Abstract for an Invited Paper
for the MAR12 Meeting of
The American Physical Society

Nanometer-scale properties of metal/oxide interfaces and "end-on" metal contacts to Si nanowires studied by ballistic electron emission microscopy (BEEM)[1]

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BEEM is a hot-electron (HE) technique based on scanning tunneling microscopy that can probe buried metal/semiconductor and metal/dielectric interfaces with nm-scale spatial resolution and energy resolution of a few meV. BEEM is a three-terminal technique, so the HE energy and interface electric field can be varied independently. I will discuss two studies of interest for future transistor technologies. The first concerns the band structure and alignments in a 20 nm-thick film of the high-k dielectric material Sc_2O_3 grown epitaxially on Si(111). Sc_2O_3 and related rare-earth/transition metal oxide films on Si were found to have similar band alignments and bandgap, and also "tailing" conduction band (CB) states extending $\sim$1 eV below the primary CB. We combined BEEM with internal photoemission to measure the band alignment and to study electron transport through these "tail" states.[2] Surprisingly, these tail states were found to form a robust band of extended states that supports elastic hot-electron transport even *against* an applied electric field. The second study concerns HE injection and transport through "end-on" metal contacts made to $\sim$100 nm diameter vertical Si nanowires (NWs) embedded in a SiO_2 dielectric. At low HE flux, We observed *lateral variations* of the local Schottky Barrier Height (SBH) across individual end-on Au Schottky contacts, with the SBH at the contact edge found to be $\sim$25 meV lower than at the contact center. Finite-element electrostatic simulations suggest that this is due to a larger interface electric field at the contact edge due to positively charged Si/native-oxide interface states near the Au/NW contact, with this (equilibrium) interface state charge induced by local band bending due to the high work function Au contact. We also observed a strong *suppression* of the hot-electron transmission efficiency at larger HE flux, likely due to (non-equilibrium) *steady-state negative charge accumulation* in metastable traps at the Si/oxide interface located near the injecting metal contact. Ongoing BEEM measurements of metal contacts to $SrTiO_3$ substrates and films may also be discussed.

In collaboration with W. Cai, Y. Che, L. F. Edge, D. G. Schlom, E. R. Hemesath, and L. J. Lauhon.

[1] Work supported by NSF Grant No. DMR-0805237

[2] W. Cai, S. E. Stone, J. P. Pelz, L. F. Edge, and D. G. Schlom, Appl. Phys. Lett **91**, 042901 (2007).