Periodic tilted Au structure fabrication by electron beam exposure

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Tilted micro- and nano-structures have various applications. For example, tilted pillars in soft materials is important for the study of artificial surface mimicking gecko feet for dry adhesive pads application[1,2]. Slantingly-aligned (tilted) nano-wire can also be introduced into photovoltaic device to improve the contact between electrodes[3]. Micro-scale tilted structures can be fabricated by photolithography with the substrate tilted. Nano-scale tilted structures have been fabricated by reactive ion etching with tilted substrate. However, modification of the etching system is needed as otherwise the spontaneously generated self-bias field in the plasma (that determines the etching direction) would remain normal to the substrate surface.

In this work we will show that 2D periodic array of tilted nanostructure can be conveniently fabricated using SEM exposure of an electron beam resist during normal imaging, without the need of pattern generator or beam blanker. Actually, it would be difficult for the regular electron beam lithography (EBL) system for this purpose because the focus cannot be maintained within the entire write field when the substrate is tilted at large angle. We made use of the dynamic focus function that is available to typical SEM systems, where the working distance is adjusted continuously during the scanning of a tilted sample in order to maintain focus across the entire imaging field that can be several millimeters. The number of tilted structures thus fabricated within one viewing field depends on the image resolution (such as 1024×768), and the array period is determined by the image resolution and magnification (and tilt angle for the period along y-direction).

To demonstrate the concept, we carried out EBL using ZEP-520A positive resist with the substrate mounted on a 45^{o} sample holder. Exposure was carried out at 20 kV acceleration voltage, and pixel average was chosen for noise reduction with a frame scanning time of 0.1-1.0 min. Figure 1 shows the hole array after development, which indicates the hole size is pretty uniform across the pattern area of ~1 mm^2. To fabricate the tiled nano-pillars, as well as to reveal the profile of the hole, we carried out Au electroplating into the hole array and subsequently removed the ZEP resist using anisole. The 45 degree tilted Au pillar array with height of ~750 nm is shown in Figure 2.

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[2] T. I. Kim, H. E. Jeong, K. Y. Suh and H. H. Lee, Adv. Mater., 21, 2276. (2009).
[3] H. Fang, X. Li, S. Song, Y. Xu and J. Zhu, Nanotechnology, 19 255703, (2008).

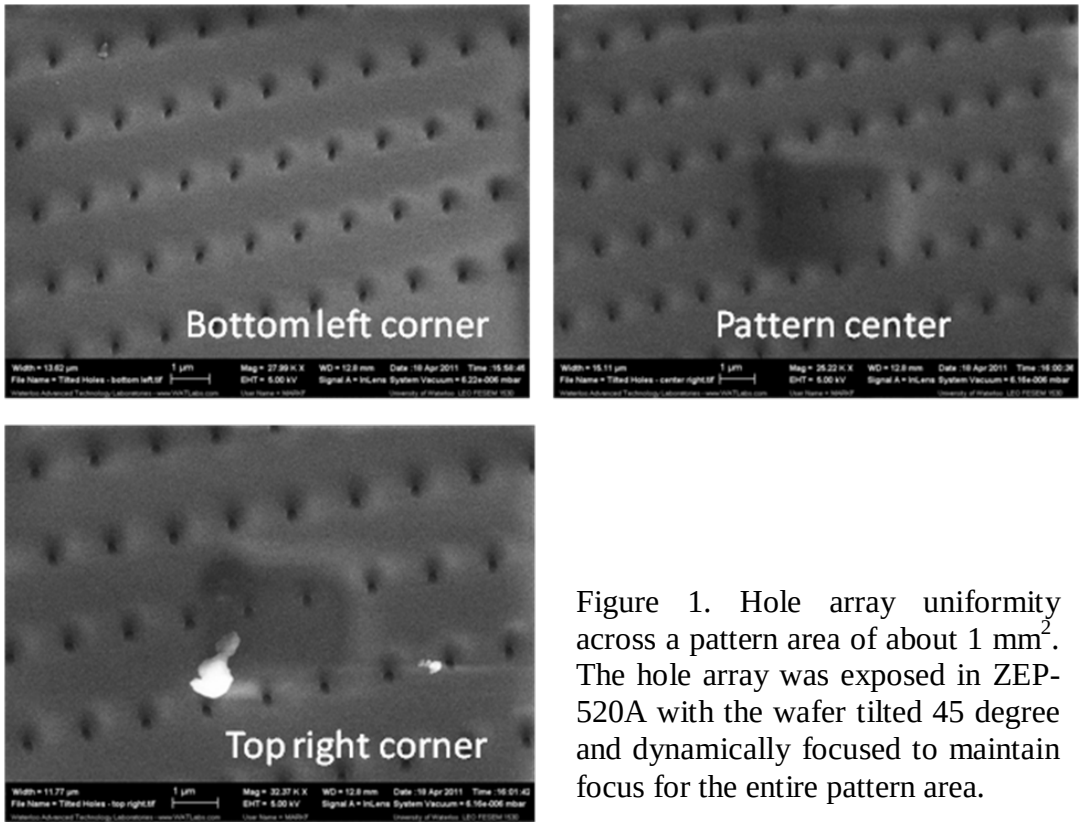

Figure 1. Hole array uniformity across a pattern area of about 1 mm^2. The hole array was exposed in ZEP-520A with the wafer tilted 45 degree and dynamically focused to maintain focus for the entire pattern area.

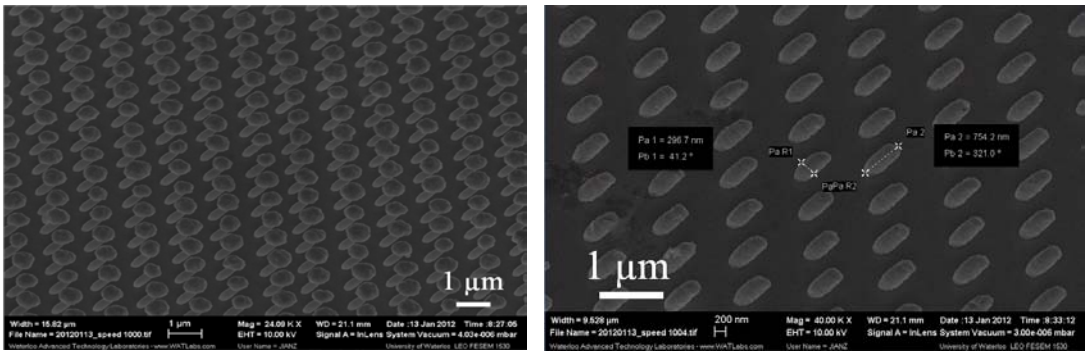

Figure 2. SEM images of 45^o tilted Au pillar arrays with period of ~1 µm. (a) Pillar array with diameter of ~250 nm, and with Au over-plating to form a tilted mushroom structure. (b) Pillar array with diameter of approximately 300 nm and height of 750 nm, and without over-plating. The two images were taken at 45 degree viewing angle.