PROPOSAL OF GRAIN BOUNDARY OXIDES FOR HIGH $K_u$ Co$_{80}$Pt$_{20}$ GRANULAR MEDIA WITH SMALL GRAIN SIZE

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I. INTRODUCTION

CoPt-oxide granular media with columnar grain growth have been widely used for perpendicular magnetic recording. To further increase the recording density of the media, enhancement of magnetocrystalline anisotropy ($K_u$) and reduction of magnetic grain diameter ($GD$) are required. In the previous study, it was found that a granular medium with high $K_u$ can be obtained when oxide with low melting point ($T_m$), especially B$_2$O$_3$, was utilized due to the promotion of columnar grain growth$^{11}$. However, the effect of $T_m$ of the oxide on the $GD$ is still unclear. Therefore, in this report, after examining the influence of various grain boundary oxides on $GD$, we will discuss about the guiding principle of choosing grain boundary oxide materials.

II. RESULTS AND DISCUSSION

Figure 1 show dependence of (a) magnetocrystalline anisotropy ($K_u$) and (b) grain diameter ($GD$) for Co$_{80}$Pt$_{20}$ $\sim$30vol% single oxide granular media with $d_{mag}$ of 16 nm on melting point ($T_m$) of the grain boundary oxides materials. The inset shows the definition of $GD$, which is evaluated from CoPt (11.0) diffraction from the XRD in-plane profiles by Scherrer’s equation$^{2,3}$. Here, from the result of out-of-plane XRD profiles for the granular media with grain boundary oxide materials with various $T_m$ (the result are not shown here), these granular structure magnetic grains are considered to have c-plane sheet texture orientation. When $T_m$ of oxide increases from 450 to 2410$^\circ$C, $K_u$ and $GD$ decrease from 7.7 to 4.1 $\times$10$^6$ erg/cm$^3$ and from 5.6 to 3.0 nm, respectively. From this result, it suggests that a granular medium with both high $K_u$ and low $GD$ cannot be realized by only employing single oxides.

We consider that a granular medium with reasonably high $K_u$ and small $GD$ may be achievable by utilizing double grain boundary oxides with moderate $T_m$ which consist of high and low $T_m$ oxides. To verify the effect of double oxides, second oxides with $T_m$ ranging from 450 to 2330$^\circ$C and first oxide of low $T_m$ (B$_2$O$_3$) were added to Co$_{80}$Pt$_{20}$ alloy (Co$_{80}$Pt$_{20}$-15vol% B$_2$O$_3$-15vol% second oxides). Figure 2 shows dependence of $K_u$ and $GD$ on $T_m$ of various second oxides. When $T_m$ of the second oxide is lower than 1857$^\circ$C (TiO$_2$), $K_u$ is almost comparable with that of B$_2$O$_3$. For $T_m$ higher than 1857$^\circ$C, $K_u$ decreases. In the case of $GD$, it is almost constant for $T_m$ of the second oxide lower than 1723$^\circ$C (SiO$_2$). When $T_m$ is higher than 1723$^\circ$C, $GD$ decreases. From this result, the addition of TiO$_2$ for the second oxide is effective to realize a granular medium with high $K_u$ and small $GD$.

Figure 3 shows in-plane-view TEM of Co$_{80}$Pt$_{20}$-15vol% B$_2$O$_3$-15vol% typical second oxide (second oxide: (i) B$_2$O$_3$ ($T_m$: 450$^\circ$C), (ii) SiO$_2$ ($T_m$: 1723$^\circ$C), (iii) TiO$_2$ ($T_m$: 1857$^\circ$C) and (iv) Cr$_2$O$_3$ ($T_m$: 2330$^\circ$C)). Observing the detailed in-plane-view TEM of high $T_m$ second oxides such as TiO$_2$ and Cr$_2$O$_3$, grain boundaries with different thicknesses are confirmed. The thick grain boundaries are similar to that of the second oxide of B$_2$O$_3$. Inside some magnetic grains thin grain boundaries can also be observed. It is considered that the existence of the thin grain boundaries induces the $GD$ reduction. Generally, the variation of the grain boundary thickness will lead to a wide grain size distribution. The application of underlayer with smaller grains size than current one may be effective to obtain a granular medium with homogeneous grain size.

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Fig. 1. Dependence of (a) magnetocrystalline anisotropy ($K_u$) and (b) grain diameter ($GD$) for $d_{mag}$ of 16 nm on melting point ($T_m$) of the grain boundary oxides materials. The inset shows the definition of $GD$, which is evaluated from CoPt (11.0) diffraction from the XRD in-plane profiles by Scherrer’s equation$^{2,3}$.

Fig. 2. Dependence of (a) $K_u$ and (b) $GD$ of various oxides in Co$_{80}$Pt$_{20}$-15vol% B$_2$O$_3$-15vol% second oxide granular media with $d_{mag}$ of 16 nm on $T_m$ of the grain boundary oxides materials. In-plane-view TEM of these samples (second oxide: (i) B$_2$O$_3$ ($T_m$: 450°C), (ii) SiO$_2$ ($T_m$: 1723°C), (iii) TiO$_2$ ($T_m$: 1857°C) and (iv) Cr$_2$O$_3$ ($T_m$: 2330°C)) are shown in Figure 3.

Fig. 3 In-plane-view TEM of granular media shown in Figure 2.