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HRTEM and Nano-probe EDS Studies on the Microstructure of CoCrPtO Perpendicular Recording Media with Ru/Ru-oxide Interlayers

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Double-layered CoCrPtO perpendicular magnetic recording media, composed of a magnetic layer and a soft magnetic underlayer (SUL), are of great interest owing to their low media noise characteristics [1-2]. Desirable microstructural features of the magnetic layer include small grains separated by non-magnetic grain boundaries. Control of this microstructure is accomplished by interlayers between the ferro-magnetic recording layer and SUL. Although a Ru interlayer, by itself, was reported to improve the microstructural properties of the magnetic thin film [2-3], in this study, a thin Ru-oxide layer was deposited on the Ru interlayer to further improve the well-isolated grain structure. The resulting structure of the medium is SUL/Ta (2 nm)/Ru (26 nm)/Ru-oxide (2 nm)/CoCrPtO (15 nm).

Fig. 1a shows a high resolution image of the well-defined columnar structure of the medium. Also visible is the epitaxial relationship maintained throughout the interfaces of the Ru/Ru-oxide and Ru-oxide/magnetic layers. Fig. 1b shows a series of plan-view high resolution images of the Ru/Ru-oxide film. Specimens without the magnetic layer were used for this purpose. TEM samples were prepared by the conventional grinding/polishing/ion-milling method. However, during the ion milling step, gun angles and voltage were carefully adjusted to obtain a range of thicknesses in the same plan-view specimen, such that TEM images could be taken at different levels. Therefore, in Fig. 1b, high resolution images (1-3) represent roughly the thick (3), medium-thick (2) and thin (1) regions in Fig. 1a, respectively. Compared to the thicker regions (2 and 3), which are closer to the bottom of the interlayer, it is clear that the Ru grains are well-separated with a smaller grain size and a more uniform size distribution at the top of the Ru/Ru-oxide interlayer (1). This well-isolated, small grain structure can lead to further grain isolation and grain size reduction in the magnetic layer.

Fig. 2 shows a bright field image of the CoCrPtO magnetic layer depicting the well-isolated grains with 1-2 nm-thick grain boundaries. Since the grain size of magnetic media follows a log-normal size distribution [4], grain size analysis is shown in the form of a cumulative percentage plot in Fig. 3. By adding a thin Ru-oxide layer on top of the conventional Ru layer, a significant decrease in the grain size and a more uniform size distribution were obtained compared to the 30 nm-thick Ru interlayer. The magnetic layer has a slightly smaller grain size with size distribution similar to the Ru/Ru-oxide interlayer indicating that this grain size and distribution is determined by the Ru/Ru-oxide interlayer.

Although a physically separated magnetic grain structure was observed, oxide-phase segregation at grain boundaries is also important for exchange decoupling. Since the grain boundaries are 1-2 nm thick, nano-probe energy dispersive X-ray spectroscopy (EDS) accompanied by high resolution TEM is a crucial technique to pinpoint specific areas and perform a composition analysis by focusing the electron beam to 1.5 nm diameter. The nano-probe EDS data of the Ru/Ru-oxide interlayer and CoCrPtO magnetic layer are shown in Fig. 4a and b, respectively. In both cases, the concentration of oxygen and the oxide forming element (Z) are much higher at the grain boundaries than the grain interiors, which provides evidence for the oxide phase segregation at grain boundaries.

In summary, plan-view imaging at different thicknesses was successfully performed by high resolution TEM with delicate sample preparation, and the result shows that the addition of a Ru-oxide layer on the Ru layer can reduce the interlayer grain size. Grain boundary segregation of an oxide phase in both the interlayer and the magnetic layer was demonstrated by using nano-probe EDS.

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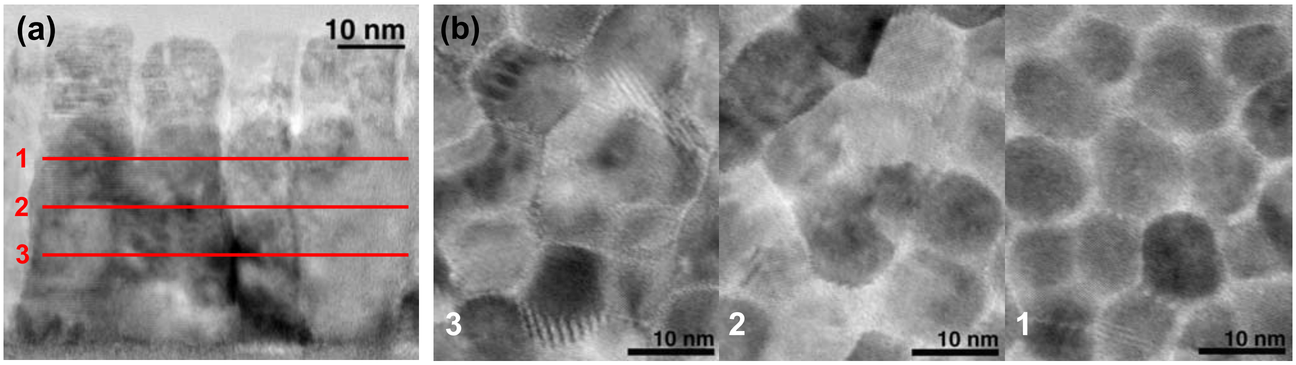

