Surface Termination Layer Dependence in Heusler Superlattices

<u>Tobias L. Brown-Heft</u>[1+], A. P. McFadden[2], J. A. Logan[1], C. Guillemard[3,4], P. Le Fèvre[4], F. Bertran[4], S. Andrieu[3], C. J. Palmstrøm[1,2]

[1]*Materials Dept., Univ. of California, Santa Barbara, CA, USA*
[2]*Dept. of Electrical and Comp. Engr., Univ. of California, Santa Barbara, CA, USA*
[3]*Univ. Lorraine, Inst. Jean Lamour, CNRS, F-54506 Vandoeuvre Les Nancy, France.*
[4]*Synchrotron SOLEIL, CNRS-CEA, L'Orme des Merisiers, Saint-Aubin, France*

Heusler atomic superlattices were recently predicted to combine both perpendicular magnetic anisotropy and half-metallicity in a single material [1]. Until now, these two properties have been optimized in separate material systems (e.g. CoFeB [2] and Co_2MnSi [3]). In Heusler superlattices, the magnetic anisotropy arises from strain and electronic structure at each sublayer interface, while half-metallicity arises from Fermi-level tuning via alloying effects.

Single-crystal atomic superlattices with periodicity of one to three unit cells (5.8 Å to 17.4 Å) have been successfully grown by molecular beam epitaxy. Superlattices consisting of B2 ordered full-Heusler Co_2MnAl and Fe_2MnAl were grown on GaAs (001), MgO (001), and Cr (001)/MgO (001). Films are fully strained to each substrate up to at least 20 nm film thickness. Electron energy loss spectroscopy confirmed well-defined Heusler layers as seen in Fig. 1. Superlattices grown on GaAs (001) with aluminum excess over 20% experienced an out-of-plane spin reorientation transition for temperatures below 200 K. Spin polarization at the bulk X point was measured via synchrotron-based spin resolved photoemission spectroscopy on samples grown *in-situ* in an attached MBE chamber. Surface spin polarization was found to depend strongly on surface termination. Pure Fe_2MnAl and superlattices terminated with Fe_2MnAl had 25% spin polarization. Pure Co_2MnAl had 65% spin polarization. Superlattice terminated with Co_2MnAl had the highest spin polarization of 95% (Fig. 2), with the Fermi level at the bottom of the Slater-Pauling gap, suggesting that the superlattice does provide some Fermi level tuning. Magnetic tunnel junction and magnetotransport behavior will also be discussed.

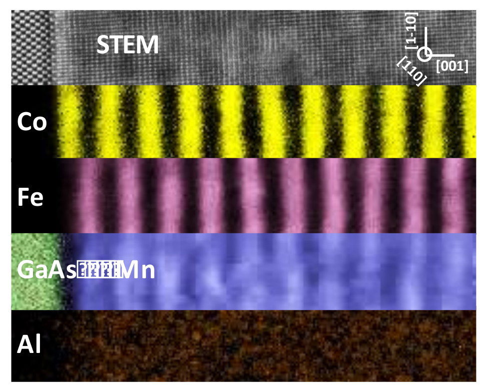

Figure 1. High angle annular dark field scanning transmission micrograph with electron energy loss spectroscopy.

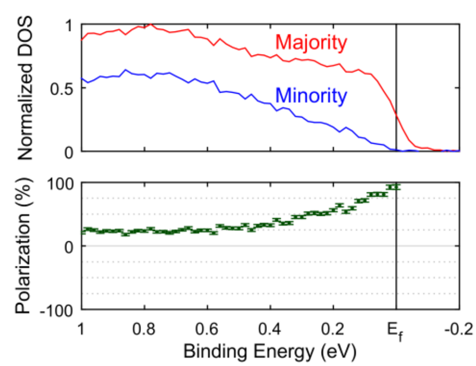

Figure 2. Spin resolved photoemission spectroscopy of a Co_2MnAl-terminated superlattice sample.

+Author for correspondence: tobias@umail.ucsb.edu

[1] J.G. Azadani, K. Munira, J. Romero, J. Ma, C. Sivakumar *et al*, *Journal. of App. Phys*, *119*(4), (2016).
[2] S. Ikeda, K. Miura, H. Yamamoto, K. Mizunuma, *et al*, *Nature Materials*, *9*(9), 721–724, (2010).
[3] M. Jourdan, J. Minár, J. Braun, A. Kronenberg, S. Chadov, *et al*, *Nature Comm.*, 5(May), 3974, (2014).

