Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 1026-1027

F-7-4

Investigation of FePt Nano-Dots Fabricated by Self-Assembled Nano-Dot Deposition Method Using X-ray Photoelectron Spectroscopy

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1. Introduction

Ferromagnetic FePt alloy with fct-$L1_0$ structure has a large magnetic crystalline anisotropy [K_u ~7×10^7 erg/cc] [1] and saturated magnetization ($4\pi M_s$ = 13.8 kG), thus, its correlated systems are promising candidates as the next-generation high-density magnetic recording materials and high performance magnets. Recently, a new non-volatile memory called magnetic nano-dot (MND) memory (Fig. 1) has been proposed [2] by the authors, where densely packed MNDs dispersed in an insulating medium acts as a floating gate. In order to realize the high device performance of MND memory, (i) the nature of MND-SiO_2 interface, (ii) the prevention of oxidation of MNDs during high temperature annealing, and (iii) the quality of SiO_2 matrix are crucial. Further, the $Fe_{(1-x)}Pt_{(x)}$ (with x~50%) dots with 10 nm in size obtained via various routes (sol-gel method, MBE technique, and co-sputtering of Fe and Pt targets, etc.) routinely shows 10 kOe of coercivity. However, this value is much smaller than the predicted value by the Stoner-Wohlfarth model for isolated single domain particles (< 20nm). Either, it is due to the possible partial oxidation of FePt or the incomplete phase transformation (from fcc to fct) of FePt nano-dots. In order to resolve this anomaly, a more careful and in-depth investigation of FePt dots is needed. It is well known that the X-ray photoelectron spectroscopy (XPS) is a versatile tool to examine the chemical state of the elements, especially at the interfaces. It is our aim in the present study to perform high-resolution XPS analysis of FePt dots formed by self-assembled nano-dot deposition (SAND) method [3] to evaluate the degree of oxidation of FePt dots.

2. Experiment

Details regarding the preparation of MND were found in elsewhere [4]. The orientation and microstructure of these films were examined by respectively, X-ray diffractometer (XRD) using Cu-Kα radiation and JEOL JEM-3000F transmission electron microscope (TEM) with a high resolution. The X-ray photoelectron (XP) spectra were recorded at photoelectron take-off angle (θ) of 10, 15, 80, and 85 degrees using high resolution electron energy analyzer R4000-10keV at undulator beam line (BL47XU) of SPring-8 [5].

3. Results and discussion

XRD results showed that the as-grown and the in-situ annealed FePt dots represented the fcc and fct-$L1_0$ phase, respectively. Cross-sectional TEM images revealed that the size of the as-grown and the *in-situ* annealed at 800 ^oC FePt dots in the 10 nm thick MND films were respectively, ~3nm and 10 nm (Fig. 2). Shown in Fig. 3(a) & 3(b) are respectively, the core level Fe 2*p* and Fe 3*p* XP spectra of 2.5-nm and 10-nm-thick MND films. It is that the standard Fe^{0+} peak for the metallic iron generally lies at around 706.75 eV (Fe 2*p*) and 52.3 eV (Fe 3*p*). On the other hand, irrespective of MND film thickness, in the as-grown films the Fe^{0+} peak of FePt-SiO_2 matrix is hardly presented. However, upon annealing the 10-nm-thick films at 600 ^oC, the Fe^{0+} peak appears at 52.3 eV that is close to the metallic Fe. For further annealing at 800 ^oC, the peak fraction of Fe^{0+} is enhanced, while the peak fractions of the Fe-oxides are correspondingly suppressed. It is presumed that in the case of as-grown films, the metals of the MND may be attached with the matrix SiO_2. In line with this, core level Pt 4*f* (Fig. 4a and 4b) spectra of as-grown films largely have Pt-oxides rather than the peak due to pure Pt. Upon annealing, the peak fraction of pure Pt increases with increase in the annealing temperature. This observation is well in agreement with the Fe 3*p* results.

