Electrodeposition of Patterned Metal and Semiconductor Micro- and Nanowires on Ultrananocrystalline Diamond Electrodes

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Research Achievement: A new layered electrode composed of conductive and non-conductive ultrananocrystalline diamond (UNCD) has been proven to produce consistent, patterned micro- and nanostructures. These structures can be electrodeposited with uniformity (Figure 1A). The technique is not material specific allowing wires to be made from nearly any material that can be electrodeposited out of aqueous or non-aqueous solutions. Electrically-conductive nitrogen-doped UNCD serves as an efficient electrode with an extremely large electrochemical window due to its chemically inert nature. A layer of insulating undoped UNCD prevents deposition on the top surface so that electrodeposition occurs only at the thin exposed edge of the underlying nitrogen doped UNCD layer.

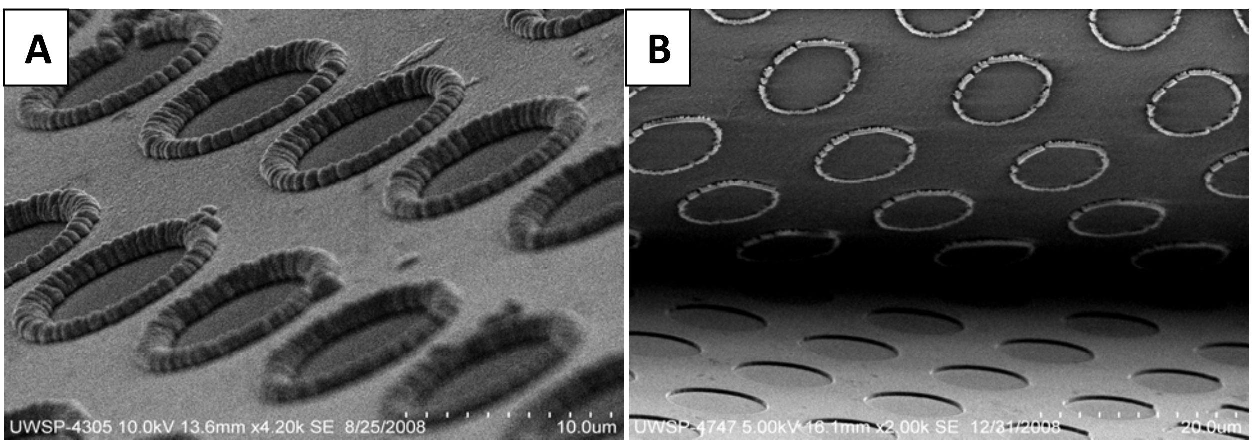

Figure 1 – A Scanning electron microscope (SEM) image of cadmium telluride microwires electrodeposited onto ultrananocrystalline diamond electrodes. **B** SEM image of platinum microwires embedded in a polymer film (upper) that is being peeled away from the diamond template (lower). The extremely sharp angle for pulling and stretching of the polymer film needed to show the interface where wires were being lifted from the template has fractured these wires, but the normal method for peeling is gentle and leaves the wires intact and continuous.

While the initial synthesis of this electrode requires numerous clean room techniques and expensive instrumentation, once the electrode has been made, it is a permanent template for synthesis of micro- and nanowires. Subsequent manufacture of nanowires becomes almost as simple as using a rubber stamp and ink. The multilayer diamond electrode is low in adhesion to the deposited materials, thus allowing easy transfer of the resulting deposited micro- or nanostructures onto an adhesive polymer (Figure 1B). The polymer also strips contamination from the electrode leaving a pristine electrode surface for repeated use. Duplicate copies of the original electrodeposited wires were made without repeating the difficult lithography steps for each batch of wires made. The combination of unique electrical, chemical and physical properties of UNCD is promising to allow mass production of uniform patterned nanostructures. Materials electrodeposited include: Pb, Au, Cu, Pd, Pt, Ag, Zn, Co (from an ionic liquid electrolyte), Te, CdTe, and CdS. The most recent work has proved that this technique can make patterned nanowires as small as 70 nm in diameter. Figure 2 shows an electrode schematic.

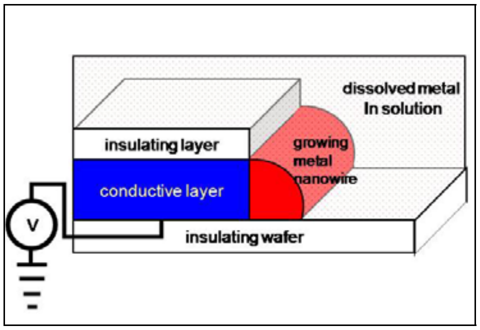

Figure 2 – Schematic of a layered UNCD electrode. Nitrogen doped UNCD forms a thin electrode that is protected on the surface by a capping layer of undoped (insulating) UNCD. Electrodeposition can occur only at the exposed edge of the doped layer.

Future Work: The UNCD nanowire templates are a fundamental and novel advance in methods for making patterned nanowires. Since the templates are extremely robust and not sacrificial, this innovation may help bring nanomanufacturing to “main street” American businesses. Future research will focus in three major areas. The first research thrust is extending the range of nanowire materials. The UNCD templates are extremely robust because diamond is inert under many extreme conditions. This will likely allow electrodeposition of extremely reactive alkali metals, refractory metals such as Ti, Nb, Ta and Zr; and expanding the range of semiconductor nanowires. The second goal is making proof-of-concept heterostructure-type devices containing two or more materials. Examples include solar cells, thermocouples, semiconductor devices or even complex circuitry. The third area is developing scalable production methods that will allow for synthesis of gram to kilogram quantities of patterned nanowires or complex circuits on a continuous basis. Because the template is permanent, once an electrode has been made, all of the extremely tedious steps of nanopatterning surfaces typically used such as electron beam patterning can be eliminated. A continuous production method for patterned nanowires would enable inexpensive manufacturing of such diverse products as nanowires for powdered metallurgy applications, plate and peel circuits as an alternative to traditional electronics manufacturing, and RFID tags for smart-dust type applications.

Publications: This work has not been published yet, but two manuscripts are being prepared for submission later this spring and summer. This conference represents one of the first public displays of this work.

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