Carbon: The Next Silicon?
Recent Developments in C-MEMS and C-NEMS.

Thursday, October 19, 2017 | 4:00 p.m. | 202 Reed McDonald

Abstract
The words MEMS and NEMS stand for Micro and Nano Electro Mechanical Systems respectively. These are three dimensional micro and nano shapes for sensing or actuating or they are passive components such as fluidic elements that used to be made almost exclusively from Si. With C-MEMS/C-NEMS the 3D building materials are any of the many carbon allotropes instead.

Shaping of most carbon allotropes into micro- or nano-devices with most machining techniques is difficult and/or expensive. Polymers on the other hand can be machined easily in a wide variety of machine tools and then converted to carbon devices through pyrolysis, resulting in shapes that often are impossible to make in carbon by any other means. Simply stated the underlying principle of C-MEMS/C-NEMS is to choose an easy to work with polymer precursor, machine, or photo pattern this precursor (in the case of a photo resist) and then convert it to carbon by pyrolysis. A recent example of this concept is the pyrolysis of origami paper where the machining is simply hand folding (see Figure 1).

In this contribution, we detail the original C-MEMS and C-NEMS fabrication process and its many new variants. We will also explain how the fabrication process itself enables one to obtain different carbon microstructures such as graphitic carbon nanowires suspended between glassy carbon contact walls (see Figure 2).

We also introduce important current and anticipated C-MEMS and C-NEMS applications. Some recent example C-MEMS/C-NEMS applications we cover will include electrochemical sensors (including redox amplifications with carbon interdigitated electrode arrays (C-IDEAS)), substrate for molecular electronics, batteries, fuel cells, dielectrophoresis, capacitors, scaffolds, nano-gaps for molecular electronics, hot nanowires for local CVD, molds for bulk metallic glasses and gas sensors.

In Fig. 3 we show two more examples of recent C-MEMS/C-NEMS realizations. One involves transferring C-MEMS from a Si substrate onto a flexible polyimide film to make neural probes and the other is the use of a carbon scaffold for stem cell differentiation and dopamine detection.

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Before joining UCI as the Chancellor’s Professor in Mechanical and Aerospace Engineering (MEA), Dr. Madou was Vice President of Advanced Technology at Nanogen in San Diego, California. He specializes in the application of miniaturization technology to chemical and biological problems (BIO-MEMS). He is the author of several books in this burgeoning field he helped pioneer both in Academia and in Industry. He founded several micromachining companies and has been on the board of many more.

Many of his colleagues became well know in their own right in academia and through successful MEMS start-ups. Madou was the founder of the SRI International’s Microsensor Department, founder and President of Tekneikon Sensor Development Corporation (TSDC), Visiting Miller Professor at UC Berkeley and Endowed Chair at the Ohio State University (Professor in Chemistry and Materials Science and Engineering).

The third edition of “Fundamentals of Microfabrication,” an introduction to MEMS and NEMS, which has become known as the “bible” of micromachining.

Some of Dr. Madou’s current research work involves a compact disc-based fluidic platform and carbon MEMS, the two latter fields were pioneered by Dr. Madou. To find out more about those recent research projects, visit www.biomems.net.

Refreshments served at 3:45 p.m.