Epitaxial Heusler Superlattices with Perpendicular Magnetization

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Magnetic tunnel junctions for use in system-on-chip memory require ferromagnetic electrodes with four key ingredients. First, single crystal thin film contacts must grow epitaxially on a variety of substrates to facilitate uniform performance across large arrays of devices. Second, perpendicular magnetic anisotropy (PMA) is desired to reduce spin transfer torque critical current, which reduces Joule losses for electrically switched devices. Perpendicular contacts also possess higher magnetic thermal stability as compared with in-plane magnetized contacts, which serves to preserve the magnetic state for technologically useful timescales. Third, Fermi level spin polarization must be high to enhance the tunnel magnetoresistance ratio and thereby improve state discrimination during read operations. Fourth, the contact must have low Gilbert damping, which further decreases spin transfer torque critical current.

Recently, J.G. Azadani *et al.* utilized theory calculations to argue that superlattices composed of alternating layers of certain full-Heusler compounds produce materials with all four of the properties mentioned above [1]. Specifically, epitaxial Co_2MnAl – Fe_2MnAl (CMA-FMA) superlattices are predicted to be half-metallic with 100% spin polarization, possess dominant PMA, and are composed of low Z elements with low damping coefficients. Furthermore, the spin polarization and PMA depend strongly on the superlattice periodicity, which is on the order of a single unit cell.

In this work, we utilize molecular beam epitaxy with computer controlled source shutters to grow CMA-FMA superlattices of varying periodicity on both GaAs(001) and MgO(001) substrates. High resolution x-ray diffraction is used to verify epitaxial growth. SQUID magnetometry and anomalous Hall effect are used to probe the magnetic and electronic properties of the films. We show that CMA-FMA films with a periodicity of 1.5 unit cells grown on GaAs(001) have lattice parameter $a \approx c = 5.98$Å, and exhibit dominant PMA below 200K. Similar films grown on MgO(001) are epitaxial with $a = 5.74$Å and $c = 5.80$Å, and work is in progress to find conditions giving strong perpendicular behavior. Future work includes spin-resolved photoemission and point contact Andreev reflection spectroscopy to probe the spin polarization of the films.

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