Supplementary Information:

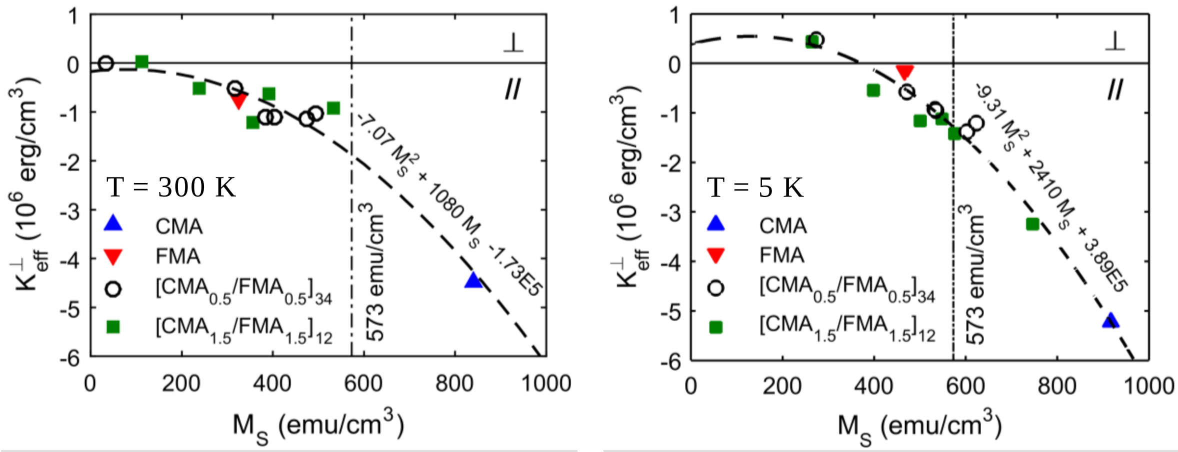

Figure 3. Perpendicular magnetic anisotropy vs. saturation magnetization at (left) 300 K and (right) 5 K. $M_S(T=0)$ of stoichiometric superlattice is 573 emu/cm^3 (dot-dashed line). Excess aluminum tends to lower M_S for superlattice samples, allowing out-of-plane easy axes to develop at low temperature.

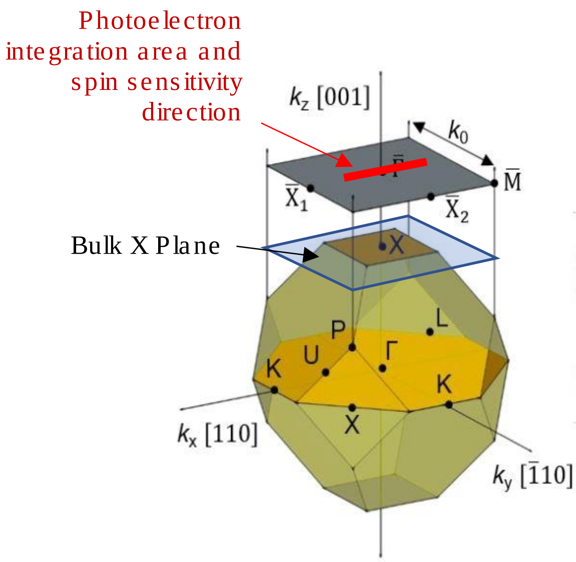

Figure 4. Photon energy selects a k_z slice from the bulk Brillouin zone. For hν = 35 eV, k_z is at the bulk X point. This slice is projected into the surface Brillouin zone, which is measured. SR-PES averages electron momenta from a line 52% of the width of the surface BZ.

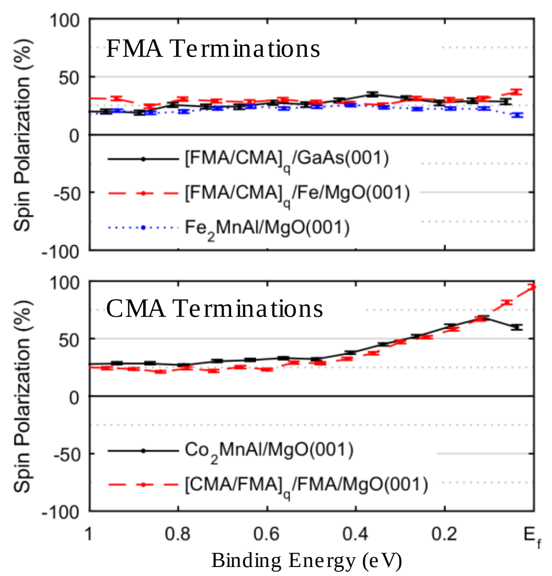

Figure 5. Summary of spin-resolved photoemission data showing 25% spin polarization at the Fermi level for Fe_2MnAl-like surfaces, 65% for pure Co_2MnAl, and 95% for Co_2MnAl terminated superlattice.