LARGE-AREA PATTERN TRANSFER OF METAL NANOSTRUCTURES VIA INTERFERENCE LITHOGRAPHY

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This paper reports a simple nanofabrication technique which can transfer metallic nanostructures deposited on photoresist (PR) pre-patterns to a transparent glass substrate. By using the PR template patterned by interference lithography, it is demonstrated that periodic metallic nanostructures can be efficiently transferred to uniformly cover a large surface area up to several inch^2 with very few cracks.

In recent years, the "direct metal transfer" method has drawn great interests because of the easiness in fabrication process and high throughput. Furthermore, the costs of the metal transfer method is much lower than the traditional metal patterning techniques such as focused ion beam (FIB) milling, reactive ion etching (RIE), or inductively coupled plasma (ICP) etching. However, most metal transfer techniques require a mold (e.g. PDMS, Si, or SiO_2) to transfer metal films to other substrates [1], which increases difficulties in fabrication process. Electrodepositing of metals directly on PR patterns does not require such a mold. However, in electrodeposition processes, film thickness and surface roughness are difficult to control.

In a new method that we have developed for this study, we used PR nano-patterns, defined by laser interference lithography, as a large-area template to transfer a variety of metal nano-patterns on a glass substrate (Fig. 1). By using an advanced "tunable" Lloyd mirror system, various nano-periodic PR patterns (200 nm – 1 μm in pitch) could be created uniformly up to 3" Si substrates (Fig. 2). An anti-reflective coating (ARC) was used an intermediate layer to eliminate the standing wave issues, enabling to create high-aspect-ratio PR nanostructures with well-defined sidewall profile. E-beam evaporation was used to deposit metals directly on the PR patterns with thickness ranging from 400 to 700 nm. By controlling the deposition rate, the surface roughness of the deposited metal layer could be maintained below 10 nm. The metal film was bonded with a glass substrate by using epoxy. Then the sample was immersed in acetone for hours to facilitate the separation. Afterward, the glass substrate could be conveniently peeled off from the template substrate by hands without significant fracture or cracks in the transferred metal film on the glass.

By using the method, we successfully fabricated large-area metallic nano-patterns of various materials (Ti, Al, and Au) in systematically controlled shapes (holes, lines, and pillars) (Figs. 3 and 4). By modulating the exposure dosages in the laser interference lithography, metallic nanostructures with sinusoidal line or ellipsoidal pillar patterns (Fig. 4) could also be realized for the study of light scattering properties [2]. The transferred metal film can be kept for months without observing significant cracks or delamination. The robust large-area periodic metallic nanostructures fabricated on a transparent glass substrate can further promote scientific and engineering applications such as plasmonic applications.

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[1] W.Lee et.al., Small **2,** 978 (2006).
[2] S.W.Lee et.al., Nanoletters **10,** 296 (2010).

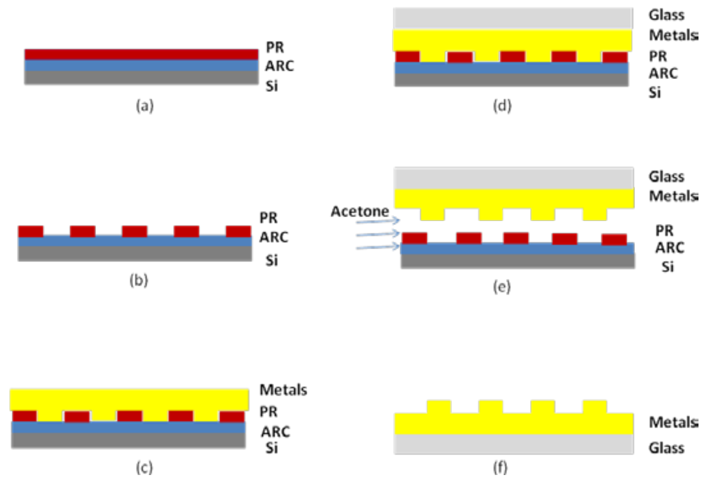

Figure 1: The overall fabrication process. (a) Dual layer of anti-reflection coating (ARC) and photoresisit (PR) on a Si substrate. (b) Laser interference lithography. (c) Deposition of metal. (d) Glass bonding. (e) Delamination by immersion in acetone. (f) Transferred metal nanostructures.

