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Perpendicular magnetic anisotropy of CoPt-TiN nanocomposite magnetic films

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Magnetic nanocomposite has been considered promising as next generation magnetic recording media. In this work, we investigate the magnetic property and microstructure of CoPt-TiN nanocomposite. The reason titanium nitride (TiN) was chosen as the matrix is that this material is wear resistive, thermally and chemically stable, such properties may contribute to the reliability and durability of magnetic recording media. The precursor films were DC-sputter deposited on fused quartz substrates at room temperature. The as-deposited films are amorphous-like, and the formation of CoPt (FCC) and TiN crystallites are confirmed by diffraction methods when the films were thermally annealed at temperatures above 600°C. One of the interesting properties of such films is that they show perpendicular magnetic anisotropy, which is considered due to the unique microstructure of the films. Cross-sectional TEM observation of the films reveals that such films are featured with fibrous microstructure with the nano-sized fibers perpendicular to the substrate surface. The fibers are composed of CoPt crystallites and separated by TiN. We consider that CoPt crystallites are magnetically coupled more closely in perpendicular direction than in the longitude direction and thus perpendicular anisotropy developed.

Key words: perpendicular anisotropy, shape anisotropy, annealing temperature, nano-fiber

1. INTRODUCTION

Magnetic films for perpendicular magnetic recording material were studied by many researchers in recent years. As methods of preparing films for perpendicular magnetic anisotropy material, for example, making films with $L1_0$ or applying CoCr systems are prevailing [1]. But we haven't chosen method getting films with $L1_0$ structure. We are aiming to obtain CoPt-TiN films with perpendicular anisotropy by applying shape anisotropy. Because TiN films have a property to deposit with a fibrous structure, TiN has been selected as matrix to gain films with shape anisotropy of the film. This research has been conducted to clarify how the columnar fiber structure of films is effective for the material of perpendicular magnetic recording. Especially in this paper, we report about how the thermal annealing temperatures take effects on perpendicular magnetic property.

2. EXEPERIMENT

Co-Pt-Ti-N films were deposited onto fused quartz substrates by the DC reactive sputtering, with pure Ar as the sputtering gas and N_2 as the reactant gas. A complex target set was used which consists of a pure Co disc at the back and Pt chips fixed with a center-holed Ti disc at the front.

The composition of the film can be controlled by changing the number of Pt chips at the front. The vacuum chamber was evacuated to 1.3×10^{-4} Pa before depositions. Then Co-Pt-Ti-N as precursor films were prepared at Ar + N_2 atmosphere, where N_2 gas pressure has been set to 6.7×10^{-4} Pa, and Ar gas pressure has been set to 1.6×10^{-1} Pa. The working gas pressure was about 5 Pa. All the depositions were conducted at the room temperature (especially not adjusted), at the power of 2.5kV, 12mA for 120 mins. Thermal annealing of the films was conducted in vacuum at the range from 600°C to 800°C for 180 mins.

The annealed films were evaluated by cross-sectional transmission electron microscopy (cross sectional TEM). The crystallinity of the films was evaluated by X-ray diffract meter (XRD). The in-plane and perpendicular saturation magnetization (4πMs) and coercivity (Hc), hysteresis curve of the films were measured by vibrating sample magnetometer (VSM). The composition of the films was analyzed by X-ray photoelectron spectroscopy (XPS).

3. RESULT AND DISCUSSION

3.1 VSM measurement

The dependence of in-plane and perpendicular magnetic properties on the annealing temperature with range from 600°C to 800°C was studied. Here, Fig. 1 shows the hysteresis loops of $Co_{75}Pt_{25}$-TiN film annealed at 600°C, 700°C and 800°C respectively. Each value of perpendicular magnetic properties is greater than value of in-plane. The highest perpendicular Hc and Ms value was obtained at 700°C. The annealing temperature at under 500°C was not so effective for developing ferromagnetic coupling. In Fig.1, perpendicular hysteresis loops are corrected for the demagnetizing field by applying demagnetizing factor N according to the formula about demagnetizing field

$$\mathbf{H_{eff} = H_{appl} - NM.}$$

(H_{eff} : effective field, H_{appl} : applied field).

But this correction is provisional, not exactly essential.

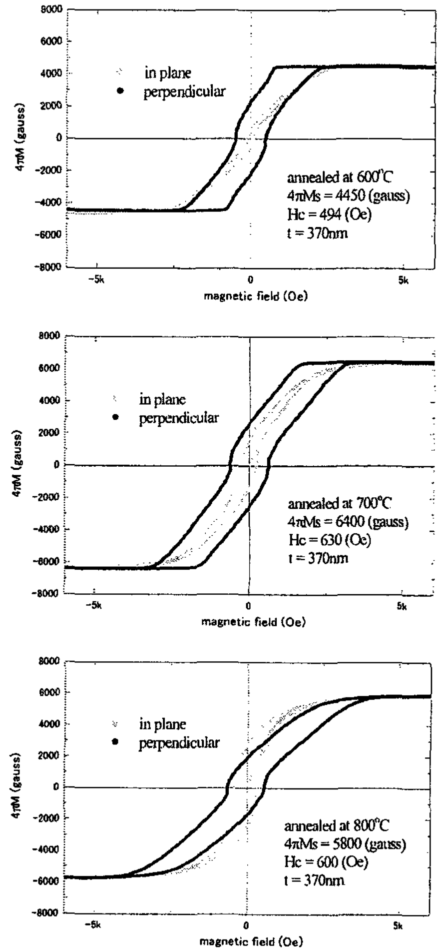

Fig. 1. Dependence of Transition of hysteresis loop on annealing temperatures.