4. Conclusions

We have investigated the effect of *in-situ* annealing on the FePt dots by XPS. It is inferred that in the as-grown stage, the metals (Pt and Fe) of the FePt are in the oxidized state. The *in-situ* annealing at high vacuum ambient highly helps to suppress the oxidation of FePt dots.

Acknowledgment

This work was performed in Venture Business Lab, Tohoku University, and supported by Core Research for Evolutional Science and Technology (CREST) of Japan Science and Technology Agency (JST). The authors would like to thank Prof. K. Hirose of Institute of Space and Astronautical Science, Prof. S. Samukawa of Institute of Fluid Science, Tohoku University, Prof. S. Kono of IMRAM, Tohoku University for their fruitful discussions and collaborations.

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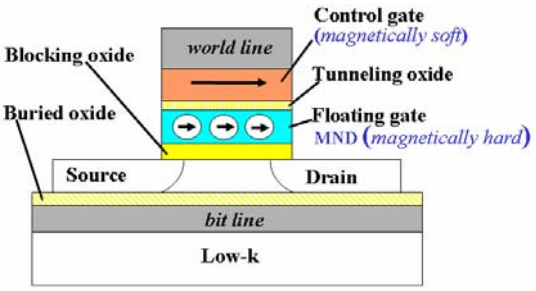

