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Multi-layered Pyrolytic Carbon MEMS Devices

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ABSTRACT

The most successful MEMS devices to date are made from micro machined silicon based materials. These devices have limitations that carbon devices do not. They cannot perform in high heat or radioactive environments. Carbon is inexpensive, easy to produce, can withstand high temperatures and radioactive environments. Carbon can also be tuned for specific performance characteristics, unlike traditional MEMS devices. At Sandia National Laboratories, electrical components using carbon have been fabricated using many approaches. An introduction to these methods will be discussed, with an emphasis on three very different approaches.

Most MEMS devices are fabricated from traditional silicon based materials and micromachining, such as polysilicon, silicon nitride, and silicon oxide. Several universities, individuals and semiconductor industry have researched carbon as an alternative mechanical material. This work has focused specifically on pyrolytic carbon derived from photoresist precursors. The ability to tune photoresist in order to achieve desirable characteristics makes it an ideal precursor for CMEMS devices. By controlling precursory photoresist thickness, a wide range of variability in the carbon layer thickness can be controlled. Carbon can also be tuned for specific performance behaviors by the incorporation of nanoparticles. The loading of photoresist precursor with carbon nanotubes, graphene, reduced graphene oxide and nano-nickel has been explored. Using advanced blending techniques to optimize particle suspension times, quantity of materials and material size, these additives have been used to effectively tune resistivity, Young's modulus and Poisson's ratio.

Photo patterning prior to pyrolysis has been a common approach in defining device structures. A novel approach using traditional silicon micromachining as a foundation for carbon mechanical structures, marries Sandia National Laboratory's SUMMiT-V MEMS process with a tunable carbon mechanical structure. Also discussed is another unique process enabling multilayered fabrication of devices such as resonators, cantilevers, accelerometers, RF/DC switches, bridge structures and thermal actuators comprised of all carbon.

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