Fabrication of surface periodic nano metallic structure on meso-polus SiO₂ substrate and high density isolated FePt grains

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In this report, meso-polus SiO₂ substrate with periodical surface nano-pores are prepared by utilizing self-assembling / self-organizing phenomenon of tri-block copolymer (Nano Dent Arrey: NDA) [1]. Continuous metallic double layer of Au (2.5 nm) / Fe (1.0 nm) is deposited on the NDA. In order to get isolated Au particles smaller than 10 nm diameter and periodicity of ~15 nm, the deposited metallic layer is etched by Ar ion in incident angle of 85° from normal to the film surface. Fabricated surface periodic nano Au particles have average diameter of ~9.5 nm and the periodicity of 12.5 ~ 15.0 nm. Isolated FePt grains are fabricated by Rapid Thermal Annealing with rapid cooling process (RTA) [2] on the fabricated surface periodic nano metallic structure. The FePt grains have average grain diameter $D_s = 7.63$ nm, areal density of particles $N_p = 3.82$ T particles / inch², standard deviation of $D_s$, $S_D = 1.37$ nm. On the other hand, in the case of FePt grains fabrication on flat thermally oxidized Si substrate, the grains have $D_s = 14.1$ nm, $N_p = 0.76$ T particles / inch² and $S_D = 2.48$ nm. Thus, fabricated FePt grains on surface periodic nano metallic structure are decreased $\Delta D_s = 6.5$ nm, increased $\Delta N_p = 3.06$ T particles / inch² and decreased $\Delta S_D = 1.11$ nm comparing with fabricated on flat thermally oxidized Si substrate.

1. Introduction

The idea of this study could achive to get small FePt grains less than 10 nm and high density grains to several T particles / inch² for the purpose as Bit Patterned Media of ultra high density recording media. We reported that meso-polus SiO₂ substrate with periodical surface nano-pores were prepared by utilizing self-assembling / self-organizing phenomenon of tri-block copolymer (NDA). And showed possibility of leading fabricated position of FePt grains on filling middle of particles with Au structure in fabricated self-assembled nano-sillica particles by difference of surface energy between Au and SiO₂ [3]. In this report, We fabricate surface nano periodic Au particles structure utilizing method of Ar ion Dry Etching to deposited continuous Au / Fe double layer on NDA in incident angle of 85° from normal to the film surface. The structure has small diameter less than 10 nm and periodicty of ~12 nm utilized periodical structure of NDA. We fabricate high density FePt several nm grains on surface nano periodic metallic structure and flat thermally oxidized Si substrate as reference structure.

2. Fabrication of NDA

Surface nano periodic metallic structure is fabricated utilized NDA. Thus, surface nano periodic metallic structure depends on periodic structure of NDA. In order to form periodicity of ~12 nm nano-pores, molecular weight of a tri-block copolymer is used 8400 g / mol. Transmission Electron Microscope: TEM planer view images of Fabricated NDA is shown in Figure 1. The meso-polus SiO₂ substrate film is consisted from face-center-cubic lattice. The periodicity of pores is approximately 11.2 ~ 14.0 nm, in Figure 1.

3. Ar ion Dry Etching for Au layer on NDA

Continuous metallic double layer of Au (2.5 nm) / Fe (1.0 nm) is deposited on the NDA using DC magnetron sputtering. The thin film is observed uniform surface structure by Scanning Electron Microscope: SEM and Atomic Force Microscope: AFM. The deposited metallic layer is etched by Ar ion in incident angle 85° from vertical line to thin film. The etching gas is

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Ar ion, the acceleration voltage is 500 V, the incident ion electric current density is 1.5 mA / cm² and the etching time is 75 sec. The images of SEM planar view, TEM planar view, and electron beam diffraction view were shown Figures 2,3(a) ~ (c). The average periodicity of Au particles in a domain of reflect periodic NDA structure is approximately 12.5 ~ 15 nm clearly the periodic structure depend on etching direction and periodic structure of NDA. Crystallographic structure is observed by electron beam diffraction in only black region of Figure 3 (a), as in Figure 3 (b). Non-crystalline structure region is confirmed by observation of electron beam diffraction in only white region of Figure 3 (a), as in Figure 3 (c). As a result the fabricated surface structure consist from metallic particles and non-crystalline SiO² region.

4. Fabrication of isolated FePt grains
To get smaller isolated FePt grains and higher density grains, FePt grains are fabricated on (A): surface nano periodic metallic structure, (B): flat thermally oxidized Si substrate as reference. Pt (1.05 nm) / Fe (0.83 nm) double layer deposited on sub using DC Magnetron Sputtering. The composition of the films are Fe₅₀Pt₅₀. At first, substructure is used (A): surface nano periodic metallic structure. Isolated FePt grains are fabricated by RTA at the heating rate Tₑ = 107 °C / s and the maximum temperature Tₑₑ = 406 °C for continuous double films shown in Figure 4 (a). Dₐ = ~7.63 nm, Nₐ = 3.82 T particles / inch², S₀ = 1.37 nm. At second, substrate is used (B): flat thermally oxidized Si substrate, FePt grains is fabricated by RTA at the Tₑ = 112 °C / s and the Tₑₑ = 672 °C for continuous double films shown in Figure 4 (b). Dₐ =14.1 nm, the Nₐ = 0.76 T particles / inch² and the S₀ = 2.48 nm. Therefore, fabricated FePt grains on surface nano structure make ΔDₐ decrease ~ 6.5 nm, ΔNₐ increase 3.06 T particles / inch² and ΔS₀ decrease 1.11 nm comparing with fabricated on flat thermally oxidized Si substrate.

5. Conclusion
We fabricate surface nano metallic structure by utilized NDA having the average periodicity of pores approximately 11.2~14.0 nm. The structure consist on metallic particles on meso-porous SiO₂ that average diameter is approximately 9.5 nm and the average periodicity is 12.5 ~ 15.0 nm. On surface nano metallic structure, fabricated FePt grains have Dₐ = 7.63 nm, Nₐ = 3.82 T particles / inch² and S₀ = 1.37 nm. On the other hand, fabricated FePt grains on flat thermally oxidized Si substrate have Dₐ =14.1 nm, Nₐ =0.76 T particles / inch² and S₀ = 2.48 nm. Fabricated FePt grains on surface nano structure decrease ΔDₐ = ~ 6.5 nm, increase ΔNₐ = 3.06 T particles / inch² and decrease ΔS₀ = 1.11 nm comparing with fabricated on flat thermally oxidized Si substrate.

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References