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# Oxidation of Al thin layers in tunnel junctions probed by Raman spectroscopy

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The degree of oxidation of aluminum thin layers in tunnel junction structures is probed using Raman spectroscopy. Tunnel junction structures consisting of 5-nm Ta/17-nm $Co_{90}Fe_{10}$/7.5-nm $Ir_{20}Mn_{80}$/5-nm $Co_{90}Fe_{10}$/Al were prepared on silicon substrates by a four-target rf magnetron sputtering system under typical base pressure below $5\times10^{-7}$ Torr. Deposition was done under Ar pressure of 2 mTorr. The thickness of the top Al layer was varied between 0.8 nm and 12.8 nm. Aluminum oxide films were formed by oxidizing Al layers under rf plasma environment with the oxygen partial pressure of 100 mTorr and the plasma power of 50 W. The oxidation time was varied linearly with the Al layer thickness. The oxidation time for the 1.6-nm Al layer sample, which we took as the standard, was 50 s. It is the condition that typically gives the best results in TMR characteristics. The Raman spectra of all samples were measured at room temperature, using the 514.5-nm line of an argon ion laser as the excitation source. The laser power measured at the sample was 75 mW. The scattered light was collected and dispersed by a 55-cm monochromator and detected by a liquid-nitrogen-cooled CCD (charge coupled device) array detector. A weak Raman signal from the Si substrate was observed because the metal layers are partially transparent. By monitoring the intensity of the Si Raman peak, the transmittance of the multilayer structure could be deduced. Since the samples are identical, except for the thickness of the top aluminum layer, any difference in the intensity of the Si Raman peak is due to the difference in the transmittance of the top aluminum (oxide) layer. It was found that the intensity decreases monotonically with the aluminum layer thickness, which means that there is a substantial underoxidation. Furthermore, the intensity for the 1.6-nm sample is measurably lower than that for the 0.8-nm sample, which indicates that even the "optimized" 1.6-nm sample may have some degree of underoxidation. This work demonstrates that Raman spectroscopy could be a useful tool in probing the oxidation state of the aluminum oxide tunnel barriers.

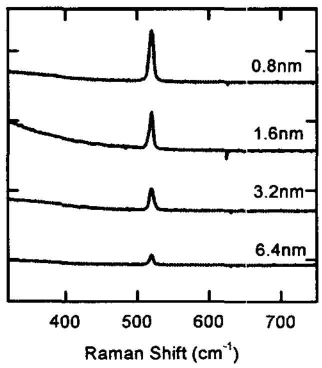


Fig. 1 Raman Spectra of samples with different Al thicknesses.

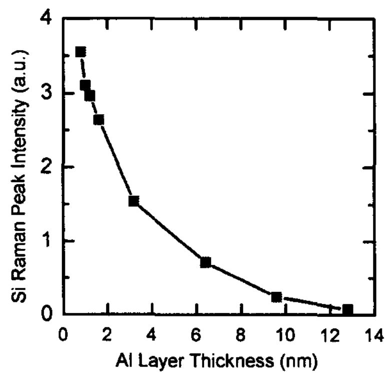


Fig. 2 Dependence of the intensity of the Si Raman peak on the Al thickness.