Nanopatterning of "Disconnected" Metal Nanostructures on Polydimethylsiloxane (PDMS) Substrate by Using Free-Standing Photoresist Film as Stencil Lithography Mask

Ke Du, Yuyang Liu, Ishan Wathuthanthri, Wei Xu, Chang-Hwan Choi
Stevens Institute of Technology, Hoboken, NJ 07030, USA
cchoi@stevens.edu

Flexible and transparent electronics, photonics, and microfluidics devices have drawn great interests in recent years. Among the elastomeric substrate materials for such applications, Polydimethylsiloxane (PDMS) has been widely used due to the good transparency, flexibility and bio-compatibility. However, because of the different coefficients of thermal expansion (CTE) between PDMS and photoresist (PR), it is difficult to pattern photoresist film directly on PDMS for the development of functional nanostructures, e.g., "disconnected" metal nanostructures for nanoelectronic and -photonic applications. Alternative techniques have been available, including lift-off with Poly acrylic acid (PAA)[1] and pattern transfer[2]. However, it is challenging to fabricate high-aspect-ratio nanostructures by using such pattern transfer techniques, where high-aspect nanostructures are prone to collapse during the transfer. In this paper, we report a new technique which can pattern metal nanostructures directly on PDMS substrate, capable of creating high-aspect-ratio nanostructures, by using free-standing photoresist film as a stencil lithography mask.[3]

Fig. 1 shows the schematic of fabrication process. First, anti-reflective coating (ARC) and PR were spun on a silicon wafer and patterned by laser interference lithography capable of large-area nanopatterning.[4,5] After the exposure and development of the PR film, the ARC layer was etched through the PR film by using reactive ion etching (RIE) with oxygen plasma. Then the PR/ARC bi-layer was released from the silicon substrate by using a mixture of H_2O_2/NaOH and DI water. The concentrations of each chemical were characterized to ensure that the bi-layer could be lifted without fracture. The bi-layer membrane was then put on a PDMS substrate (Fig. 2), followed by the deposition of metal through the nanoporous bi-layer membrane. When the bi-layer was removed by using the mixed solution of H_2O_2/NaOH and DI water, well-ordered "disconnected" metal nanostructures were fabricated. By using this technique, we were able to fabricate large-area (wafer-level) metal nanostructures on PDMS with controllable feature size, period, and aspect ratio (Fig. 3). The introduced nanopatterning technique will be of great benefit in fabricating flexible nano-electronics/photonics devices such as plasmonic nanostructures.

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[3] Y. Liu *et al*., in *Proc. MEMS 2012*, Jan. 29-Feb. 2, 2012, Paris, France.
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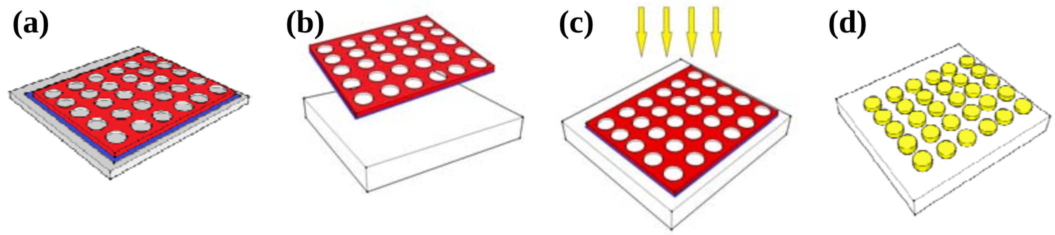

Figure 1: Schematic of pattern transfer of metal nanostructures on PDMS substrate by using free-standing PR membrane as stencil lithography mask. (a) Nanopatterning of PR film via laser interference lithography. (b) Release of the nanopatterned PR membrane from a template substrate (Si). (c) Alignment of the free-standing PR membrane onto PDMS substrate, followed by the deposition of metal (e.g., gold). (d) Removal of the PR stencil, resulting in the nanopatterning of "disconnected" metal nanostructures on PDMS.

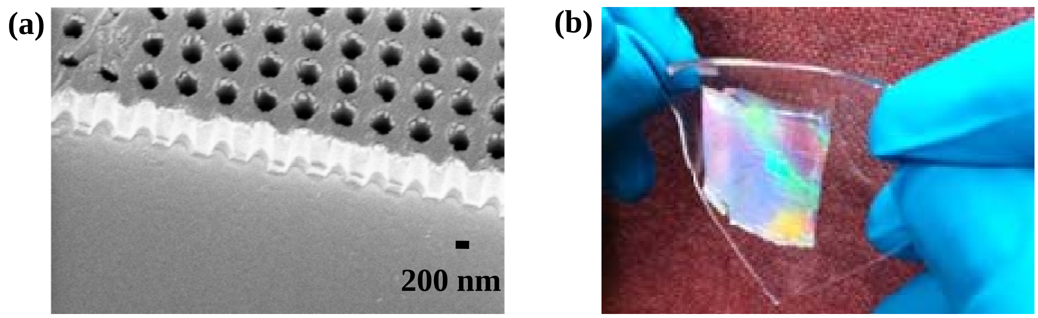

Figure 2: (a) SEM image of the free-standing PR membrane transferred onto PDMS substrate. (b) Optical micrograph of (a).

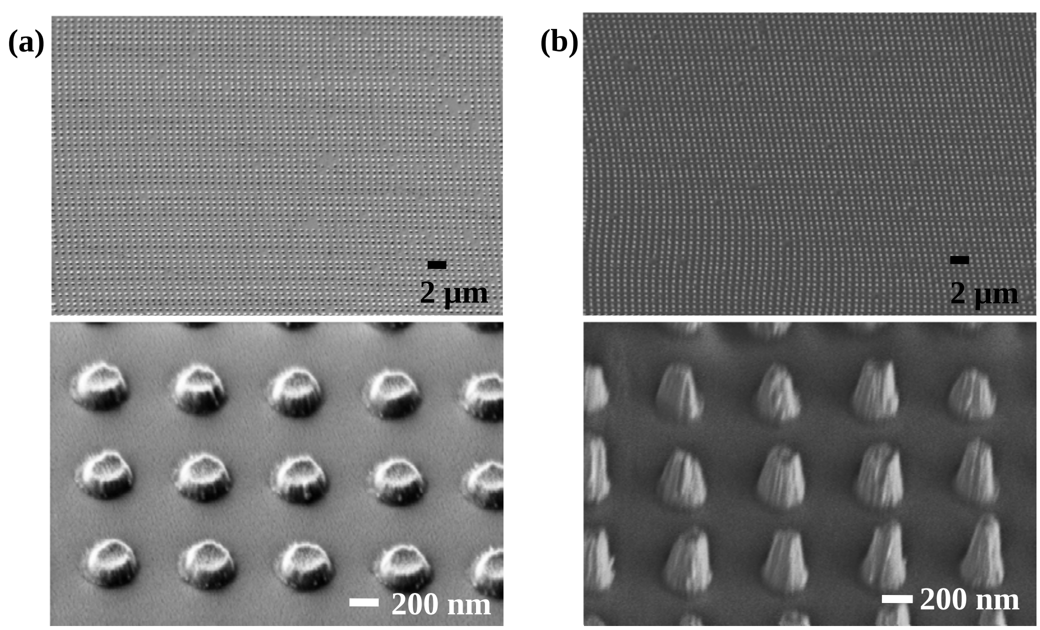

Figure 3: (a-b) Low (1:1) and high (3:1) aspect ratio gold nanostructures patterned on PDMS substrate, respectively.