NSF-CCI Center for Nanostructured Electronic Materials

Lisa McElwee-White, W. David Wei, Gregory S. Girolami, Joseph. W. Lyding, and Marcus Lay

The University of Florida, The University of Illinois at Urbana-Champaign, and The University of Georgia

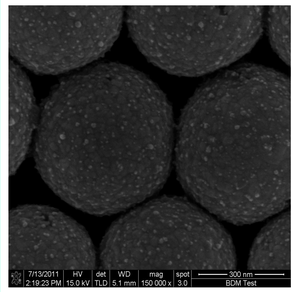
CHE -1038015

The Center for Nanostructured Electronic Materials is on a mission to make transformative advances in computing technology by developing new chemistry to wire molecules and nano-scale materials into electronic devices.

Molecular Approaches to Directional Growth of Nanostructures as Circuit Components

The Wei and McElwee-White groups are developing techniques to achieve controlled directional growth of wires between nanostructures by a new technique: surface plasmon-mediated chemical deposition (SPMCD). In SPMCD, optically induced plasmon resonance excitations are used to raise local temperature and promote spatially-localized chemical deposition.

SPMCD of metallic gold is investigated using the soluble precursor methyl(triphenylphosphine)gold(I):



$$CH_3I + Mg \xrightarrow{Et_2O} CH_3MgI$$

$$Cl{-}Au{-}PPh_3 + CH_3MgI \xrightarrow{Et_2O} CH_3Au{-}PPh_3$$

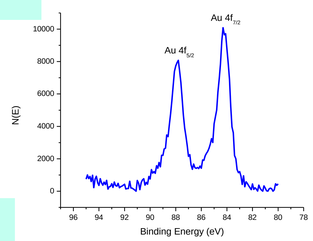
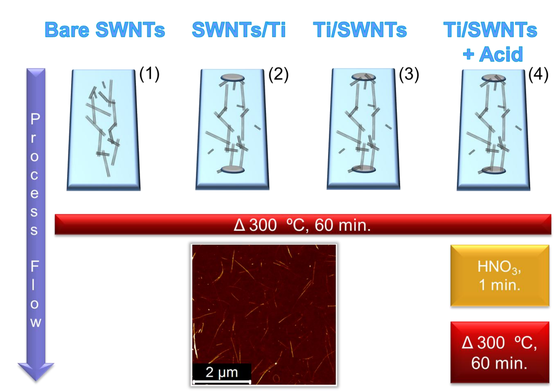


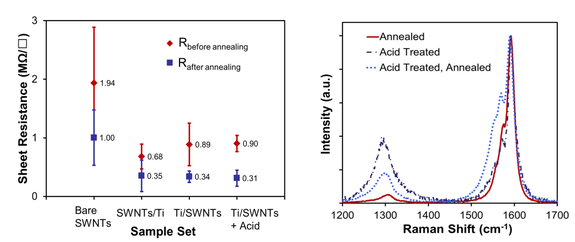
Image on right shows SPMCD of <10 nm metallic gold clusters on silver nanoparticles from CH_3AuPPh_3 upon irradiation with a Xe lamp at 0.65 W/cm^2 for 3 h. No deposition is observed in the absence of irradiation. Future work will involve directional growth using polarized light.

Top: SEM image of gold SPMCD on silver nanoparticles. Bottom: Deposition is identified as metallic gold using XPS.

Reducing the Contact Resistance at Carbon Nanotube Junctions



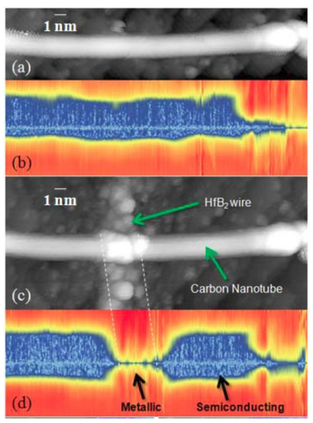
The Lay group is using electrodeposition and other low-temperature methods to investigate ways to reduce the contact resistance at junctions between single-walled carbon nanotubes and themselves as well as with metal electrodes. We have shown that the resistance can be reduced by several methods, including annealing, deposition of Ti contacts, and treatment of SWNT networks with acid. These nanotube arrays are potentially useful in a new generation of thin film electronics.

