# Fabrication of Memristive Network Devices on Nanomembranes

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Wearable electronic devices on flexible substrates with various functionalities have been wildly applied in mobile monitoring and healthcare applications. The working principles of most current wearable sensing devices are based on the resistance modulation of the printed metallic channels.[1,2] To integrate more sophisticated functions in such devices, researchers have been demanding new methods to produce semiconductor structures, especially 2D semiconductor patterns on flexible substrate.[3-5] However, synthesis and patterning of 2D semiconductor device patterns on flexible polymeric substrates remain challenging, because the conventional fabrication routes based on resist-based lithography and plasma etching processes are not compatible with most polymeric substrates. In addition, current standard device cleaning methods (e.g., piranha and RCA processes) can seriously damage the electrical and mechanical properties of the devices and degrade the device-to-device consistency. Recently, we demonstrated a multiplexing rubbing-induced site-selective (RISS) method capable of generating pre-defined 2D material patterns on $SiO_2$ surfaces with no need of additional lithography or etching processes.[6] In the last EIPBN presentation, we further presented the RISS-produced $Bi_2Se_3$ memristive sensory devices, implying the potential application of such devices in the fields related to neuromorphic controlling and computing.[7] To integrate such RISS-produced devices on flexible polymeric substrates, additional fabrication-oriented research effort is demanded.

In this paper, we report our recent progress in leveraging the multiplexing RISS technology to realize site-selective production of 2D semiconductor features on inorganic nanomembranes which can be subsequently transferred to polymeric substrates, remaining a good flexibility. The demonstrated $Bi_2Se_3$ device channel arrays show a high crystallinity, and the fabrication process is highly repeatable. We further report the memrsitive switching characteristics of such RISS-produced $Bi_2Se_3$ memristors, which paves the way for producing memristive sensory networks on flexible substrates.

Our current multiplexing RISS process includes two main steps: (i) controllable rubbing of a $SiO_2$ nanomembrane (thickness 20 – 500 nm) with a template bearing pillar arrays to pre-define the locations and shapes of target $Bi_2Se_3$ device patterns (i.e., triboelectric charge patterns); (ii) site-selective chemical or physical deposition of few-layered semiconductor patterns (e.g., $Bi_2Se_3$ and $MoS_2$) at the designated locations. **Fig.1(a-d)** shows the schematic illustration of the rubbing process and the growth of $Bi_2Se_3$ patterns, and **Figs. 1 (e)** displays the photo of our lab-built system for performing multiplexing RISS processes. **Fig.2 (a)** shows the optical micrograph of RISS-produced $Bi_2Se_3$ memristive channel networks on 25nm thick $SiO_2$ nanomembranes, and **(b)** shows the high-resolution TEM image of a $Bi_2Se_3$ channel on a $SiO_2$ nanomembrane.

This work presents a novel nanomanufacturing method for fabricating $Bi_2Se_3$ memristive networks on nanomembranes, which could be further transferred onto flexible polymeric substrates. Additional details of the presented fabrication method as well as device demonstrations will be presented in the formal presentation.

