From Nanocone to Nanodisk: Structural Transformation of Nanoarrays via Mechanical Stresses

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The optical properties of nanostructures are highly dependent on their size, shape, and alignment on a surface.[1] Among the variations, those with controlled geometric anisotropy are particularly interesting because the decreased symmetry allows one to tune their optical and electrical properties to a great extent.[2] To date, there have been many attempts for the fabrication of various types of nanostructures with controllable geometry including spherical, rod-like, cubic, disk, and planar.[3] However, only a few methods have been useful for the design and fabrication of nanostructures with good control over their sizes and heterogeneities. Moreover, in most methods, once the nanoarrays are prepared, it is almost impossible to change their shape and alignment with simple post-processes. Such inadequacy has limited the broader scientific and engineering applications of nanostructures. Here, we demonstrate a novel post-process to tune the shapes as well as the alignments of nanoarrays, using simple mechanical pressing with controlled directionality and compressibility (Fig. 1).

Large-area (wafer-level) periodic nanocone arrays were first fabricated by e-beam deposition through nanoporous photoresist (PR) template films defined by laser interference lithography.[4] Then, structural transformation was achieved via mechanical pressing, including tangential shearing (Fig. 1a) and normal compression (Fig. 1b). Fig. 2 shows the structural transformation of gold nanocone arrays via the horizontal shearing with a gradual increase of the force by rolling a glass cylinder over the surface. The results show that the shape and alignment of the gold nanocone arrays are tunable by the process from the vertically aligned nanocones (Fig. 2a) to bending (Fig. 2b) to lying (Fig. 2c) and finally to oblate nanodisks (Fig. 2d). Fig. 3 shows the structural transformation made by the vertical compression with a flat plate (polished Si wafer). The results show that the shape and alignment of gold nanocone arrays are also configurable with the control of normal pressure, from the vertical nanocones (Fig. 3a) to vertical nanocylinders (Fig. 3b), and finally to oblate nanodisks (Fig. 3c).

This works demonstrate that a simple mechanical pressing procedure can transform the shape and alignment of nanoarrays effectively. By controlling the intensity and direction of the mechanical stresses, nanoarrays with anisotropic shapes and alignment can be realized conveniently. Such nanoarrays of well-controlled nanotopography via simple fabrication step will allow broader and new application possibilities, e.g., to optical and photonic devices.

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[1] S. Hong *et al*., *Chem. Mater.* **23**, 2011 (2011).
[2] S. Kim *et al*., *Nano Lett.* **8**, 800 (2008).
[3] R. Luttge, *J. Phys. D: Appl. Phys.* **42**, 123001 (2009).
[4] W. Mao, I. Wathuthanthri, and C.-H. Choi, *Optics Lett.* **36**, 3176 (2011).

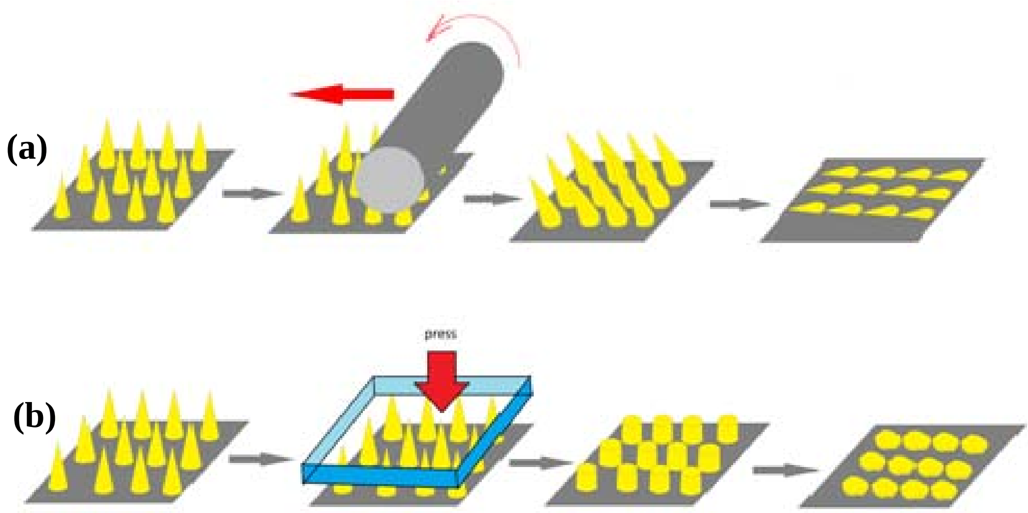

Figure 1: Schematics of structural transformation of gold nanoarrays through mechanical pressing. (a) Horizontal pressing by shear rolling. (b) Vertical pressing by normal compression.

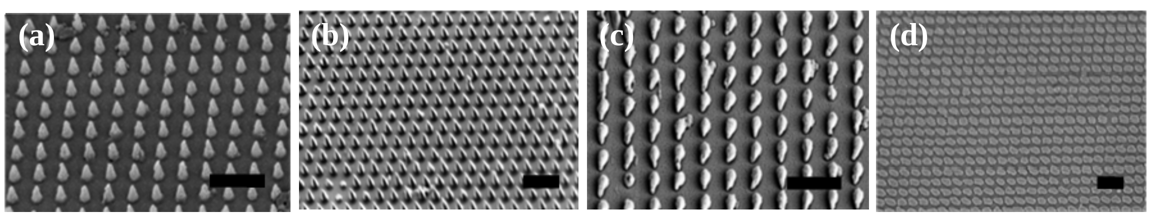

Figure 2: Fabrication results of structural transformation of gold nanocones by horizontal pressing (scale bar=1µm for all images).With a gradual increase of the shear force, the initial vertical nanocone array (a) was transformed to bending nanocone (b), lying nanocone (c), and oblate nanodisk (d).

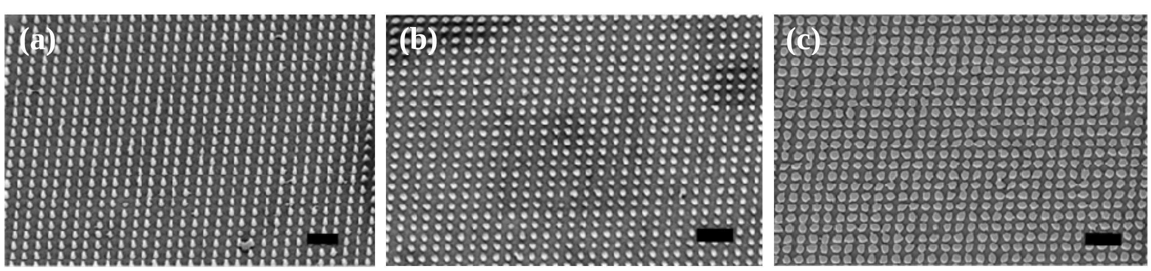

Figure 3: Fabrication results of structural transformation of gold nanocones by vertical pressing (scale bar=1µm for all images).With a gradual increase of the pressing force, the initial vertical nanocone array (a) was transformed to nano-cylinder (b) and oblate nanodisk (c).