Metallic Nanostructures on Arbitrary Surfaces Fabricated by Solution-processed Nanopatterning and Nanotransfer Printing

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Nanofabrication has been essential to both academic research and industry manufacturing nowadays. Many unique applications have been developed based on nanofabrication, for example, plasmonic devices, metamaterials, surface enhanced spectroscopy, nano-optics, transistors and photovoltaics, to name a few.[1-3] Structures in nanometer scale regime show unique physical properties like enhanced mechanical strength comparing to bulk materials. With the shrinkage of structures, the manufacturing efficiency and power saving of very-large-scale integration (VLSI) chips could be significantly enhanced. However, conventional nanolithographic methods like e-beam lithography and deep-UV lithography are bulky and costly. The vacuum-based evaporation techniques make the fabrication process even more expensive and time-consuming. In this research, we have developed a versatile nanopatterning technique to overcome these limitations through a fully solution-processed strategy by combing the strengths of nanoimprint lithography (NIL), electrodeposition and nanotransfer printing. A nanopatterned electrodeposition mask is replicated from a flexible template by NIL, various metals could be uniformly deposited through the mask. The metallic nanopattern could be easily stripped by an adhesive poly(vinyl alcohol) (PVA) film and transferred to the target substrate. The PVA film is ultra-thin thus could form a conformal contact with diverse substrates by electrostatic force. Thereafter, PVA is simply dissolved in water, leaving the metallic nanostructures firmly transferred with high fidelity.

Figure 1 schematically demonstrate the fabrication of a nanodisk array through this method. A nanohole array pattern is first created in the imprint resist on a conductive ITO glass substrate by NIL using a flexible stamp. Next, the imprinted resist is used as an electrodeposition mask for deposition of gold through the holes. After removal of the resist, a thin layer of PVA (~3 μm) is spin-coated on the substrate and stripped as the intermediate transferring film. The PVA film is then attached to the target substrate and heated above the glass transition temperature of PVA (120 °C) to further enhance the adhesion. Finally, after immersing in water for 30 min to dissolve PVA, the gold nanodisk array is transferred and firmly attached to the substrate. **Figure 2a-b** shows a 500-nm-pitch gold nanodisk array patterned on a silicon substrate and a glass substrate through the proposed method, respectively. Besides from rigid planar substrates, nanodisk could be transferred to flexible, stretchable and non-planar substrates. **Figure 2c-e** shows 500-nm-pitch gold nanodisk arrays successfully fabricated on polyimide, polydimethylsiloxane and surface of a glass reagent bottle.

