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Study of Magnetic Domain Structure in Co(Fe)/Pd Multilayers using Off-axis Electron Holography

D. Zhang[1], J. M. Shaw[2], D. J. Smith[3] and M. R. McCartney[3]

[1.] School of Engineering for Matter, Transport, and Energy, Arizona State University, Tempe, AZ 85287
[2.] Electromagnetics Division, National Institute of Standards and Technology, Boulder, CO 80305
[3.] Department of Physics, Arizona State University, Tempe, AZ, 85287

Magnetic nanostructures that are magnetized perpendicular to their surface are central to many developing technologies, including spintronics devices and patterned media, because of the requirement to maintain thermal stability as device dimensions are scaled further into the nanoscale. Multilayer or superlattice materials such as Co(Fe)/Pd are convenient for these applications due to their highly tunable perpendicular anisotropy [1]. In this study, Co(Fe)/Pd multilayers with structure: Ta/Pd/[Co(Fe)/Pd] **X** n/Pd were deposited by dc-magnetron sputtering on thermally oxidized Si wafers. Samples were thinned to electron transparency in cross-section and plan-view geometry. High-resolution images were recorded with a JEM-4000EX HREM at 400keV and a CM-200 at 200keV to reveal crystal structure. STEM images were recorded by JEM-2010 to characterize the multilayer interfaces. The magnetic domain structure was studied by off-axis electron holography using a CM-200 equipped with electrostatic biprism and Lorentz lens. In addition, perpendicular magnetic domain morphology and surface roughness was characterized by AFM/MFM. Here, we correlate crystal structure and magnetic properties.

Observation of the sample with structure: Ta(3nm)/Pd(3nm)/[Co(4nm)/Pd(11.6nm)]×8/Pd(3nm) using cross-section HR-STEM showed that the multilayer structure increasingly became wavy away from the substrate and the interfaces appeared to be less well-defined [Fig. 1(a)]. Plan-view HREM images showed a fine-grained microstructure [Fig. 1(b)] consistent with the {111} texture observed in XTEM images. After saturating the magnetization of the multilayers in specific directions, electron holograms were recorded in field-free conditions using the Lorentz lens [2]. Reconstructed phase maps show fringing magnetic field outside a thick part of the sample in cross-section geometry while only noise is visible within the sample [Fig. 2(a)]: this result confirms magnetic anisotropy perpendicular to the sample surface. Phase maps reconstructed from the plan-view sample also show fringing fields indicating magnetic anisotropy parallel to the surface [Fig. 2(b)]. Phase maps also indicate that the magnetic induction is weak but MFM could not reveal any clear magnetic signal. However, MFM images from the sample with structure: Ta(3nm)/Pd(3nm)/[CoFe(t)/Pd(2t)]×12/Pd(3nm) revealed clear domain structure [Fig. 3], which should make It possible to correlate the magnetic properties of the multilayers with their crystal structure and composition. Further results from samples with different growth parameters will be reported [3].

References:

[1] J. M. Shaw *et al,* Phys. Rev. B. 80, (2009) 184419.
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State University, and we acknowledge assistance from the M02 Group, Institute of Physics, Chinese Academy of Science for use of the AFM/MFM facility.

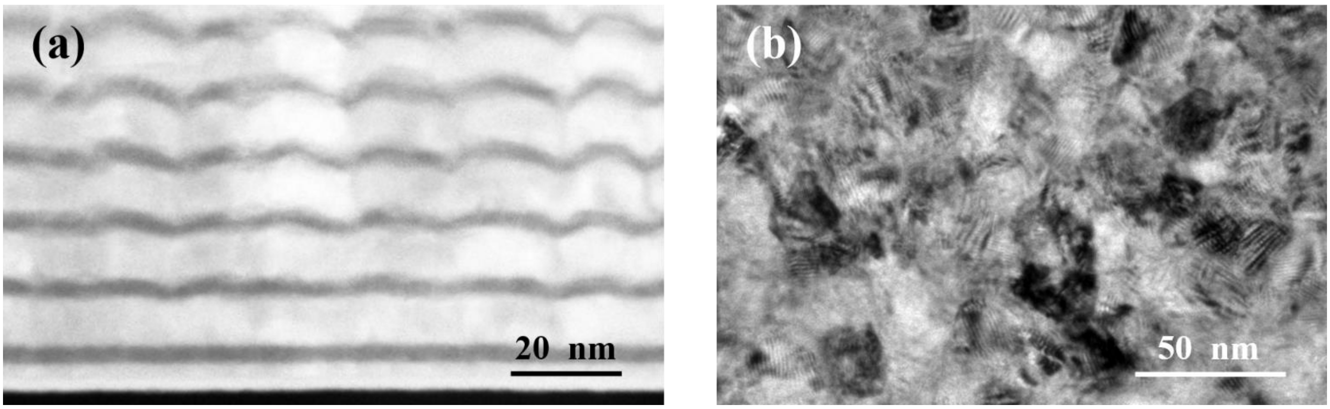

Figure 1. (a) Cross-section HR-STEM image showing Co/Pd multilayers; (b) Plan-view HR-TEM image showing random fine-grain morphology.

