Transfer Printing Approach for Fabricating Molecular Electronic Junctions

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The combination of molecules and semiconductors is one of the most promising configurations for next-generation semiconductor electronics. Molecules offer small size, flexibility, and advanced functionality. Utilizing a silicon substrate, the basis of the computer industry, reduces cost and development time and also promotes integration of molecular-based devices with conventional CMOS technology. In addition, the silicon-molecule electronic coupling can be tailored by altering the semiconductor dopant type and concentration. Making electrical contact to the organic molecules remains one of the most important challenges in this field. Conventional metal vapor-deposition techniques often lead to electrical shorts and degradation of the organic molecular layer. Nanotransfer printing (nTP), commonly based on an elastomeric stamp, provides a simple and low cost route to fabricate metallic nanostructures at desired locations.

We have adapted nTP to fabricate ultrasmooth gold (uS-Au) films and nanodots on plastic substrates for use as top metal electrodes in molecular electronic devices, as shown in Figure 1. Utilizing this uS-Au approach, we are able to create a metal-molecule junction without the destructive forces of vapor-deposition and the very smooth metal and flexible substrate ensure conformal contact with the monolayer terminus. We have investigated the fabrication of molecular junctions by first forming self-assembled monolayers of bifunctional molecules either on uS-Au[1] or Si substrates. We demonstrate that by application of moderate pressure, the molecular terminus can be covalently bonded to the silicon substrate producing robust and reproducible uS-Au/molecule/Si junctions, as shown in Figure 2. Terminal groups such as thiols, silanes, alkenes and carboxylic acid have been investigated to covalently bond monolayers to both electrodes. Organic monolayer quality has been evaluated prior to junction formation by means of infrared spectroscopy, x-ray photoelectron spectroscopy, and spectroscopic ellipsometry. After formation of uS-Au/molecule/Si structure, molecular conformation has been examined by polarized-backside infrared spectroscopy (pb-RAIRS). This uS-Au approach provides a versatile platform to fabricate a wide range of molecular junctions and to achieve the electronic and chemical characterization basis necessary for the realization of molecule-semiconductor hybrid devices.

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[1] M.Coll, C.A. Hacker, L.J.Richter, L.H. Miller, D.R. Hines, C.A. Richter, ECS Trans, accepted for publication.

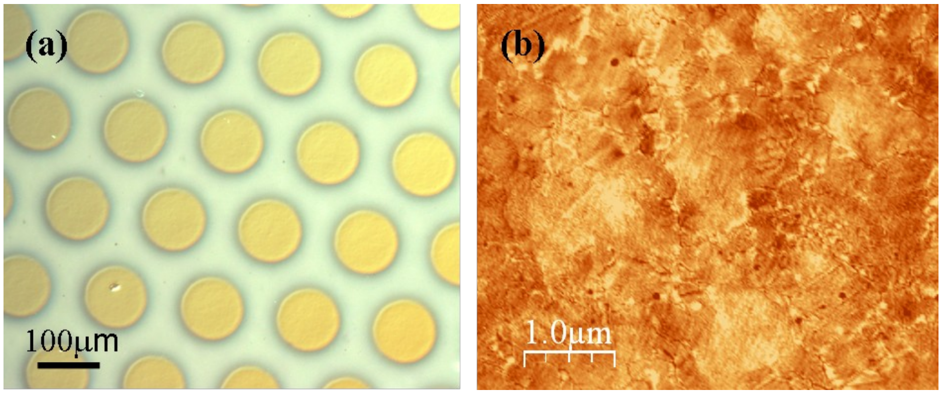

Figure 1 (a) Optical microscope image of transfer printed ultrasmooth Au dots on plastic substrate (b) AFM topographic image of ultrasmooth gold surface on plastic substrate.

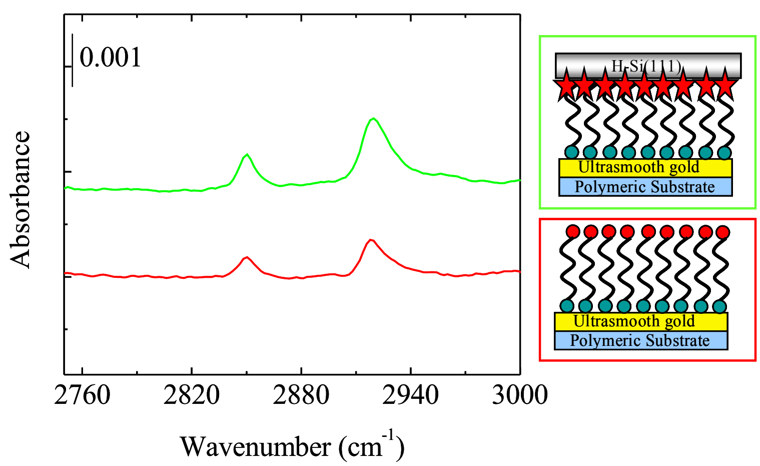

Figure 2 Vibrational spectra of the C-H region of self-assembled mercaptohexadecanoic acid before and after formation of uS-Au/molecule/Si sandwich structure. In both cases, organic monolayer exhibits well-ordered packing.