Fabrication of Nano-Bowl Arrays via Simple Holographic Patterning and Lift-Off Process

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Recently, periodic nano-bowl structures have attracted great interest due to their potential applications in nanoparticles [1], biomedical and nanofluidic devices [2], magnetic nanomaterials [3], plasmonic devices [4], and electrocatalysis [5]. Nano-sphere lithography is the most commonly used method to fabricate such nano-arrays with well-controlled pattern periodicity and shapes [6]. It uses the self-assembled monolayer of spherical polystyrene nanoparticles as a template layer to form nano-bowl structures. Although the nano-sphere lithography is a cost-effective approach, it is still challenging to obtain the uniform patterns over a large surface area with well-regulated pattern periodicity. It also requires complicated fabrication steps including assembly, etching, and milling processes [2]. In this work, we report a new and simpler way to fabricate uniform nano-bowl arrays with well-controlled pattern periodicity and shapes over a large substrate area (e.g., on a full wafer scale), based on holographic nanopatterning.

Figure 1 shows the fabrication procedure and the resultant structures of the nano-bowl arrays of gold. The uniform nano-bowl arrays with a large coverage area are achieved by directly depositing gold onto the nano-hole resist patterns defined by holographic lithography, followed by removing the resist template with a lift-off process. In this study, the well-defined periodic nano-hole patterns are first prepared on a silicon substrate by laser interference lithography [7] (Figs. 1a-b). Then, gold is deposited onto the nano-hole template through e-beam deposition (Fig. 1c). After the gold layer fully covers the bottom of the nano-hole, the resist layer including the top gold film is removed by using lift-off process (Fig. 1d). Then, it results in the uniform gold nano-bowl arrays on the silicon surface (Fig. 1e). The depth of the nano-bowl structures can conveniently be controlled by modulating the deposition thickness. While Fig. 1e shows the fabricated nano-bowl arrays of ~100 nm in depth, Figs. 1f-h show the nano-bowl arrays of the increased depth of ~250 nm. Compared to a nano-sphere lithography method, the fabrication process demonstrated in this work has advantages to provide a simpler route to realize uniform nano-bowl arrays over a large area with precise control of the structural morphology, which will be of great significance in many applications described above.

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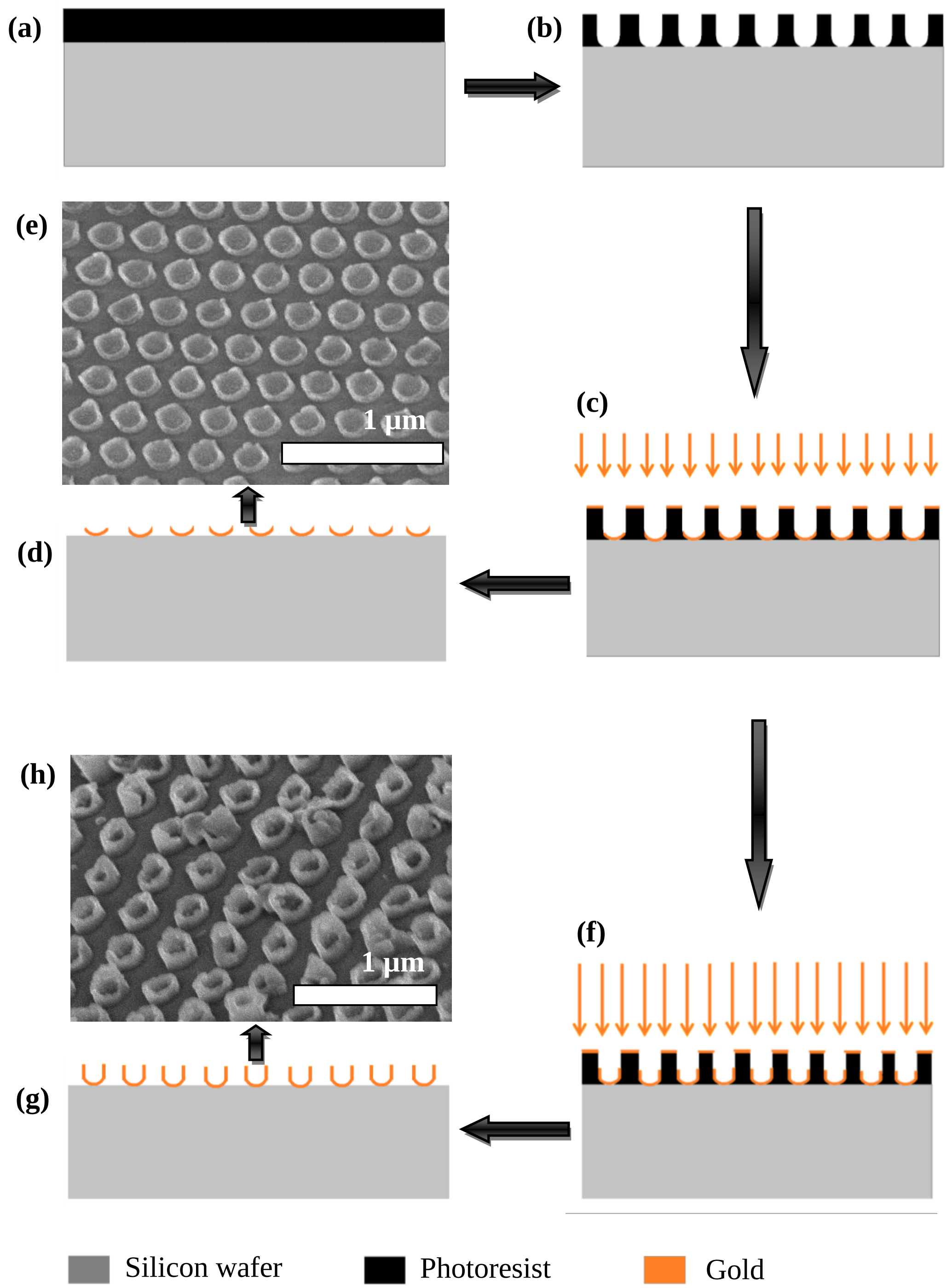

Figure 1: Fabrication of gold nano-bowl arrays. (a) Spin-coating of a photoresist layer on a silicon substrate. (b) Nano-hole pattern created by laser interference lithography. (c, f) E-beam deposition of gold layers of varying thicknesses (c: ~50 nm, f: ~100 nm). (d, g) Lift-off process. (e, h) Fabricated nano-bowl structures of varying depths (e: ~100 nm, h: ~250 nm).