circles at + and - indicate the positions of the GIF entrance aperture on the Thales circle (dashed line circle). (b) The Fe $L_{2,3}$ edge spectra Chiral Plus (Minus) collected at the + (-) in the position shown in Fig. 2a. EMCD signal, the difference between Chiral Plus and Minus, is also presented.