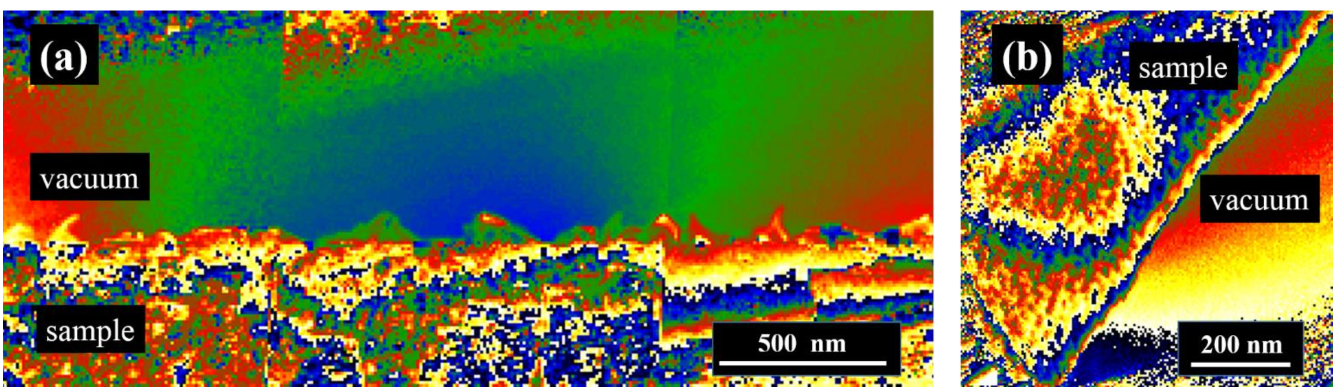

Figure 2. Reconstructed phase maps of Co/Pd multilayers in: (a) cross-section geometry; and (b) plan-view geometry.

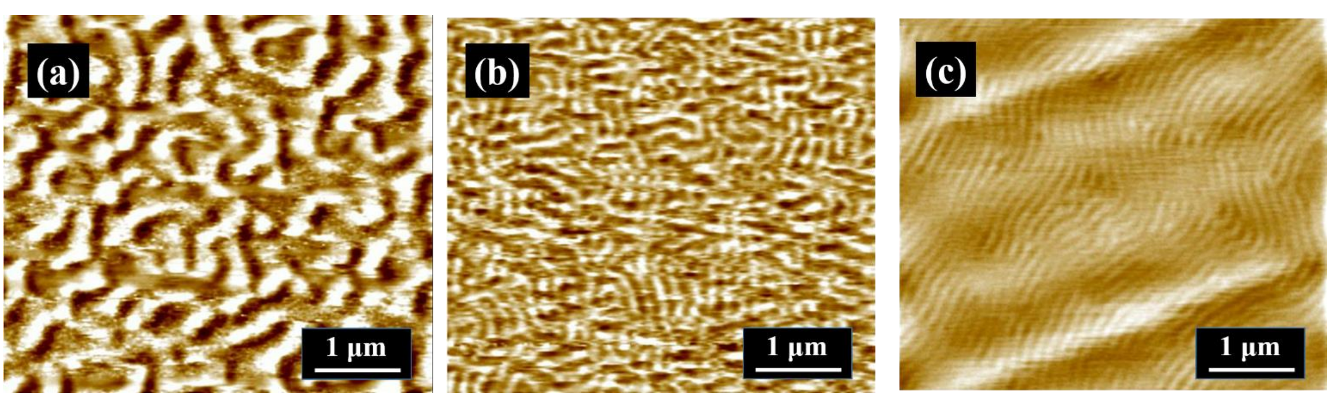

Figure 3. MFM images of Ta(3nm)/Pd(3nm)/[CoFe(t)/Pd(2t)]× 12/Pd(3nm) with: (a) t=0.45nm; (b) t=0.6nm; and (c) t=1nm. Images qualitatively indicate the morphology of the magnetic domains perpendicular to sample surface by bright (anisotropy pointing up) and dark (anisotropy pointing down) contrast.

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