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STEM/EDS Spectral Imaging of Magnetic Tunnel Junction Nano-Devices

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Thanks to their high tunnel magnetoresistance (TMR), magnetic tunnel junctions (MTJs) are now used in hard-disk drives (HDDs) as read sensors. In a commercially available HDD, the areal density is ~400 GB/in^2, which requires a reader sensor width of ~50 nm. The tunnel barrier (MgO) thickness is typically 1-2 nm. Many of the metrology requirements for semiconductor technologies [1], e.g., dimensional metrology [2] and compositional metrology, are observed during the nano-manufacturing of MTJs. So far STEM is virtually the only technique capable of simultaneous imaging and chemical mapping at atomic resolution [3]. That said, the integration of heavy and light, polycrystalline and amorphous materials (often with rough interfaces between each other), in those MTJ nano-devices introduces enormous challenges for TEM characterization.

In this work, we have demonstrated the application of high spatial resolution STEM/EDS mapping in MTJ reader characterization. A typical TMR reader is shown in Figure 1 (a) bright-field TEM image, and (b) a High-Angle Annular Dark Field (HAADF) "Z-contrast" image of the same device. A STEM/EDS dataset is collected with drift compensation. For qualitative elemental mapping, the dataset is reconstructed with multivariate statistical analysis [4]. The peaks used for mapping are carefully chosen (e.g., $L\alpha_{1,2}$ instead of $K\alpha_1$ is chosen for Mn mapping) in order to minimize the artifacts introduced by overlapping peaks. Maps of twelve elements are given in Figure 2. Alumina layer was largely damaged by e-beam exposure. Gaussian fitting of the vertical Mg line profile (not shown) gives a full-width at half-maximum (FWHM) of 1.4 nm. In order to visualize distribution of phases, the raw dataset is reconstructed with multiple linear leas-square fitting [5] to illustrate eleven phase in a composite phase map shown in Figure 3.

The data collection time in this example is ~2hr on a FEI Tecnai X-twin instrument. Recent exciting development of Cs-corrected microscope, large area x-ray detector, and high-efficiency EELS spectrometer as well as multivariate data processing algorithms [4-6] provide promising feasibility to simultaneously collect atomic resolution STEM/EELS and STEM/EDS datasets from a large area within in tenth of that time, which is critical to reduce beam damage.

References

[1] E.M. Vogel, *Nat. Nanotechnol.* 2 (2007) 25.
[2] H. Wang et al., *Microscopy Today* 16 (2008) 24.
[3] D.A. Muller et al., *Science* 319 (2008) 1073.
[4] Burke et al., *J. Mat. Sci.* 41 (2006) 4512.
[5] A. Maigné et al., *J. Electron Microsc.* 58 (2009) 99.
[6] P.G. Kotula et al., *Microsc. Microanal.* 12 (2006) 538.
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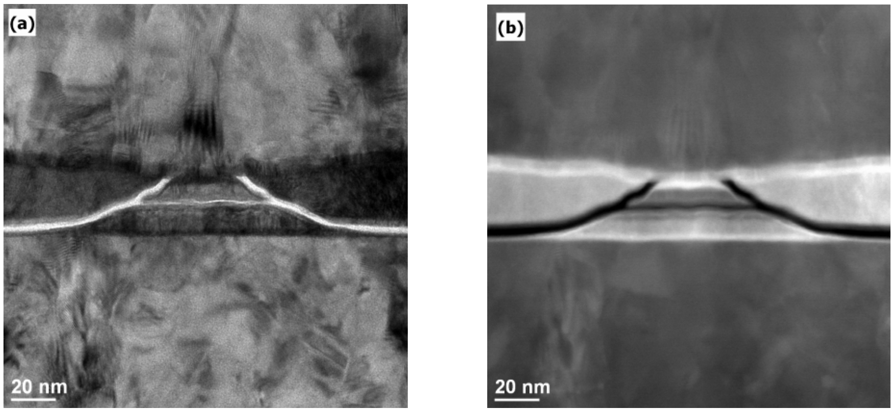

FIG. 1. (a) Bright-field TEM image of a commercial TMR reader, and (b) HAADF STEM image.

