Low-cost fabrication of large area periodic nanopatterns with tunable feature sizes using soft UV-Nanoimprint at ambient atmosphere

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Fabricating large area nanostructured substrate is in general costly, especially for large area and small feature sizes. A processing chain with a simple shrinking technique using a serial of well-known technologies to fabricate periodic nanopatterns with tunable feature sizes is designed and realized. The process generates multiple nanostructured substrate from a single master at very low-cost and in a short processing cycle.

The soft UV-Nanoimprint (NIL) using a center-to-edge scheme in ambient atmosphere is employed for large area nanopatterning (Fig.1). Imprinting in ambient atmosphere is the most appropriate condition for soft UV-NIL excluding sophisticating tools as long as alignment is not necessary. The ambient atmosphere brings additional challenges, such as the evaporated solvent in the resist and possible by-products resulting from the interaction between the UV light, oxygen and the polymer-based material. In this work, performance of up to twenty consecutive imprints at 100 mm size using a PDMS/toluene-diluted PDMS bi-layer soft stamp is demonstrated. It proves the reusability and uniformity of large area imprinting at the ambient atmosphere [1].

A master wafer featuring periodic nanopatterns fabricated by electron beam lithography (EBL) serves to initialize the reproduction of new substrates with tunable feature sizes. Soft UV-NIL combined with etch process, are employed to fabricate an intermediate template that is further used for an imprint on the final substrate. The feature size of the SiO_2 etch mask on the final substrate can be tuned simply by varying the duration of mask etching. The final patterning of the template can be realized depending on the applications. For instance, NIL templates with smooth and vertical sidewalls can be etched by cryogenic etching based on SF_6/O_2 chemistry, which can also contribute to fabricate nanoneedles and such. BOSCH process can be performed in the case that scallops are necessary for further processing. Besides, the metal-assisted chemical etching (MaCE) can be followed as well to generate high aspect ratio and porous surface of silicon (Fig.2).

As a result, periodic nanopillar patterns with diameters of 150/200/250 nm, respectively, have been fabricated in silicon on wafer level from a single master with 450 nm feature size [2]. 150 nm high aspect ratio nanoneedles are realized using the same master as well. Wafers featuring square holes with 130/160/190/220 nm feature sizes are also fabricated from a master containing circular holes with a diameter of 350 nm (Fig.3).

Reference:

[1] S. Si, and M. Hoffmann, "Consecutive imprinting performance of large area UV nanoimprint lithography using Bi-layer soft stamps in ambient atmosphere", *Microelectronic Engineering,* 176, 62-70 (2017)

[2] S. Si, L. Dittrich, and M. Hoffmann, "Low-cost fabrication of nanoimprint templates with tunable feature sizes at a constant pitch", *Microelectronic Engineering,* 170, 34-38 (2017)

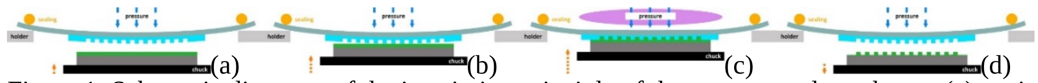

Figure 1: Schematic diagrams of the imprinting principle of the center-to-edge scheme: (a) positioning; (b) contacting; (c) imprinting and UV expo-sure; (d) detaching

