doi:10.1017/S1431927616008643
Microsc. Microanal. 22 (Suppl 3), 2016

Nano-scale characterization of $L1_0$-ordered FePt granular films for heat-assisted magnetic recording devices

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Heat Assisted Magnetic Recording (HAMR) is currently the most promising solution to improve the areal density of hard disk drives to well beyond 1 Tb/in^2, the maximum that today's recording technique can achieve. With HAMR, high magnetic anisotropy $L1_0$-ordered FePt granular film grown on (001)-textured MgO underlayer is used as magnetic media to circumvent the superparamagnetic effect. Local laser heating is applied to overcome the resistance from the coercive field of FePt during writing.

The texture and ordering of $L1_0$-FePt, the two factors that greatly influence the recording performance, are highly dependent on the structural properties of MgO underlayer and FePt-MgO interface (e.g., grain size/morphology, orientation, epitaxy, interface roughness, etc.). The commonly used methods, such as XRD and ratio of in-plane vs. out-of-plane magnetization, can only provide information at the device scale and are not sufficient to understand sub-nanometer scale structures. To overcome these limitations we exploited aberration-corrected high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM).

Figure 1 is a high-resolution (HR) HAADF-STEM image acquired using TEAM 0.5 (Molecular Foundry, LBNL) at 300 kV. The image shows the variants of $L1_0$ ordering (alternating Fe (dark) and Pt (bright) atomic layers) in a defective FePt grain grown on MgO underlayer. Out-of-plane (OP) texture as highlighted with green is desired. In-plane (IP) (red segment) and non-ordered fcc (blue segment) sub-grains are defined as defective. The inset shows the enlargement of a region where the defective grain formation is originated at the atomic steps in FePt/MgO interface.

It is also critical to understand the distribution and size of the defective sub-grains. Figure 2 displays a plan-view HR-STEM image acquired using TEAM I (Molecular Foundry, LBNL) at 300 kV. The inset shows a multi-variant $L1_0$ FePt grain with out-of-plane (OP) and in-plane (IP) textured sub-grains. The false-color image of OP (green) and IP (red) sub-grains was extracted by means of Fourier filtering of (110) and (001) super-lattice atomic planes. Figure 3 shows large field-of-view high-resolution out-of-plane (left) and in-plane (right) texture maps reconstructed from a tilt-series of HR-STEM images using scripts implemented in Digital Micrograph platform.

In this contribution we will demonstrate how to measure quantitatively grain-to-grain variations in ordering and texture of sub-10 nm FePt grains by means of HR-STEM. The guidelines for optimization of the illumination condition as well as reliable reconstruction of the two-dimensional maps from tilt-series of HR-STEM images will be discussed. Structural and chemical properties of $L1_0$-FePt granular films grown on single and poly-crystalline MgO underlayers will be compared and correlated with the magnetic measurements.

Work at the Molecular Foundry was supported by the Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

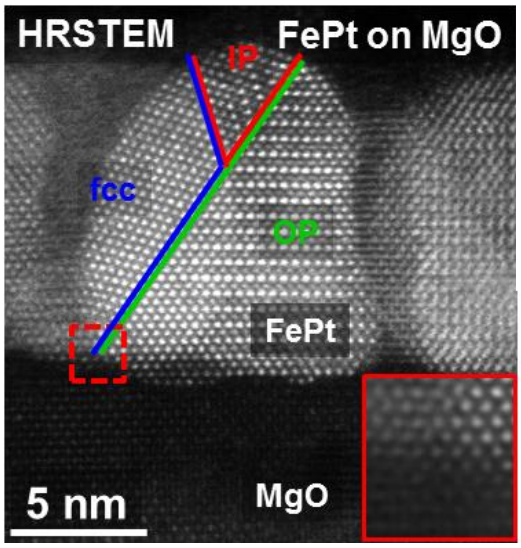

Figure 1. Cross-sectional high-resolution HAADF-STEM image of a defective $L1_0$ FePt grain grown on poly-crystalline (001)-textured MgO underlayer. Out-of-plane (OP) texture as highlighted with green is desired. In-plane (IP) (red segment) and non-ordered fcc (blue segment) sub-grains are defined as defective.

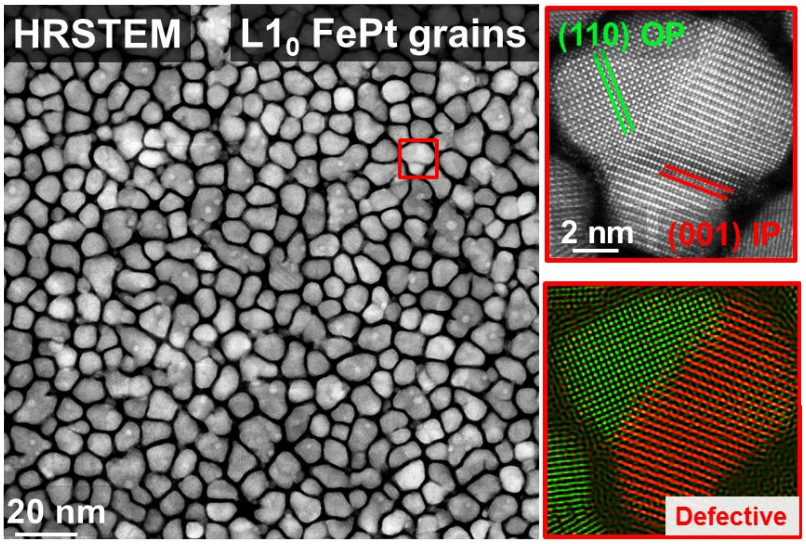

Figure 2. Large field-of-view HR-STEM image of an L10 ordered FePt granular film. The inset shows a grain with out-of-plane (OP) and in-plane (IP) sub-grains. The false-color image of OP (green) and IP (red) sub-grains was extracted by means of Fourier filtering of (110) and (001) super-lattice atomic planes.

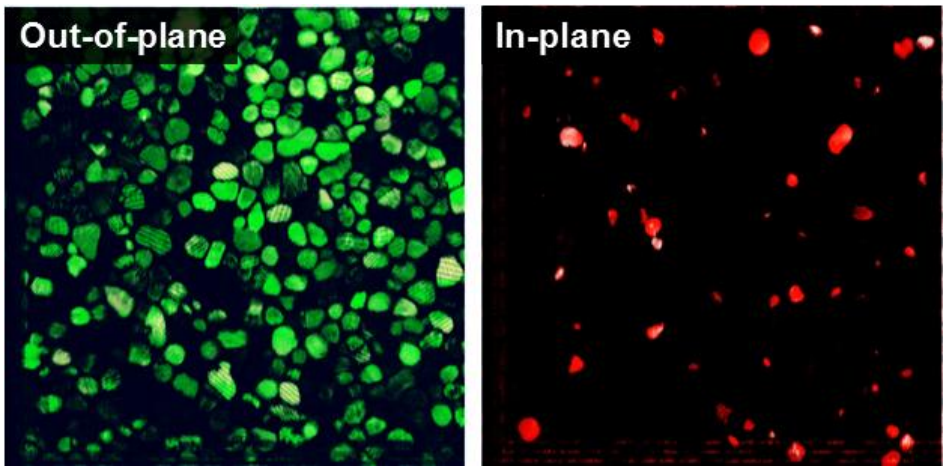

Figure 3. Out-of-plane (left) and in-plane (right) ordering maps reconstructed from a tilt series of HR-STEM images; α-β tilt ± 4° away from average (001) zone-axis.

https://doi.org/10.1017/S1431927616008643 Published online by Cambridge University Press