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Direct Measurement of Quantum Confinement and Environmental Pinning Effects on Metal/Nanostructure Schottky Contacts

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I will discuss direct nm-resolution measurements of metal/quantum well (QW) Schottky contacts made using Cross- sectional Ballistic Electron Emission Microscopy (XBEEM), in order to quantify the influence of small-size effects on hot- carrier injection into semiconductor nanostructures. Molecular Beam Epitaxy was used to grow a sequence of GaAs QWs with width varying from 1nm to 15 nm, separated by thick $Al_{0.3}Ga_{0.7}As$ barrier layers. The samples were cleaved ex-situ and polycrystalline Au contacts were electron-beam evaporated on the cleaved edge using shadow mask or photo-lithography. Samples were studied in ultra-high vacuum using Scanning Tunneling Microscopy and XBEEM. The Schottky barrier height over the QWs was found to systematically increase with decreasing QW width, by up to $\sim$140 meV for the 1 nm QW. This is mostly due to a large quantum-confinement increase (up to $\sim$200 meV) of the QW conduction band minimum (CBM), as estimated by a simple 1D QW model. We also did finite element electrostatic modeling to estimate the "environmental" effects of the surrounding metal/$Al_{0.3}Ga_{0.7}As$ interface on the QW CBM. Excellent quantitative agreement over the full QW width range is obtained when both quantum confinement and electrostatic effects are considered.I will also discuss on-going measurements to use the metal/QW nanocontacts as unique "nano-apertures" to directly image and quantify the lateral hot-electron spreading profile in the metal film. This profile is surprisingly large, with a FWHM of $\sim$15nm ($\sim$21nm) for a 4nm (7nm) thick Au film. XBEEM images directly show that hot-electron spreading is strongly modified by the grain structure in the metal film. In collaboration with J.P. Pelz, M.K. Hudait, and S.A. Ringel. Work supported by NSF and ONR