Stretchable and conductive substrate with undulating surface by imprint lithography for Flexible Electronics

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Stretchable and conductive substrates are highly desirable for applications in flexible electronics, soft-robotics and other engineering fields for its ability to preserve its integrity and performance under considerable strain. People have tried two paths to achieve this goal. The first method is by developing intrinsically stretchable materials, such as elastomers and elastomeric composites of conductive polymers. The second approach is by geometrical engineering of conductive surface[1, 2]. There are several key parameters when evaluating the quality of a stretchable substrate: stretchability, process easiness, and conductivity perseverance under strain. In this study, we provide a simple method to fabricate multidirectional stretchable, translucent, and conductive substrate.

The process is described in Fig.1. To start with, imprint molds featuring hexagonal cylinders with different diameters and spacing are fabricated by photolithography and dry etching. Then the patterns are further transferred to a PMMA film by nanoimprint lithography. In order to release the residual stress around the edges and corners of the holes of the PMMA structures, the film is heated at elevated temperature for a certain amount of time. At temperatures above the glass transition point of the polymer, the polymer will reflow to smooth out sharp edges and corners. After the heat treatment, the substrate is used as a temple to pattern PDMS film by replication. The PDMS film can be applied either by casting or spin coating.

There are two routes to make the PDMS film conductive. One is to deposit thin metal film and the other one is to spray coat silver nanowires (Ag Nws) on the substrate. The PDMS substrate which is free of sharp edges and corners is designed to better accommodate Ag Nws for form a conductive surface through interconnected mesh network. When stretching the product, the PDMS bumps act like buffer to the strain thus showing great stretchability whilst preserving its conductivity.

Figure 2 show SEM images of the patterned PMMA structures annealed at 100ºC for various amount of time. It illustrates the geometrical change of the PMMA microstructures upon heat treatment. The sharp corners and edges change into round corners and edges. Figure 3 shows the successful pattern transfer from PMMA template to PDMS and the preliminary results of spreading Ag Nws onto the PDMS undulating surface. Further experiments will optimize the undulating surface pattern on PDMS and the deposition of Ag Nws to form dense mesh network. The strechability and the conductivity under different strains will be reported.

[1] H.B. Lee, C.W. Bae, L.T. Duy, I.Y. Sohn, D.I. Kim, Y. J. Song, Y.J. Kim, and N.E. Lee, Advanced Materials, 28, 3069-3077, 2016.
[2] C.H. Wu, J.T. Jiu, T Araki, H Koga, T Sekitani, H Wang and K Suganuma, Nanotechnology, 28, 01LT01, 2017.

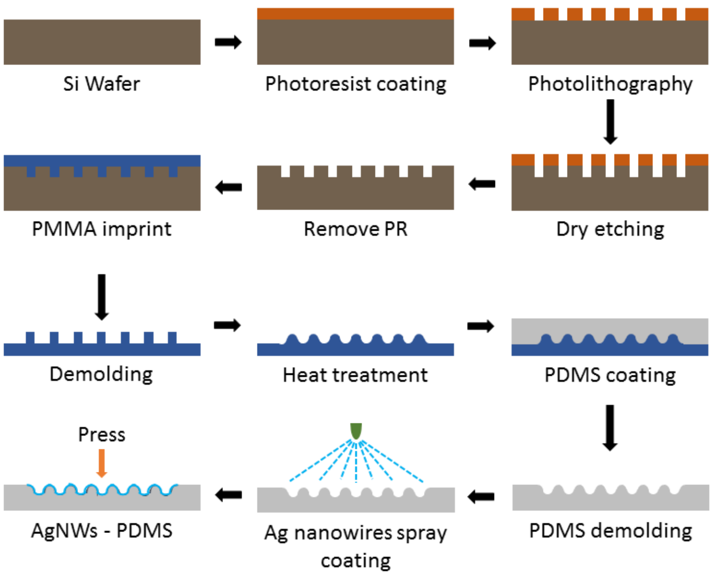

Fig. 1 The fabrication scheme for stretchable and conductive substrate.

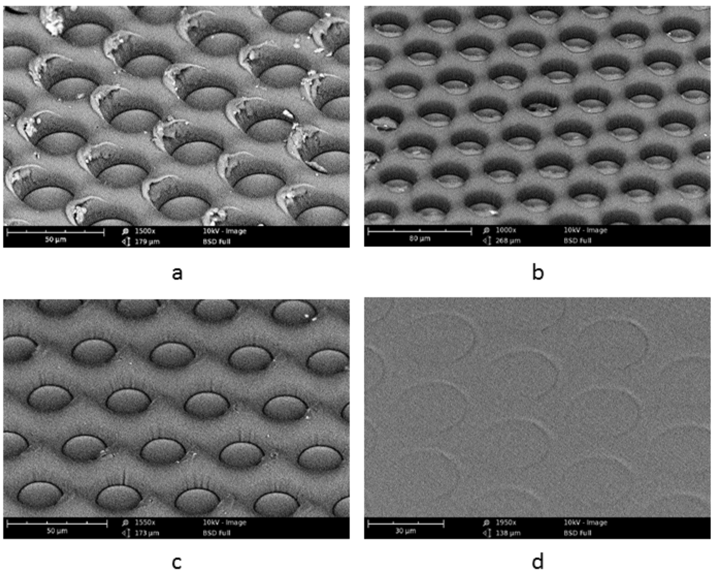

Fig. 2 SEM images showing geometrical changes of PMMA microstructures upon heat treatment. (a) no treatment; (b) 3 minutes heating at 100C°; (c) 6 minutes heating at 100C°; (d) 20 minutes heating at 100C°.

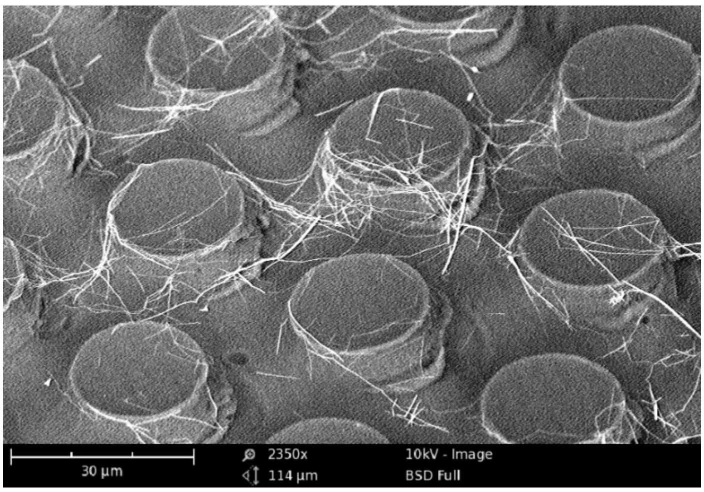

Fig. 3 SEM image showing successful pattern transfer from PMMA to PDMS and Ag Nws deposited onto the undulating PDMS surface by spin coating.