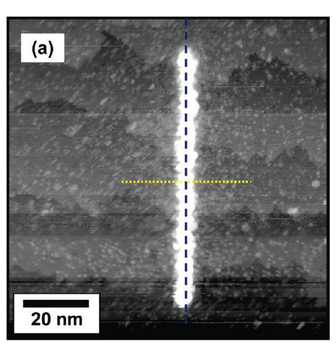


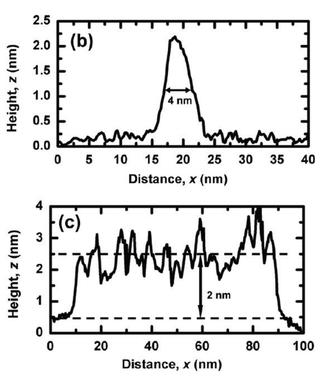
Top: The effect of low-temperature annealing was observed for various electrode/network conformations (see text), Bottom right: Raman spectroscopy indicated that annealing removes defects and adsorbates, Bottom left: annealing results in a consistent reduction in resistance

Nanometallization by Electron Beam Induced Deposition

Lyding and Girolami are working to connect molecule-sized circuit components into functional arrays with precisely-positioned electrically conductive nanowires. This is being accomplished through the development of nanometallization schemes that combine scanning tunneling microscope (STM) nanofabrication methods with novel carbon-free precursors. We have shown that electron beam induced deposition (EBID) can be used to deposit metallic features from novel carbon-free precursors. The STM-EBID methodology is now being used successfully to create metallic quantum dots, nanowires, and electrical contacts between metallic HfB_2 and nanostructures such as carbon nanotubes and graphene.





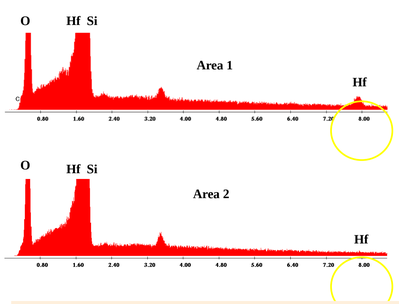


Top: Before (a) and after (c) STM images of STM-EBID metallic junction of HfB_2 over carbon nanotubes and their corresponding STS spectra to demonstrate a change in conductivity.

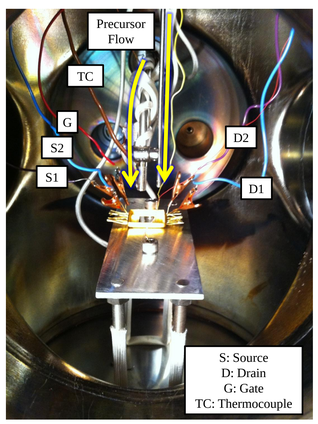
Left: (a) STM image of HfB_2 nanowires made by STM-EBID on a Si(100)-2x1:H surface. (b) Line contour from (a) perpendicular to the nanowire. (c) Line contour from (a) parallel to the nanowire.

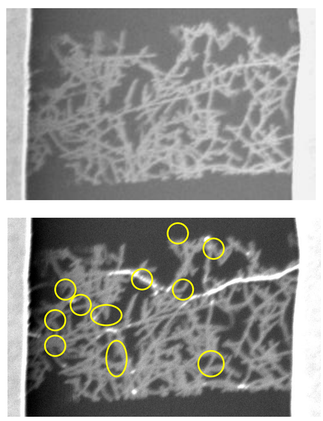
Automatic Nanosoldering of CNT Junction Hot Spots

The Lyding and Girolami groups are developing a nanosoldering technique to improve the performance of carbon nanotube field-effect transistor (FET) arrays. Nanotube FET arrays are easy to fabricate compared to single nanotube devices but have much lower carrier mobility due to junction contact resistances. In the technique we have developed, we use resistive heating at nanotube-nanotube junctions to trigger a local thermal CVD reaction that encases the junction in metal.



Above: EDS spectra of a bright spot in the SEM image (top) and a dark spot (bottom) showing the presence of hafnium only in the former.





Above: SEM images of a carbon nanotube array before (top), and after (bottom) nanosoldering with HfB_2. The yellow circles indicate nanotube-nanotube junctions that are locally encased in HfB_2..

Left: The nanosoldering apparatus for use in a deposition chamber.