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Formation of ordered phase of CoPt with self-similar fractal-like voids on Al_2O_3(0001) substrates

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Ordered phases of CoPt, especially $L1_0$-ordered CoPt, have been studied extensively for application to spintronic devices such as magnetoresistive random access memory and ultrahigh-density hard disk drives owing to their strong perpendicular magnetocrystalline anisotropy and large coercivity (H_c). Recently, we reported the formation of $L1_0$-ordered CoPt on Si/SiO_2 substrates using electron-beam (EB) evaporation and rapid thermal annealing (RTA).[1)] Graded films consisting of $L1_2$-ordered $CoPt_3$, $L1_0$-ordered CoPt, and $L1_2$-ordered Co_3Pt were found to be formed during the interdiffusion of equiatomic Pt/Co bilayer thin films with a Ti underlayer by RTA at 800 °C, where the films showed an in-plane H_c of 2.1 kOe.[1)] We also reported the Ti underlayer effect on the ordering of CoPt in equiatomic $(Co/Pt)_4$ multilayer thin films on Si/SiO_2 substrates.[2)] In the film without a Ti underlayer after RTA at 900 °C, $L1_0$-ordered CoPt with an isolated round grain structure was confirmed, showing an in-plane H_c of 2.7 kOe.[2)] In contrast, in the film with a Ti underlayer after RTA at 900 °C, $L1_2$-ordered $CoPt_3$ was confirmed together with Co-rich $A1$-disordered CoPt, which exhibited an angular-outlined continuous film structure, showing an in-plane H_c of 500 Oe.[2)]

In this study, we report the formation of ordered phase of CoPt in $(Co/Pt)_4$ multilayer thin films with a Ti underlayer on single-crystal Al_2O_3(0001) substrates by RTA. Equiatomic [Co (1.2 nm)/Pt (1.6 nm)]$_4$ multilayer thin films with a Ti underlayer (3.0 nm) were fabricated on Al_2O_3(0001) substrates by EB evaporation and were annealed by RTA at 900 °C. The crystal structure and surface morphology were characterized by grazing incidence X-ray diffraction (GI-XRD) and scanning electron microscope (SEM), respectively. The ordered phase of CoPt was confirmed in the film after RTA by GI-XRD. The SEM image of the film after RTA is shown in Fig. 1, where the dark and bright regions correspond to CoPt and Al_2O_3(0001) surface, respectively. The self-similar fractal-like voids were clearly observed (bright regions in Fig. 1), which is apparently different surface morphology from that of the films with the Ti underlayer on Si/SiO_2 substrates in our previous study.[2)]

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1) R. Toyama, S. Kawachi, S. Iimura, J. Yamaura, Y. Murakami, H. Hosono, and Y. Majima, *Mater. Res. Express* **7**, 066101 (2020).
2) R. Toyama, S. Kawachi, J. Yamaura, Y. Murakami, H. Hosono, and Y. Majima, *Jpn. J. Appl. Phys.* **59**, 075504 (2020).

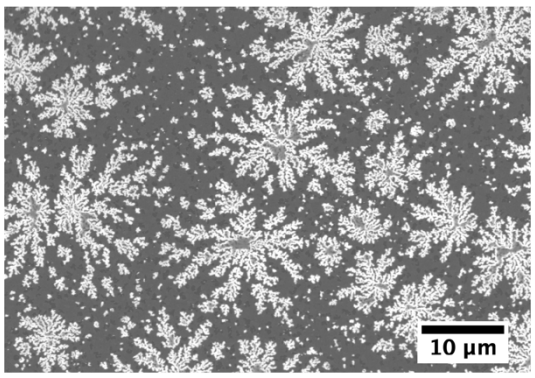

Fig. 1. SEM image of $(Co/Pt)_4$ multilayer thin films with Ti underlayer on Al_2O_3(0001) substrates by RTA at 900 °C. The dark regions correspond to CoPt, whereas the bright regions correspond to Al_2O_3(0001) surface.