Fig. 1. (a) Cross-section high resolution image of CoCrPtO (15 nm)/Ru-oxide (2 nm)/ Ru (26 nm)/Ta (2 nm)/SUL medium and (b)-(d) plan-view high resolution images of Ru-oxide (2 nm)/Ru (26 nm)/Ta (2 nm)/SUL specimen in different thicknesses.

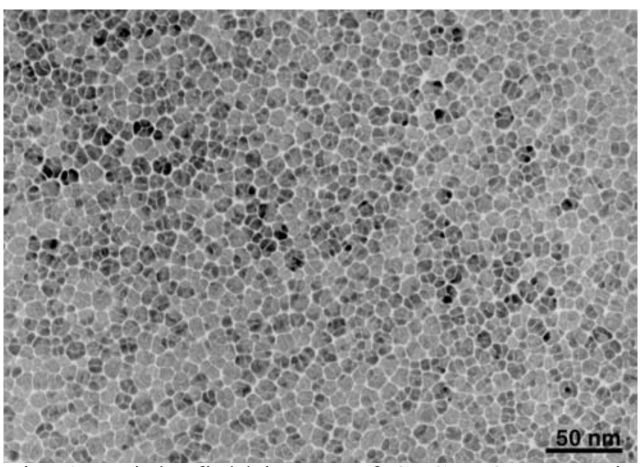

Fig. 2. Bright field image of CoCrPtO magnetic layer.

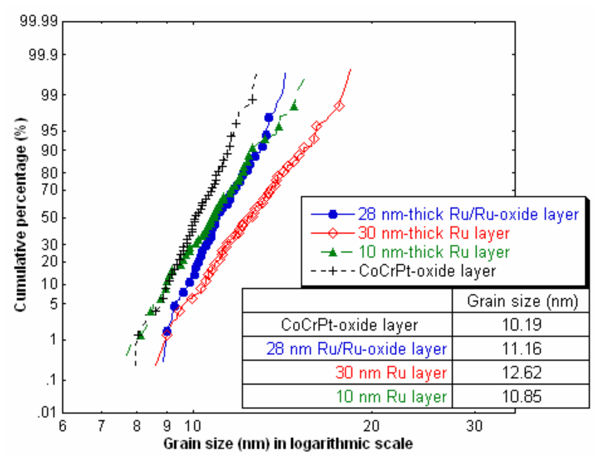

Fig. 3. Grain size analysis in the form of cumulative percentage plot.

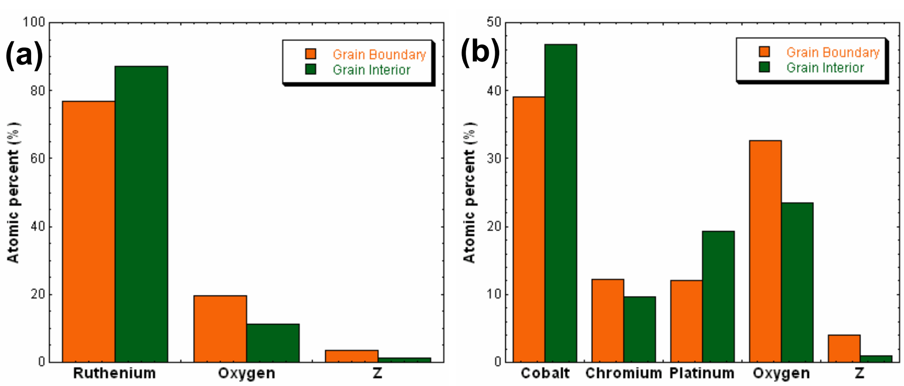

Fig. 4. Nano-probe EDS analysis data of (a) the Ru/Ru-oxide interlayer and (b) the CoCrPtO magenetic layer, showing composition distribution between grain core and grain boundary regions.

* Z is an oxide forming element in both cases.

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