Glass Nanofiber and Nanotube Devices

**Abstract:**

We have employed an electric field assisted polymer fiber deposition technique (electrospinning) for the fabrication of single and aligned polymer nanofibers. The nanoscale fibers created in this way are used in combination with lithographically defined microstructures for the fabrication of mechanical and fluidic nanodevices.

A glass precursor was dissolved in a polymer solution and spun over microfabricated trenches, followed by a bake to create suspended silica glass fibers, which were operated as nanomechanical resonators. A sacrificial polymer was spun over trenches, and coated by sputtered or vapor deposited glass, followed by a heat induced depolymerization and evaporation process, yielding suspended silica glass channels, which were operated as nanomechanical resonators, as well as nanofluidic channels for observation of labeled biomolecules.

**Summary:**

Electrospinning is a technique that allows for fast and easy fabrication of nanoscale polymer fibers. An electric field applied between a source and target draws polymer fibers from solution at the source into fibers which are stretched and deposited at the nanometer scale on a target substrate. Rotation of the target allows for these fibers to be deposited as individual, locally straight, and oriented nanostructures. We have used these fibers to define the nanometer-sized elements of two classes of glass nanodevices.

Suspended glass fibers have been fabricated by spinning a solution consisting of a glass precursor called Spin-On-Glass (SOG), dissolved in a Poly-vinylpyrrolidone (PVP) solution. Fibers were electrospun over microfabricated trenches, and then heated at 850°C for three hours to eliminate PVP, and to cross link the SOG. Energy Dispersive X-ray analysis (EDX) was used to confirm the elimination of the organic polymer material during the baking. This process yielded free-standing silica glass nanofibers. These fibers have been operated as nanomechanical resonators, with piezoelectric actuation and optical interferometric detection employed [1].

Fibers made of a heat depolymerizable polycarbonate (HDPC) were spun over microfabricated trenches. These fibers acted as a scaffold for subsequently added material. The suspended HDPC fibers were coated conformally by sputtered or vapor deposited glass, followed by a heat-induced elimination of the polymer core. The resulting free-standing glass nanochannels have been operated as resonant nanodevices, using the same methods used for the glass fibers. These channels have also been used as nanofluidic devices, providing both focal volume confinement, and low background from nanofluidic channels that can be made on a silicon chip.

Chips with suspended channels were cleaved, and capillary-filled with various solutions. A solution containing Rhodamine Red-X labeled cellulase enzymes was examined with a confocal microscope. A laser spot focused onto the channel produced an examination volume defined by the width of the laser spot in one direction, and the channel diameter in the other two directions. When single cellulase molecules diffused into this volume, fluorophores were excited by the observation laser and fluorescence was emitted, and detected by a photodetector. A 2 nM solution concentration was chosen such that single molecule focal volume occupancy was roughly 200 times more likely than double molecule occupancy [2].

The two types of nanodevices described here demonstrate the utility of the electrospinning technique as a nonlithographic approach for the definition of the nanoscale elements of nanodevices, allowing for straightforward integration of nanoscale structures with lithographically defined microstructures.

**References:**


Spin-on-glass/polymer nanofibers were electrospun over microtrenches and baked, yielding suspended silica glass nanofiber resonators.

Heat depolymerizable polycarbonate fibers were spun over trenches, coated with sputtered or vapor deposited glass, and baked for the fabrication of suspended glass nanochannel resonators.

Suspended glass nanochannels offer low-background and focal volume confinement sufficient for fluorescent studies of individual biological molecules.