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Increase of areal particle density and magnetic particle volume of isolated FeCuPt grain by multistep particle formation with rapid thermal annealing and rapid cooling process

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We fabricated isolated FeCuPt grains using a combination of rapid thermal annealing (RTA) with rapid cooling process (RCP). The isolated grains have $L1_0$ - FeCuPt ordered structure. $L1_0$ - FeCuPt ordered structure has high uniaxial magnetic anisotropy *K*u; it is thought to be one of the promising materials for high density magnetic recording media. We have to make high density magnetic recording media to increase their magnetic particle volume and areal particle density. Reducing the initial deposition thickness (*T*s) shows increase of areal particle density; however magnetic particle volume decreased. Increasing *T*s shows the high *H*c and *M*s; however areal particle density decreased. Therefore first, the sample was formed at thinner *T*s to increase their areal particle density. After particle formation, particle formation method was repeated for increase their magnetic particle volume instead of changing areal particle density.

1. Introduction

The purpose of this study was making ultra high density magnetic recording media which can archive large capacity data. Because of the recent rapid growth of the information society, $L1_0$ - FeCuPt ordered structure was studied as the material of having high uniaxial magnetic anisotropy *K*u. We already reported [1], [2] that RTA with RCP of FeCuPt multilayer film on the flat thermally oxidized Si substrate effectively obtained $L1_0$ - FeCuPt grains of which c-axis is perpendicular to the film surface. We investigated increase of magnetic particle volume and areal particle density from adjusting *T*s and particle formation process. In order to use ultra high density magnetic recording media, increase of areal particle density is required. To avoid the problem of thermal fluctuation from too much tiny grain size, magnetic particle volume should be increased instead of changing areal particle density.

2. Experiment

Films with Pt / Cu / Fe / sub. multilayer structures were fabricated using DC magnetron sputtering on flat thermally oxidized Si substrates. Fe, Pt and Cu layers were fabricated in 0.18 Pa pressure ArH (H_2: 3 vol. %) gas atmosphere. $Fe_{43}Cu_{14}Pt_{43}$.films are deposited under various *T*s values as 1.25 nm, 2.5 nm and 3.75 nm. For crystallization, multilayer continuous films were annealed by RTA process in the vacuum chamber at 8.0×10^{-4} Pa with the 2 kW infrared ray lamp. At the end of RTA, FeCuPt multilayer continuous films were quenched by RCP. As heating process, the annealing time from room temperature (RT) to the required maximum temperature (T_m: 460 ℃ ~ 600 ℃) was around 4 sec (2.9 sec ~ 5.3 sec); After it reached T_m , the shutter was closed to shut out the optical pass with introducing N_2 gas flow to prevent the particle growth. Initial cooling rate from T_m to 300 ℃ was -33 ℃ / sec ~ -68 ℃ / sec. The size and the shape of isolated particles were observed by Scanning Electron Microscope (SEM). The dependence of magnetic property was evaluated by Superconducting Quantum Interface Device - Vibrating Sample Magnetometer (SQUID - VSM).

3. Dependence of particle properties by initial deposition thickness

3.1 Particle shape by initial deposition thickness

Important issues to make high density magnetic recording media are to increase their areal particle density in order to achieve high densification. We focused attention to the dependence of areal particle density by controlling *T*s. As for grains formed with *T*s = 3.75 nm, we carried out additional annealing for crystalizing as single crystalline grains from these poly-crystal grains. The annealing condition was set to 600 ℃ for 1 h[3].

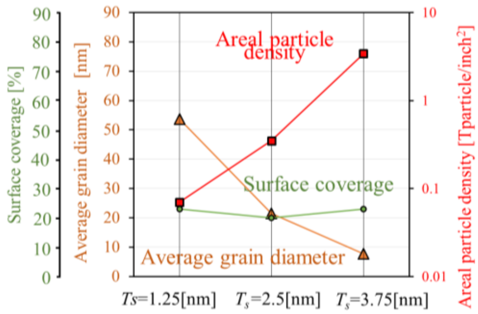

Figure 1. Surface structure dependence with each initial deposition thickness

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Figure 1. shows surface structure dependence of each *Ts*. Figure 1. indicates that the value of areal particle density increased exponentially and average grain diameter decreased by reducing *Ts*. For this reason, reducing *Ts* is necessary to form ultra high density magnetic recording media.

