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Electronic Conduction and Switching in Metal / Molecule / Metal Structures

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We report both physical and electrical characterization of several metal / organic monolayer / metal device structures which display electrical switching behavior. Devices comprised a planar lower metal electrode of aluminum (Al) or platinum (Pt), a Langmuir-Blodgett or self-assembled organic alkane monolayer, and an evaporated metal upper electrode of titanium (Ti) or platinum. Single crosspoint devices of area 1600 nm^2–100 um^2incorporated 10^3-10^7 molecules in parallel. Electrode surfaces, monolayer structure, and electrode-monolayer interactions were very sensitive to sample preparation. X-ray photoelectron spectroscopy (XPS) indicated that the thickness and stoichiometry of PtOx and TiOx species at both metal-organic interfaces were strongly affected by process conditions including deposition pressures and plasma treatments. Infra-red spectroscopy (RAIR) using ultra-flat template-stripped metal substrates showed that the physical structure of the monolayer was similarly sensitive to nanometer-scale electrode roughness. Electrical conductance hysteresis was observed in Al/monolayer/Ti and Pt/monolayer/Ti devices. Local-pressure modulated atomic force microscopy (AFM) suggested that the electrical hysteresis was dominated by one or two nano-conduction channels <30 nm in diameter. The asymmetric, reversible conductance switching observed remains inconsistent with a simple dielectric breakdown process. Instead, for each electrode system we suggest either an interface electrochemical process or a reversible nanoparticle growth & dissolution as primarily responsible for the observed electrical switching. Technology proof-of-principle demonstrations of ultra-dense nanoscale memory and logic integrated crossbar circuits, including latch circuits showing signal restoration, have successfully utilized these organic monolayer structures.