Nanofabrication of Test Architectures for Molecular Electronics Applications

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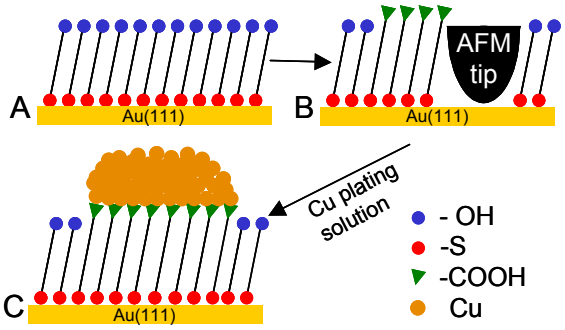
The ability to precisely construct nanoscopic metal-molecule-metal junctions is of great importance for the development of robust molecule-based electronic and optoelectronic devices. By combining scanned probe lithography with electroless metal deposition, metal-molecule-metal junctions can be constructed where the dimensions and surface organization are dictated by the placement of surface groups active for electroless deposition, such as carboxylates, into a desired pattern. These structures will provide a means of reproducibly measuring transport (current-voltage) properties of ensembles of molecules with a fixed a real density to assess the role of the molecule in the transport process and to determine the scalability of per molecule conduction in such junctions.

The CSTL research team develops a robust, systematic nanoscale test structure to critically evaluate electrical properties of candidate materials that are used in the development of nanoscale molecular-based electronic devices.

The CSTL research team developed methodologies to construct confined molecular assemblies of metal-molecule-metal junctions with nanoscale dimensions for the evaluation of electron transport in small ensembles of molecules (10's to 1000's) to determine the scalability of per molecule conduction values in prototypical device architectures. To this end, automated scanned probe lithography is employed to pattern surfaces with self-assembled monolayers, where specific molecular linking groups are placed into organized structures on Au surfaces with features sizes ranging from approximately 10 nm to 200 nm in lateral dimension with the Au surface functioning as a bottom electrode. A completed metal-molecule-metal junction is then formed by the electroless deposition of metal yielding the top electrode. Here we have developed and demonstrated the needed fabrication capabilities to enable construction of these test architectures.

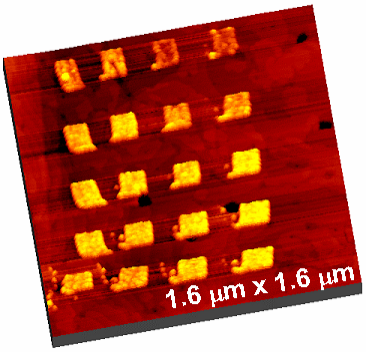
Patterning of metal-molecule-metal junctions with nanoscale dimensions, specifically Cu on carboxylic acid terminated SAMs on Au, has been demonstrated using a combination of automated scanned probe nanofabrication and electroless metal deposition. The architecture of the nanostructures formed can be precisely tuned in all dimensions by controlling the lateral 2-D pattern size of the fabricated structures, the surface density of reactive acid groups placed into the structure, and the concentration of reactants in the electroless metal plating solution. An overview of the key steps to fabricate the Cu nano-contacts is illustrated in the figure below. Using this approach metal structures ranging from approximately 20 nm to 200 nm in lateral dimension with 5 nm to 10 nm metal top contacts have been formed.

Scheme for fabrication of nanoscale metal junctions.
A. First a resist layer is deposited on the surface.
B. A structure of 16- Mercaptohexadecanoicacid (MHA) is then patterned into the resist by nano-grafting.
C. The surface is then exposed to a Cu plating solution yielding C.
*** AFM = Atomic Force Microscopy**



An array of final structures fabricated using this approach is shown in the figure to the right. The patterning process requires only on the order of 30 min for forming all of the junctions. This provides a means a fabricating a range of structures with varying dimensions to assess scalability of current with junction dimension and molecular packing density. This approach should be readily extended to other metals that can be electrolessly deposited such as Pt, and be applicable to the construction of more complicated multidimensional metallic structures including combined vertical and lateral junction geometries. Additionally, well-defined nanoscale metal-metal junctions can be also formed which may be employed in the development of enhanced optical spectroscopic methods for sensing.

Current experiments are now aimed at probing the electrical behavior of ensembles of molecules within the nano-patterned junctions. These measurements can then be compared to those from prototypical device structures. This approach for building nano-patterned metallic structures will also be transferred to Si substrates as a means to construct hybrid semiconductor-molecule-metal junctions.



Topographic AFM image of nano-patterned array of sixteen 150 nm x 150 nm Cu structures (about 5 nm high) on carboxylic acid terminated SAMs.