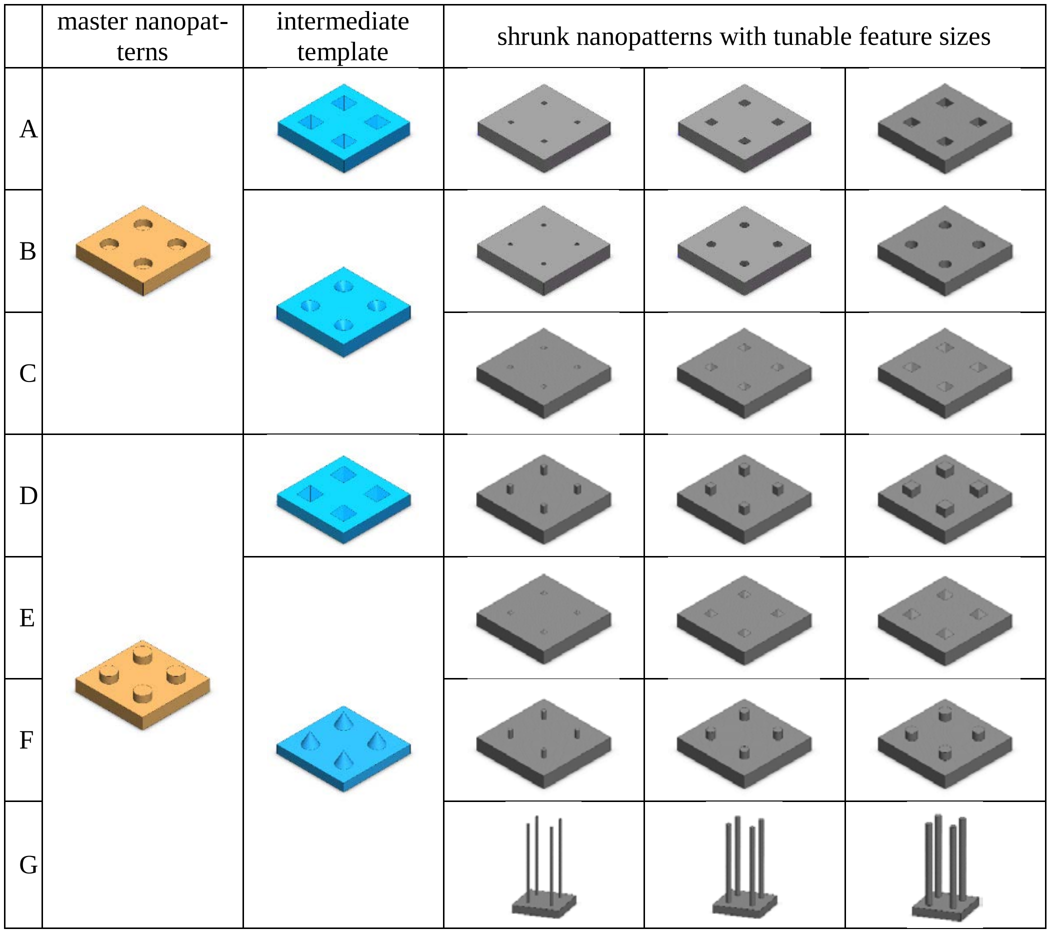

Figure 2: Perspectives of new nanopatterns fabrication using the shrinkage methodology

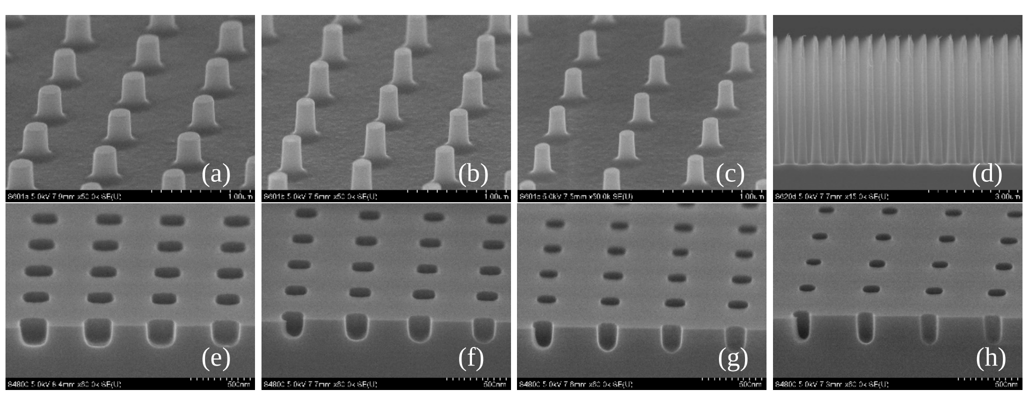

Figure 3: SEM images of the titled views of the fabricated nanopillar patterns with feature sizes of 250 nm (a), 200 nm (b), and 150 nm (c); nanoneedles with feature size of 150 nm and length of 4.5 um (d); nanocavity patterns with feature sizes of 130 nm (e), 160 nm (f), 190 nm (g) and 220 nm (h)