ISOLATED $L1_0$-FePt GRAINS AND FORMATION PROCESS FABRICATED BY RAPID THERMAL ANNEALING

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I. INTRODUCTION

We reported that isolated several tens of nano-meters FePt grains were fabricated by Rapid Thermal Annealing (RTA) for Pt / Fe double layered ultra-thin film deposited on thermally oxidized Si substrate[1]. It was unclear how the double layered Pt / Fe film turned to isolated magnetic grains during RTA process. In this report, we discuss about compositional dependency of morphological and magnetic properties of isolated FexPt100-x grains, and grain formation process during RTA by using the in-situ conductivity measurements.

II. EXPERIMENTAL METHODS

Pt / Fe double layered ultra-thin films were deposited on flat thermally oxidized Si substrate by DC magnetron sputtering in condition of a 0.18 Pa ArH (H_2: 3 vol. %) gas atmosphere. The base pressure was less than 4.0×10^{-5} Pa. The total deposited thickness of all double layered films was 1.88 nm. The composition ratio of deposited Fe_xPt_{100-x} was varied from $x = 50$ to 63.7. For fabrication of isolated FePt grains, the deposited continuous double layered films were annealed by RTA (heating rate was about 90 ℃/s) in the vacuum chamber (less than 3.5×10^{-3} Pa) with the 2 kW infrared ray lamp. At the target maximum temperature ($T_m = 600$ ℃), the shutter was closed to shut out the optical pass, and then N_2 gas flow was introduced to prevent the particle growth by quench with RCP (cooling rate was -60 ℃/s during 500 ℃ decrease). Morphology of isolated FePt grains was observed by a scanning electron microscope (SEM) and a transmission electron microscope (TEM). Crystalline structure of isolated FePt grains was analyzed by a x-ray diffraction (XRD). Characterization of magnetic properties was taken on Quantum Design MPMS3 SQUID magnetometer with VSM mode (Sensitivity: 5×10^{-8} emu).

III. COMPOSITIONAL DEPENDENCY OF ISOLATED Fe_xPt_{100-x} GRAINS

Fig. 1 shows an in-plane and out of plane hysteresis loops of the fabricated Fe_xPt_{100-x} grains (x =50 to 63.7) measured by a MPMS3. Fig. 2 shows compositional dependency of coercivity H_c derived from Fig. 1. In x = 50 and 55, rather isotropic and soft magnetic phase were appeared. In x = 57, 62 and 63.7, hard magnetic phase with large coercivity around 40 kOe was observed indicating the presence of large anisotropy, although x = 57 and 63.7 observed soft magnetic phase in low field region (bellow 10 kOe). These magnetic properties indicated perpendicular magnetic anisotropic properties with high H_c appeared by increasing Fe ratio x from 50 to 62. In x = 62, hard magnetic properties were obtained with high H_c. H_c increased by increasing x ratio from 50 to 62. In x = 62, value of H_c was maximum 42 kOe. However, in x = 63.7, H_c decreased to 37 kOe. Furthermore, in x = 62, M_r/M_s = 0.9 was the highest value in this composition range. These results meant the most amount of easy axis for perpendicular to film plane grains were fabricated. In this fabricated process, expected $L1_0$ FePt type hard magnetic phase was appeared in more Fe-rich composition rate than $Fe_{50}Pt_{50}$. From the compositional dependency of magnetic properties, it is suggested that the existence of 0.41 nm dead layer originated from first deposited Fe.

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IV. FORMATION PROCESS OF FePt GRAINS

For clarification of how the layered Pt/Cu/Fe film turned to isolated magnetic grains during RTA process, the in-situ conductivity measurement was performed. The target material was 1.88 nm thick of $Fe_{43}Cu_{14}Pt_{43}$. The film was turn to insulator form conductor around 9 s before elevating to maximum temperature of 572.8 ℃. From SEM observation, isolated grains were emerged. In case of RTA with maximum temperature of 486.8 ℃, it keeps conductive property with un-isolated morphology. It is clarified that the deposited continuous film turn to isolated particles within few second at threshold temperature during RTA.

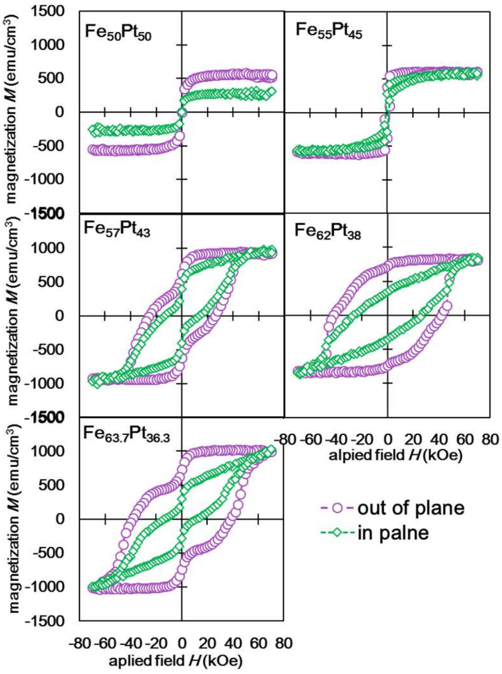

Fig. 1 Magnetic hysteresis loops of each samples.

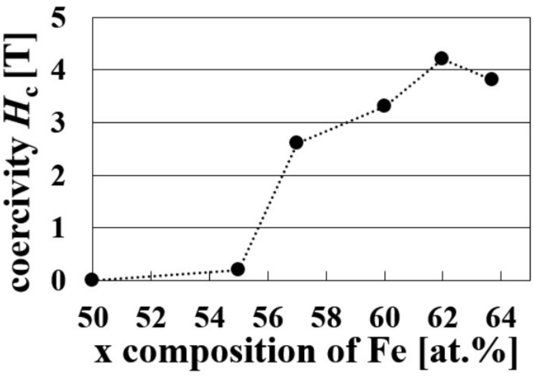

Fig. 2 The relation between controlled x ratio and Hc of isolated Fe_xPt_{100-x} grains in conditions of total deposited thickness = 1.88 nm and x = 50 to 63.7.

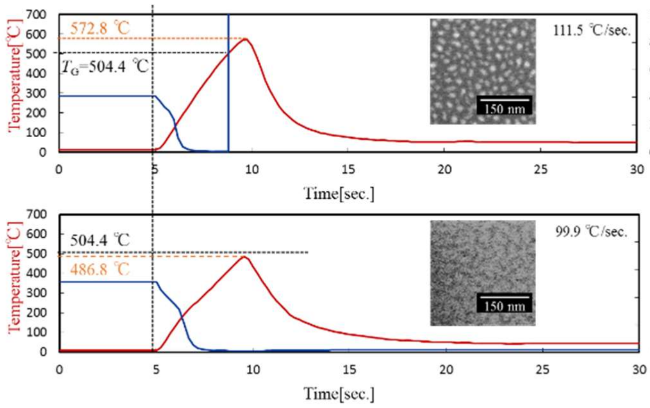

Fig. 3 In-situ conductivity measurements during RTA.

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