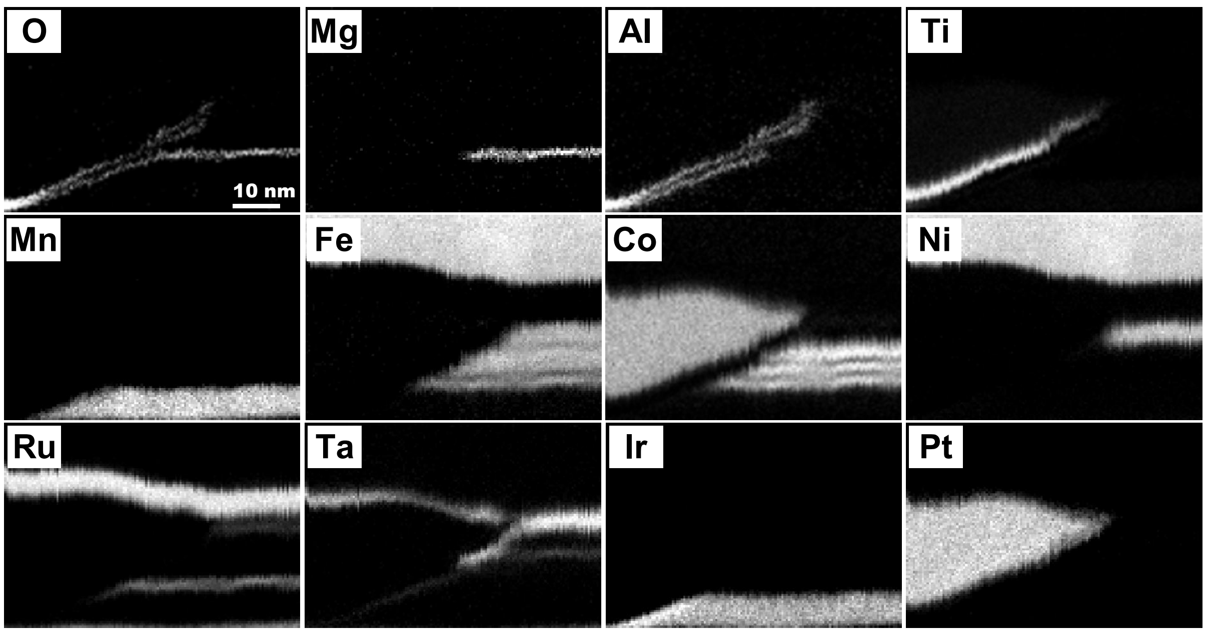

FIG. 2. Elemental maps reconstructed from the STEM/EDS dataset.

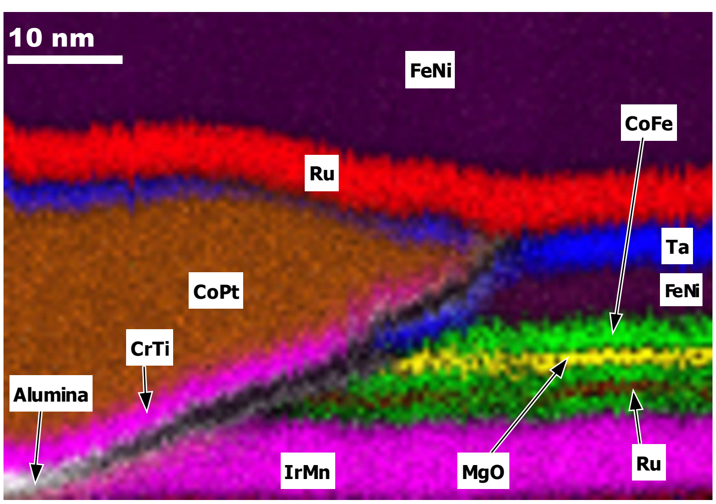

FIG. 3. Composite phase map reconstructed from the raw STEM/EDS dataset.

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