Fig. 1. Schematic view of MND memory

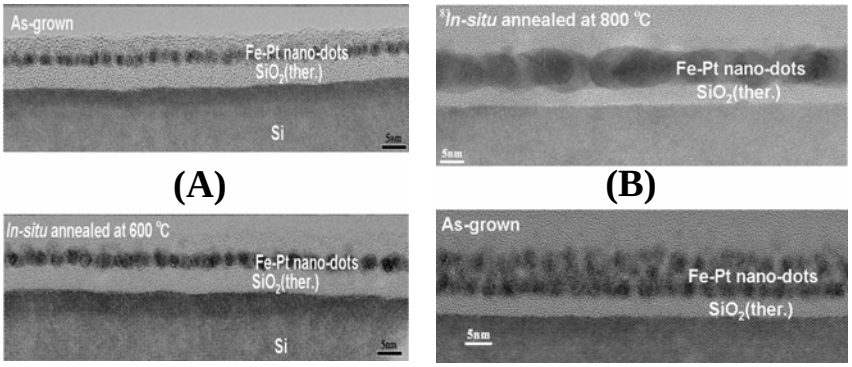

Fig. 2 Cross-sec. TEM of (A) 2.5 nm and (B) 10 nm thick MND films

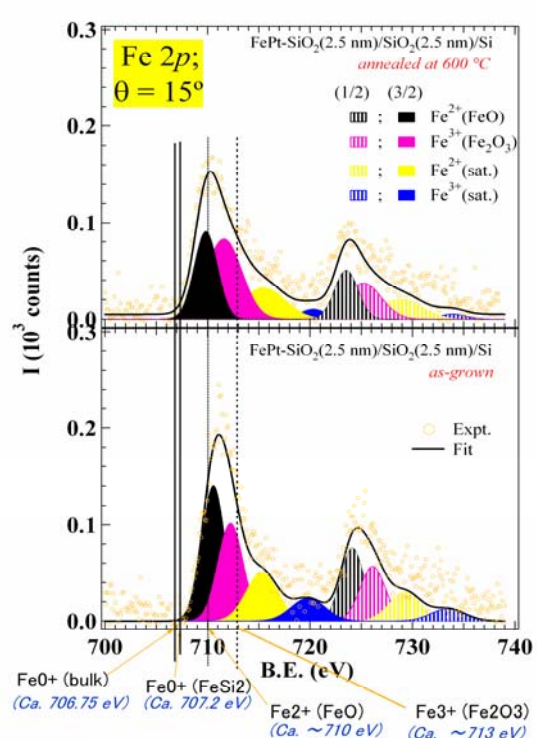

Fig. 3(a) Fe 2*p* XP spectra of 2.5 nm thick MND films

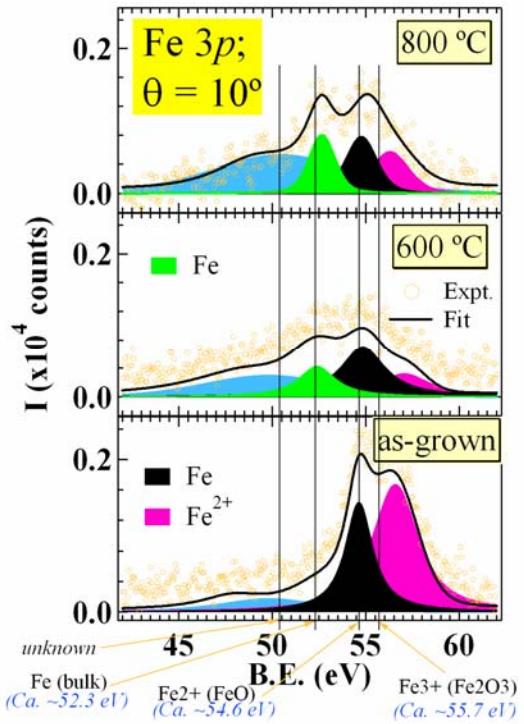

Fig. 3(b) Fe 3*p* XP spectra of 10 nm thick MND films

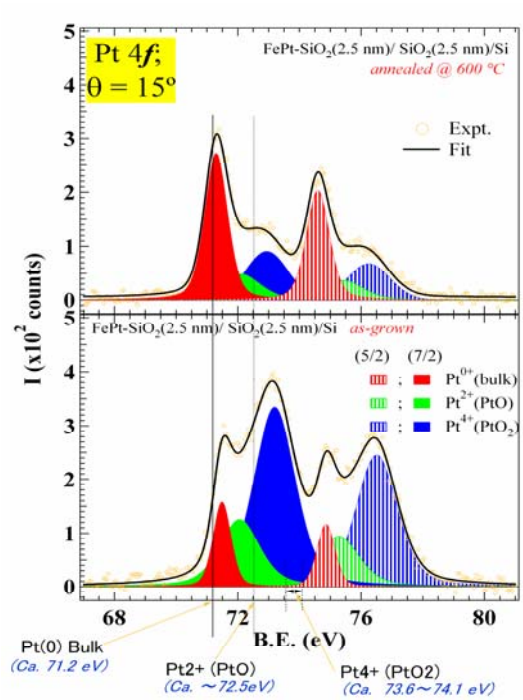

Fig. 4(a) Pt 4*f* XP spectra of 2.5 nm thick MND films

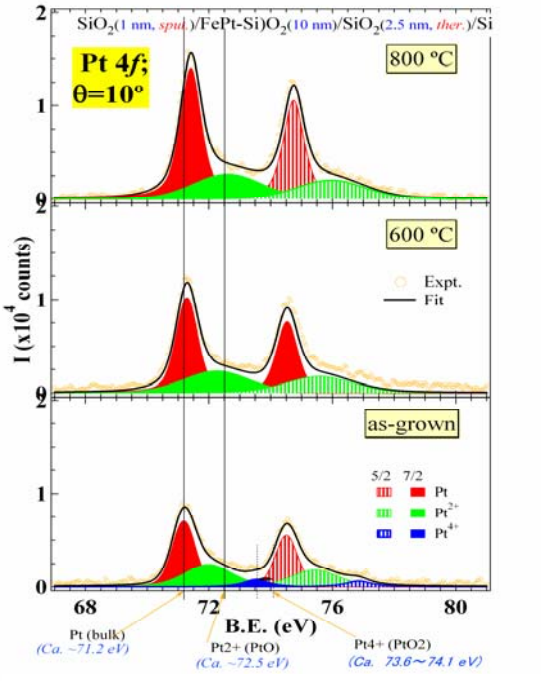

Fig. 4(b) Pt 4*f* XP spectra of 10 nm thick MND films