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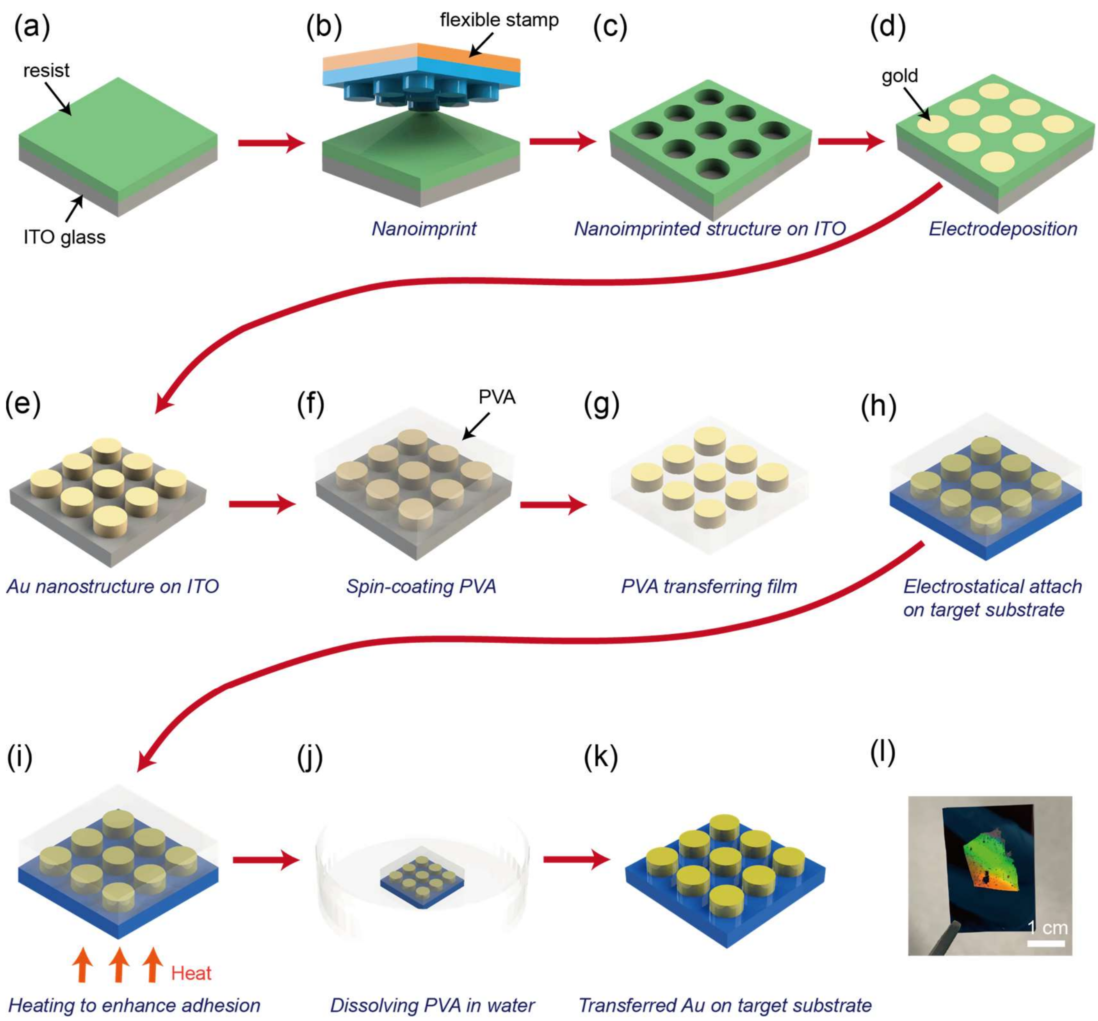

Figure 1. Schematic illustration of the solution-processed nanofabrication process.

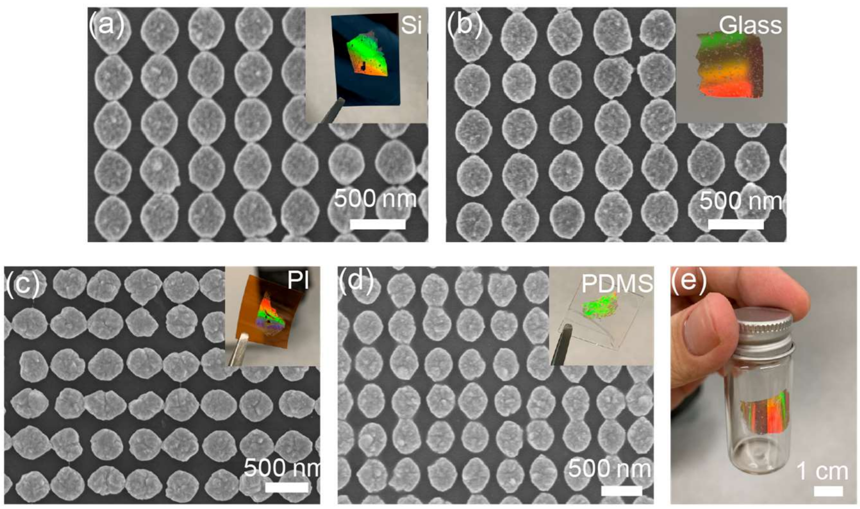

Figure 2. SEM micrographs of 500-nm-pitch gold nanodisk arrays patterned on (a) silicon substrate, (b) glass substrate, (c) polyimide film and (d) polydimethylsiloxane film by nanotransfer printing. (e) Photograph of a large-area 500-nm-pitch gold nanodisk array patterned on the surface of a glass reagent bottle.