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C, Ni, and Si Nanoscale Material Formation by C-MEMS/NEMS technology

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Recently Carbon microelectromechanical systems (C-MEMS) and carbon nanoelectromechanical system (C-NEMS) have received much attention because of the many potential applications, such as: DNA arrays and microbatteries. Microfabrication of carbon structures using current processing technology, including focused ion beam and reactive ion etching, is time consuming and expensive. Low feature resolution, and poor repeatability of the carbon composition as well as widely varying properties of the resulting devices limits the use of screen printing of commercial carbon inks for C-MEMS. Our C-MEMS/NEMS technique is based on the pyrolysis of photo patterned positive or negative photoresists.[1-3]. Figure 1 shows a typical SEM image of C-MEMS/NEMS features with carbon posts connected by carbon fibers.

For microbattery and DNA array applications, one important issue is the selection of suitable current collectors materials and contact leads. We have developed two and even three level C-MEMS processes to fabricate low resistance contacts to C-MEMS features and to make very high aspect ration structures (> 40). In the case we used the more familiar Ti/Au combination as contact material, the Au layer melted and changed to a multitude of Au balls at the high pyrolysis temperature, distorting the C-MEMS features in the layer above. An interesting discovery was made though: using SEM and TEM investigation, carbon fibers were observed near the Au balls. Unlike conventional CVD methods for growing nanotubes in which a gaseous carbon source, such as CH_4, is commonly used, in our study the only carbon source is photoresist. Therefore we suggest that the process involves a local CVD mechanism in which the pyrolyzing resist provides the gaseous carbon source. Figure 2 shows a typical SEM image of Au particles with attached graphite nanofibers.

Switching to Ni as a catalyst in the C-MEMS process, two kinds of Ni nanowires, short irregular structured nanowires and high aspect ratio long wires, are formed in very high quantities. In the absence of photoresist---the carbon source, Si nanowires are successfully grown. A modified solid-liquid-solid (SLS) mechanism is invoked to explain these results. The presence of carbon poisons the formation of Si wire and Ni wire growth dominates. Figure 3 shows a typical TEM image of a single crystalline Ni nanowire. A detailed microscopic investigation and analysis was performed and will be presented in this talk. We will also demonstrate that we can switch at will from carbon fibrous material to Ni or Si wires. Most of all, as illustrated in Figure 4, we are able to put nanostructured materials (NEMS) on the surfaces of microstructures (MEMS) while making electrical contact to these structures.

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Reference:
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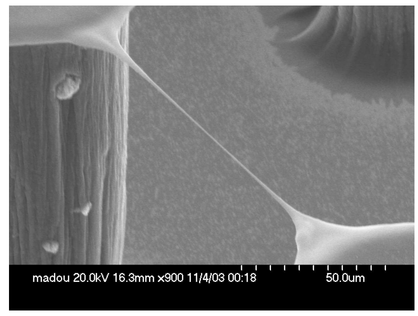

Figure 1.Typical SEM picture of C-MEMS/NEMS structure with carbon posts connected by carbon fibers.

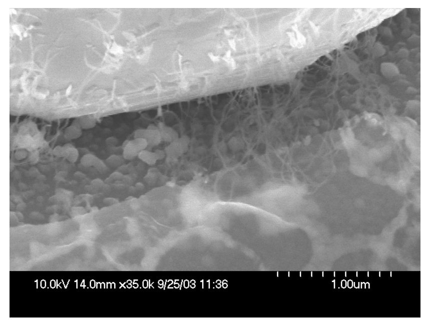

Figure 2. Typical SEM picture of Au particles and C nanofibers.

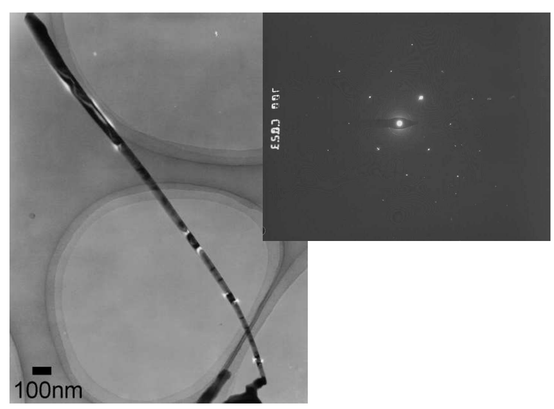

Figure 3. A Typical TEM image of a Ni nanowire and its diffraction pattern.

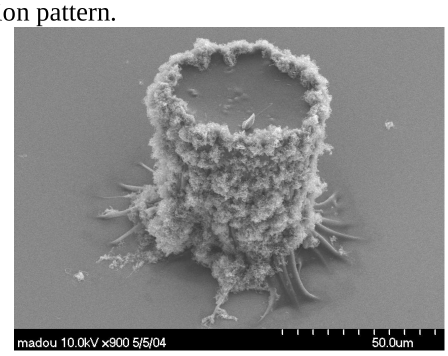

Figure 4. SEM image of a carbon post with nanofibers grown around the side walls.