Lithographically patterned flexible metallic micro wiring on an electrospun nano-fiber mesh

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In this study, we have employed lithography techniques to fabricate stretchable metallic micro-wiring with potential applications in flexible and stretchable electronics. In general, stretchable electronic systems consist of components and circuitry integrated on soft elastomeric substrates. While flexible and stretchable substrate materials like soft elastomers are well known, intrinsic stretchability in conventional electrical wiring is uncommon. Conductive polymers and conductive ion-gels have been explored as electrical wiring, but their low conductivity at small dimensions is a limiting factor for their seamless incorporation in practical applications. A strategy implemented to obtain stretchability in metals is to incorporate a physical architecture that allows for strain without significant stress. In our approach, we employ the intrinsically interconnected structure of an electrospun nano-fiber network to allow stretchability without failure. The metal is deposited directly on top of the nano-fiber mesh, and it is patterned with photolithographic techniques to demonstrate wiring for flexible and stretchable applications. Metal deposition on electrospun nano-fibers has been investigated and shown to be flexible and stretchable[1, 2], but patterning microwires on a nano-fiber platform has never been reported before.

We report a facile process of creating flexible metallic electrical wiring of 25 nm titanium (Ti) and varying thicknesses of gold (Au), conformed to a 35 ±2 µm thick Nylon-6 (N6) nano-fiber mesh (Fig 1). We intend to establish the minimum thickness of metallization on the nano-fiber mesh that allows a continuous conductive trace. Sputter-deposited gold thin films with a thickness of 200 nm and below were patterned by photolithography techniques and wet etching to form 10 mm long traces of varying nominal widths (10 µm, 100 µm, 1 mm) and varying spacing as shown in Fig 2. SEM imaging and ImageJ image processing tools were used to determine the diameter of the fibers, the density of the mesh and thickness of deposited metal. Electrical testing of metal conductive traces was performed using a digital multimeter. As an example, the sheet resistance of 200 nm Au traces for 1 mm wide traces were found to be 0.61±0.05 Ω/sq. In comparison, a flat and continuous sheet of about 50 nm gold would provide equivalent sheet resistance without the potential stretchability. In the future, we intend to fill the structure with PDMS to create a composite with potential applications as fully stretchable electronics.

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[2] Wu, H., Kong D., Ruan Z., Hsu P., Wang, S., Yu, Z., Carney, T., Hu, L., Fan S., and Cui, Y. A transparent electrode based on a metal nanotrough network, *Nat. Nanotechnol.,* 8, 421–425 (2013).

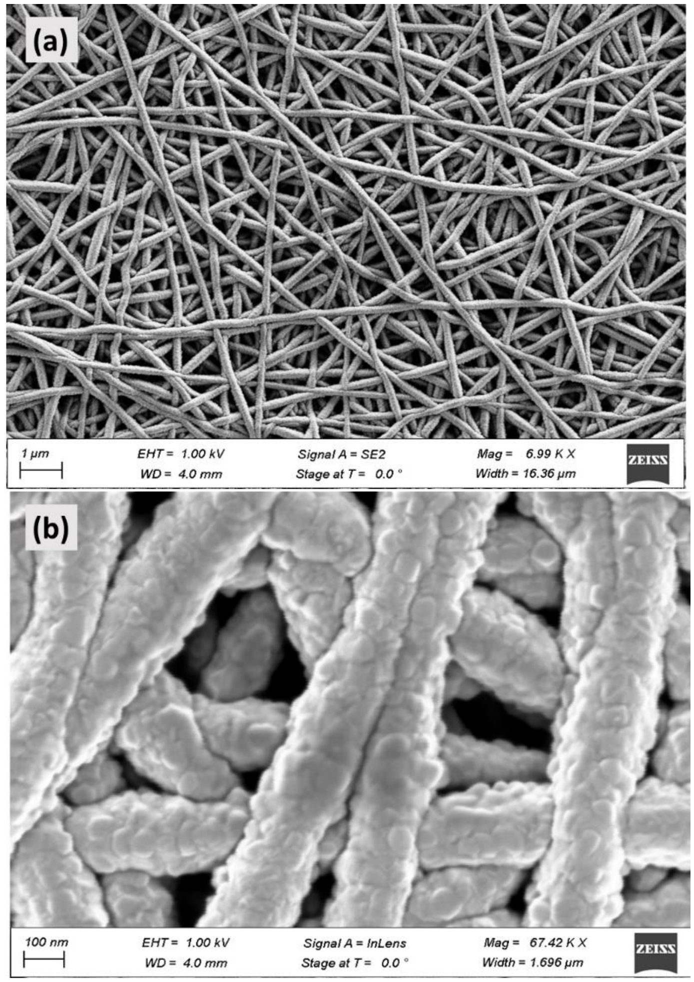

Figure 1. SEM images of (a) top surface of the metal coated nanofiber mat (b) High magnification image of the metal-coated fibers

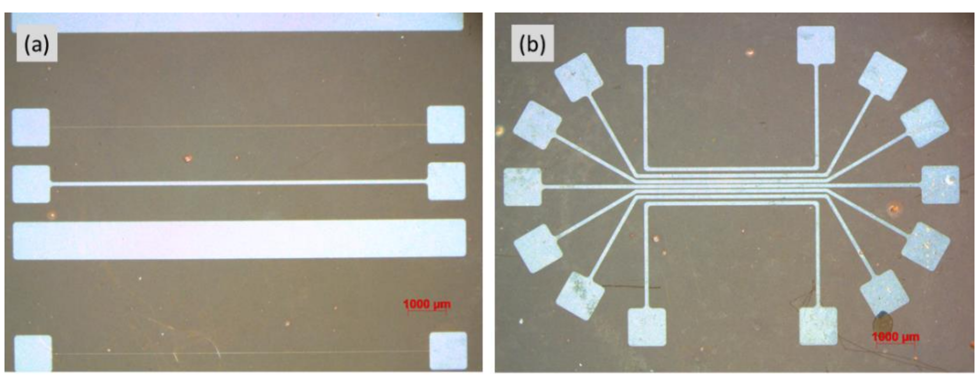

Figure 2 Optical microscope images of the 10 mm metal wires patterned on the fiber mat (a) with varying widths to measure sheet resistance (b) with varying spacing to check for isolation between traces