Name(s)
Ainesh Arumugam

Project Number
38756

Project Title
Fabricating Suspended Carbon Microfibers for 3D Carbon Microelectromechanical Systems Using Nearfield Electrospinning

Abstract

Objectives/Goals
Carbon Microelectromechanical Systems (C-MEMS) are used in microfluidic applications and are theorized to be a suitable low cost replacement for today#s silicon based electronics. The design goal was to develop a suspended carbon microfiber lattice for 3D C-MEMS using nearfield electrospinning that exhibits aligned behavior and has fibers that have a comparable diameter and spacing as produced through multilayer photolithography.

Methods/Materials
Polyacrylonitrile (PAN) polymer was dissolved in N-N-dimethylformamide (DMF) at 40 °C for 24 hours at a concentration of 9% PAN. This solution was loaded into a syringe and pumped at a flow rate of ~1.0 nL/min. 600 V was applied to the needle charging the polymer, and fibers were drawn onto a silicon wafer substrate placed on a grounded aluminum drum rotating at 2000 RPM placed approximately 1 mm from the needle. The syringe was moving laterally at a speed of 60 µm/sec along the edge of the drum. Electrospinning was done at 25.0% relative humidity. This process was repeated after rotating the substrate by 90° to get a lattice 3D shape. The PAN fibers were stabilized at 275 °C for 5 hours and then pyrolyzed with a constant nitrogen flow rate of 4600 ccm with a gradual increase of temperature up to 900 °C. By varying the RPM and voltage, it was possible to optimize the electrospinning process. The fiber diameter and spacing were measured using a light microscope and the structure was observed with scanning electron microscopy (SEM).

Results
The 3D fiber lattice had an average diameter of 1.1 µm and spacing of 5.7 µm. As the RPM increased, the diameter and the spacing of the fiber decreased to a minimum of 0.84 µm and 1.87 µm, respectively. However, past 2000 RPM, the fiber became discontinuous and lost its aligned state. Higher voltage gave coarse and bigger fibers, while lower voltage gave smooth and smaller fibers, with a minimum of 1.38 µm diameter. Below 600 V, the fiber lost its aligned state and began to curve. Voltage variations caused a negligible impact on spacing.

Conclusions/Discussion
The objective of this project was to electrospin a suspended carbon microfiber lattice for 3D C-MEMS with fibers that have a comparable diameter and spacing as those produced by multilayer photolithography. The 3D lattice#s fibers had an average diameter of 1.1 µm and an average spacing of 5.7 µm, exhibited aligned and suspended behavior, fulfilling all design goals.

Summary Statement
I fabricated suspended carbon microfibers in a 3D lattice structure through electrospinning, a cheap and easily scalable process.

Help Received
Professor Marc Madou of UCI advised me on my project and assigned me a mentor, Derosh George, who helped me throughout the project. Mario Ramos of ITESM of Monterrey, Mexico, and Tuo Zhou of UCI trained me on how to perform near field electrospinning.