3.2 Magnetic properties by initial deposition thickness

$L1_0$ - FeCuPt ordered structure has high uniaxial magnetic anisotropy *K*u; therefore it is expected to have the character of perpendicular magnetization film. Figure 2. shows the hysteresis loops in the out-of-plane direction with each *Ts*. Grains formed with *Ts* = 2.5 nm (without additional annealing) have the same quality as grains formed with *Ts* = 3.75 nm (with additional annealing). Figure shows both have the character of perpendicular magnetization film, and show high *H*c exceed 2.5 T.

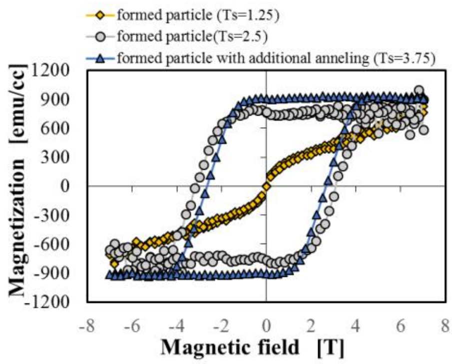

Figure 2. M-H loops comparing the magnetic properties in the out-of-plane direction with each initial deposition thickness

4. Dependence of particle properties by additional grain formation

From Figure 1. grains formed with *Ts* = 1.25 nm show high areal particle density and much tiny grain diameter. However samples show low surface coverage of 20 %. Therefore we attempted to improve magnetic particle volume associated with increase surface coverage. To increase their magnetic particle volume, sample was deposited with *Ts* = 1.25 nm. After particle formation, we repeated grain formation method with deposition thickness 1.25 nm so as to form total deposition thickness 2.5 nm, which grains show the higher *H*c and *M*s.

4.1 Particle properties by additional grain formation

Figure 3. shows surface structure dependence by additional grain formation. Both first time to formed particle and second time to formed particle show high areal particle density exceed 3 Tparticle / inch^2. Second time to formed particle increased their magnetic particle volume. According to increase magnetic particle volume, Surface coverage was increased as twice (40 %).

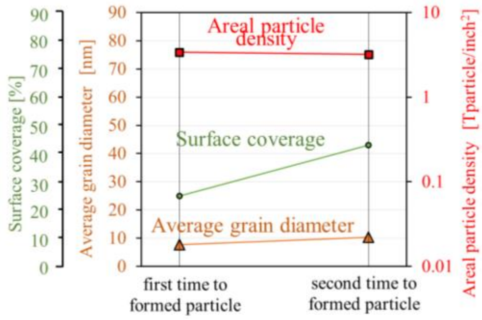

Figure 3. surface structure dependence with additional grain formation

4.2 Magnetic properties by additional grain formation

Figure 4. shows the difference of the hysteresis loops in the out-of-plane direction by additional grain formation. I compared first time to formed particle with second time to formed particle. As for first time to formed particle, we couldn't confirm the exist of *H*c and *M*s. As for second time to formed particle, we could confirm the exist of *H*c and *M*s. By increasing magnetic particle volume without changing the areal particle density, grains show *H*c≒1 T even tiny size as average grain diameter of 10 nm.

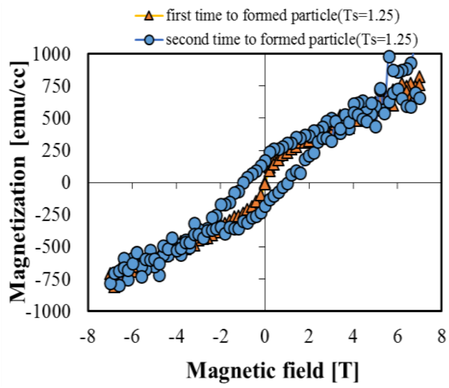

Figure 4. M-H loops comparing the magnetic properties in the out-of-plane direction with additional grain formation

5. Acknowledge

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6. Reference

[1] Y. Itoh, T. Aoyagi, A. Tsukamoto, K. Nakagawa, A. Itoh and T. Katayama: "Structural and Magnetization of Island FePt Produced by Rapid Thermal Annealing"*Jpn. J. Appl. Phys.*, Vol. 43, No. 12, pp. 8040-8043, 2004.

[2] A. Itoh, A. Tsukamoto, S. Okame and K. Mizusawa: "A Role of Rapid Thermal Annealing for Achieving Fine Isolated Grains of FeCuPt", *J. Magn. Soc. Jpn.*, Vol.36, No. 1-2, pp62-65, 2012.

[3] J. Tsukioka, T. Ubana, A. Tsukamoto, A. Itoh: "Measurement of thermo magnetic property and increase of areal density of $L1_0$-ordered isolated single crystalline FeCuPt grains", *J. Magn. Soc. Jpn.*, Vol38, No. 3-2, pp143-146, 2014.