The Fabrication of Epitaxial Magnetic Tunnel Junctions

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Why Epitaxial Tunnel Junctions?

Magnetic Tunnel junctions consist of two ferromagnetic layers separated by a thin insulating layer. Most junctions have aluminum oxide as the insulating layer. Epitaxial tunnel junctions are more ordered than tunnel junctions with an amorphous insulator and we hope to fabricate junctions which will be easily modeled by theory. We want to use Magnesium Oxide for the insulating layer because it has good lattice matching with iron which will facilitate epitaxial growth. The surface of an iron layer becomes rougher as it becomes thicker so silver is used under the bottom ferromagnetic layer because it grows more smoothly to obtain a thicker electrode.
MgO is FCC with a lattice constant of 4.21 Å. Fe is BCC with a lattice constant of 2.87 Å. These don’t appear to match, but if the iron is rotated 45°, it’s atoms line up with those of the MgO with only a 3.5% mismatch.
Coverage of Each Preceding Layer

For our magnetic tunnel junctions to have the properties we seek, each layer in the structure must fully cover the preceding layer. The reasons for this differ with each layer. The bottom iron layer must fully cover the silver layer so that tunnelling occurs. Without full coverage, silver would be exposed to the MgO layer and non-spin polarized electrons could pass from the silver layer to the top ferromagnet, yielding no magnetoresistance. If the MgO layer does not fully cover the bottom Fe layer, then the two ferromagnets would be in contact, creating low resistance channels through the insulating layer.

To investigate the coverage of each layer we used Auger Electron Spectroscopy (AES). Taking measurements intermittently during growth will indicate when a layer fully covers the preceding layer when the signal from the lower layer is reduced to zero. The measurements of the bottom Fe ferromagnet on Ag and of the MgO insulating barrier on the Fe follow.
Auger Spectrum of Fe on Ag

We can see that as the thickness of the iron layer increases, the intensity of the iron peaks increases and the intensity of the silver peaks decreases. This indicates that at 18 Å, the iron should be a uniform layer covering the silver because the silver signal is nearly zero.
We can see that as the thickness of the MgO layer increases, the intensity of the MgO peaks increases and the intensity of the silver peaks decreases. (Silver and oxygen were used due to their high signals). This indicates that at 12 Å, the MgO should be a uniform layer covering the silver because the silver signal is nearly zero.
These images show the RHEED pattern of the substrate with 20Å Fe (a) and also the substrate with 20Å Fe/100Å Ag/10Å Fe (b). The patterns indicate that the growth of the layers are epitaxial. However, the diffraction spots seem to lay on lines rather than circles. This could be due to hills and valleys in the surface of the sample which would lead to small transmission effects, leading to a resemblance to a TEM diffraction pattern.
Results and Conclusions

We have fabricated Magnetic Tunnel Junctions using the materials described here. However, magnetoresistance measurements have not been performed on the junctions at this time.