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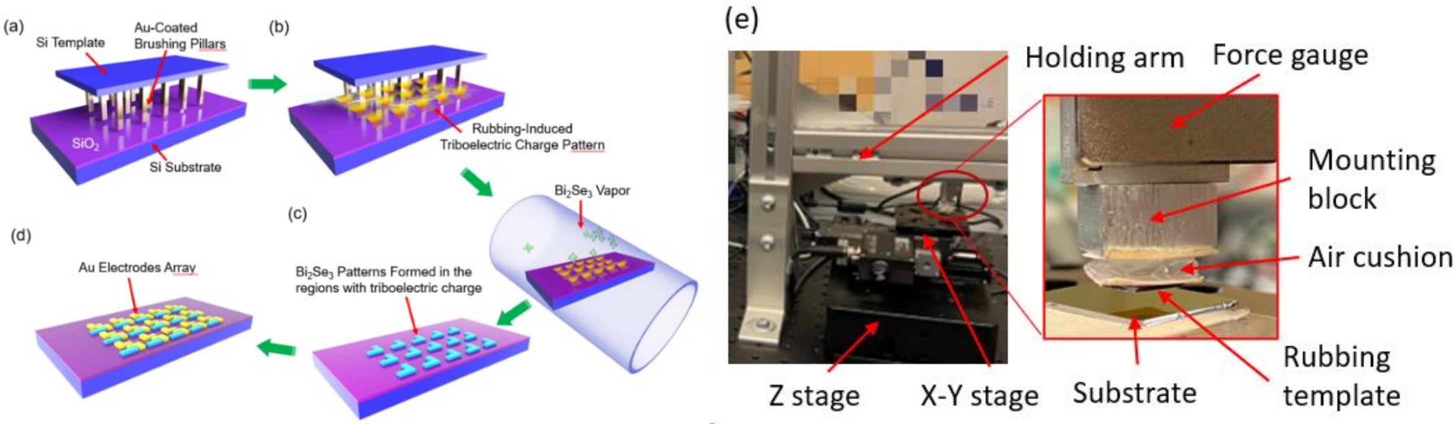


Fig.1 Illustration of the multiplexing RISS process for making Bi2Se3 memristor arrays: (a) a Si template bearing Au-coated pillars brushing on a $SiO_2$/Si substrate; (b) generation of triboelectric charge patterns through a stage-controlled rubbing process; (c) site-selective deposition of $Bi_2Se_3$ arrays in the rubbed areas on the $SiO_2$/Si substrates; (d) fabrication of the electrodes of the $Bi_2Se_3$ memristors; (e) photo of the lab-built system for performing multiplexing RISS processes.

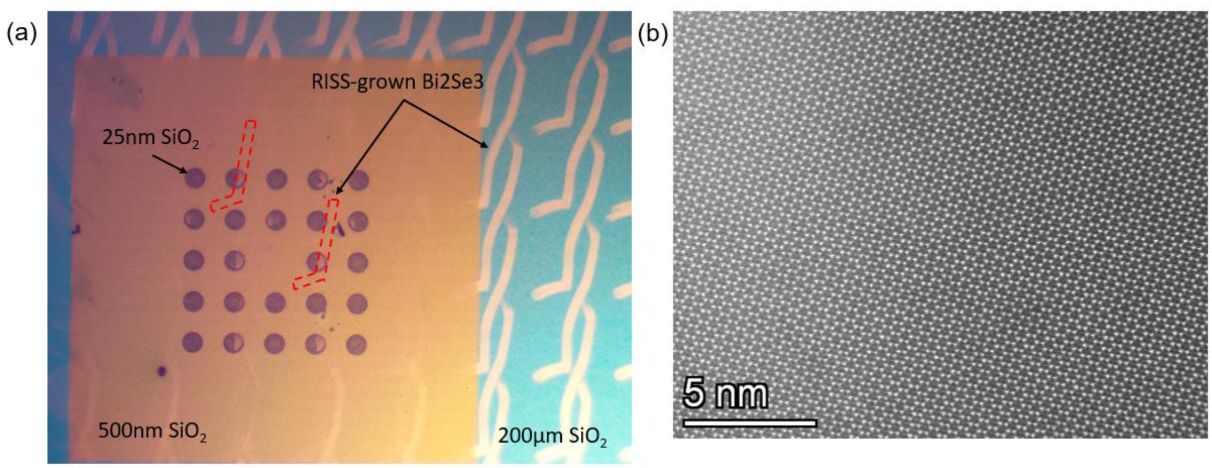


Fig.2 (a) Optical micrograph of a representative array of RISS-produced $Bi_2Se_3$ memristive channel on 25nm thick $SiO_2$ nanomembrane, 500nm thick $SiO_2$ nanomembrane and 200µm thick $SiO_2$ substrate; (b) high-resolution TEM image of $Bi_2Se_3$ thin film on $SiO_2$ nanomembrane.

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