Nanoscale magnetic domains in Fe/NiO/Fe trilayer structures

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Spin-polarized low-energy electron microscopy (SPLEEM) is a powerful tool to reveal details of sample morphology and spin-resolved electronic structure in nanostructured materials during *in-situ* preparation.

Using SPLEEM to study magnetization in single-crystalline layered structures, we discovered that magnetic domains and domain walls in the top Fe layer of Fe/NiO/Fe/MgO(100) as well as Fe/NiO/Fe(100) (atomically flat single crystal) strutcures are dramatically smaller than the corresponding domain structures observed in Fe/MgO(100) films. The domains are separated by 180° domain walls and have complex, meandering structures as shown below. Interestingly, even though both the [010] and [001] directions are degenerate, large regions of the samples are covered with intricate patterns of domains that are all magnetized along just one of the two easy axes. This is because the AFM easy axis of NiO grown on top of Fe substrate latches onto the magnetization direction of an underlying large FM domain (magnetized along either [010] or [001] directions) via exchange coupling. Consequently, the antiferromagnetism of the NiO scramble the coupling direction with respect to the top Fe-layer, but conserve the axis with respect to the underlying domain in the Fe substrate, as confirmed by our observation of the AFM domains in the NiO layer using the Photo-Emission Electron Microscopy (PEEM) with x-ray magnetic linear dichroism (XMLD) technique.

Another surprising feature is that the observed domain walls are one order of magnitude narrower than the size of 180° walls we observe in the Fe substrates. Using a simple model based on frustrated exchange forces at the Fe/NiO interfaces, we show that the strength of the exchange coupling across the interface can be estimated directly from the magnetic domain microstructure of the top Fe layer.

The discovery of nanoscale domains in Fe/NiO/Fe/MgO(100) and Fe(100) is important to understand the basic magnetic phenomena as well as for its potential to enable miniaturization of spin-electronics devices.

(a) (b)

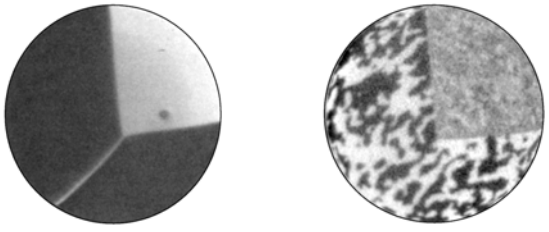

Figure: SPLEEM images (field of view 7 micron, electron beam spin parallel to [001])

(a) magnetic domains in Fe/MgO substrate prior to growth of trilayer structure. Large domains are magnetized along [010] or [001] easy axes.

(b) domain structures in the top Fe-layer after completion of the Fe/NiO/Fe/MgO trilayer.