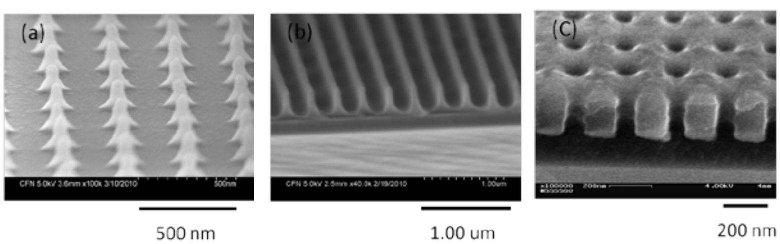

Figure 2: PR nano-patterns created by the laser interference lithography (a: pillar pattern, b: line pattern, c: hole pattern). The periodicity of each pattern is 325 nm and the height is 200-300 nm.

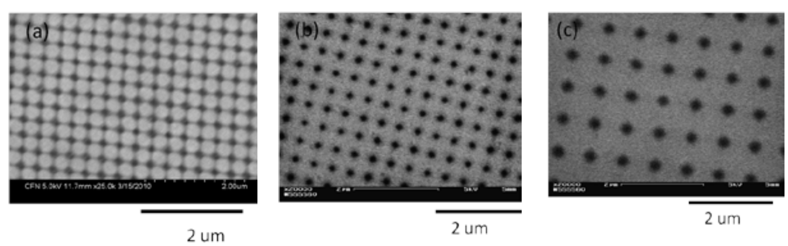

Figure 3: Aluminum nano-hole patterns of varying pattern periodicities (a: 325 nm, b: 475 nm, c: 935 nm), transferred on a glass substrate by using a pillar PR pattern as a template.

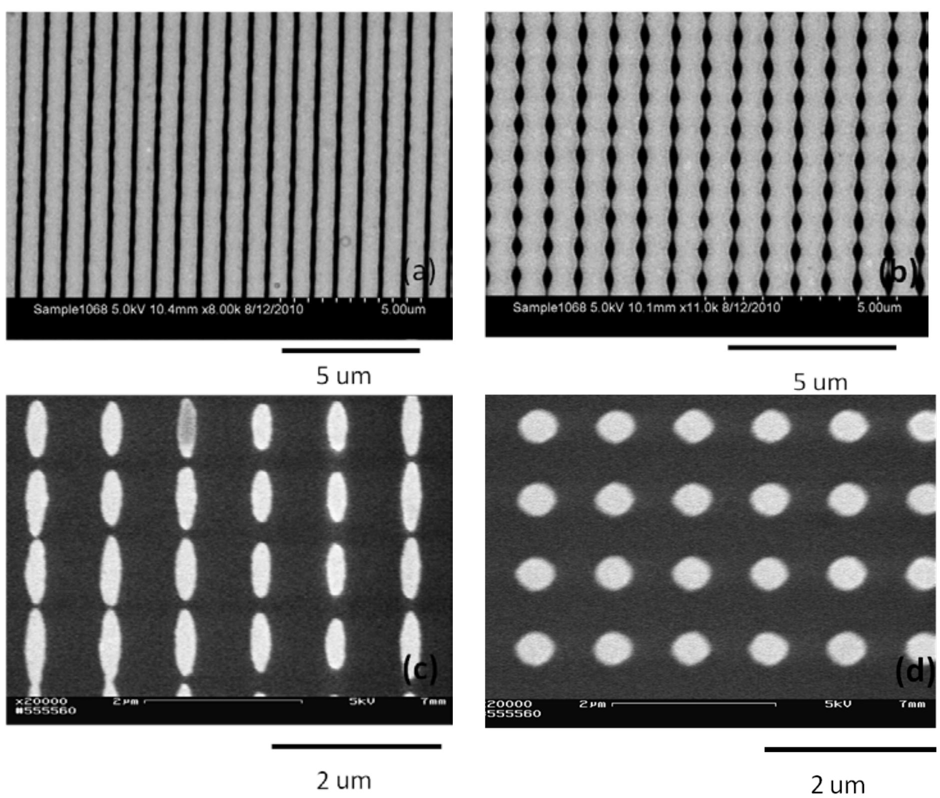

Figure 4: Gold nanostructures of varying shapes. (a) Straight line patterns. (b) Snake-like sinusoidal patterns. (c) Ellipsoidal patterns. (d) Dot patterns. All patterns have the pitch of 935 nm. Patterns (b-d) were created by modulating the second exposure time in the interference lithography.