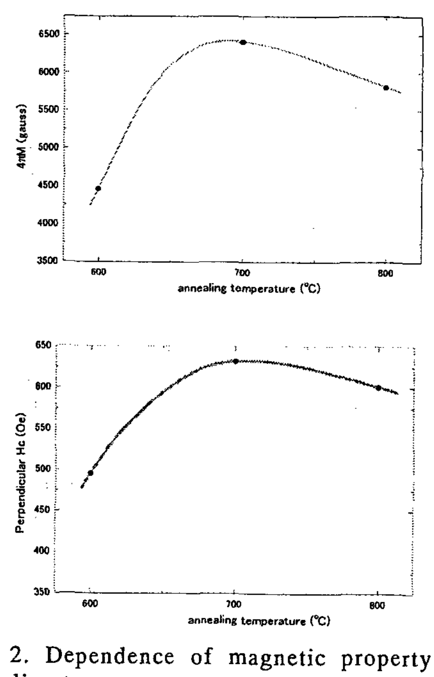

Fig. 2. Dependence of magnetic property on annealing temperature.

Because the loops showed in Fig.1 are distorted around the origin of graph. So these loops cannot be corrected simply by applying demagnetizing factor. This treatment will be challenge in future work.

Supposing it were corrected properly, except for distortion, each loop of 600°C and 700°C would be rectangle shape which is characteristic of perpendicular hysteresis. At 800°C, the shape of loop is collapsed. In this case, we can suppose that some change of structure has arisen in a film. To clarify the cause of transition depending on annealing temperature, we have carried out cross sectional TEM observations.

3.2 XRD and cross sectional TEM observation

XRD evaluations and cross sectional TEM observations were conducted about above three samples (three kinds of annealing temperature). Now we show three XRD profiles and TEM bright field images in Fig.3 and Fig.4. Images showed in Fig.3 and Fig.4 are 600°C, 700°C and 800°C annealing in order. In Fig.3, we can see that a film annealed at 600°C consists of fine fibrous structure. On XRD profile, a film annealed at 600°C has been amorphous-like. At 700°C, microcrystallite has begun to appear in fiber and fiber has become bold. At 800°C, microcrystallite has grown still larger and fiber has collapsed completely [2]. As in Fig.3, above 700°C, XRD profiles have revealed that the crystallinity of films has been developed. Obviously, these developments of crystallinity result from the growth of microcrystallites.

To refer past paper[3], the film which has been annealed at 600°C can be classified into zone 1, at 700°C can be classified into zone 2 and at 800°C can be classified into zone 3. At 600°C, thermal diffusion has not advanced so much. Thus its fibrous structure has remained without collapse. At 700°C, in comparison with 600°C, diffusion has taken advances, and then adjoining columns have united with each other into bold column. At 800°C, columns have diffused into like blocks, and microcrystallites have grown up. So, perpendicular magnetic anisotropy has decayed.

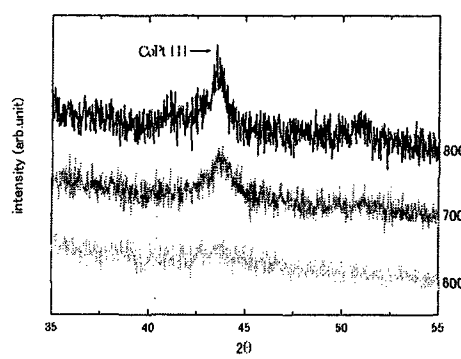

Fig. 3. XRD profiles at three kinds of annealing temperatures.

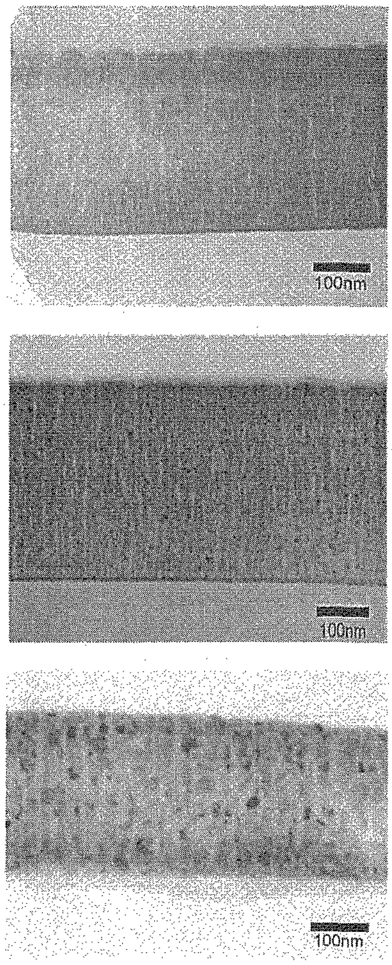

Fig. 4. Transition of cross sectional structure depending on annealing temperature. (from top 600°C, 700°C and 800°C annealing.)

4. CONCLUSION

The magnetic properties of $Co_{75}Pt_{25}$-TiN films for perpendicular magnetic recording media were studied in terms of the annealing temperature to confirm their potential. A film annealed at 700°C showed highest perpendicular coercivity(Hc) value greater than 600 Oe and saturation magnetization(4πMs) value greater than 6000 gauss. But in terms of perpendicular hysteresis shape, a film annealed at 600°C has more ideal perpendicular hysteresis loop (rectangle shape) than annealed at higher temperatures.

On TEM observation, it is turned out that the structure changes cause hysteresis transition. Fiber structure becomes collapsed as annealing temperature becomes higher [3]. And by the result of XRD profiling, the crystallinity and the quality of perpendicular magnetic properties are not so related. Perpendicular properties are more related to the structure rather than crystallinity.

All hysteresis loops have been distorted around the origin. Resolution of this issue needs to be more detailed investigations.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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