Metal Patterning and Grain Boundary Engineering by Template Assisted Dewetting

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We have demonstrated the use of template assisted dewetting to fabricate high aspect-ratio ~10-nm apertures in gold [1]. In contrast to methods such as ion-beam milling, lift-off, and atomic layer deposition (ALD) [2–4], template assisted dewetting, which can be conducted on a hot plate, simultaneously reduces metal grain boundaries and smoothens the surface. However, due to incomplete dewetting, the method has thus far not been able to generate apertures with dimensions larger than 100 nm [1]. Here we introduce strategies to pattern structures with dimensions ranging from 20 nm to 200 nm.

Arrays of dots/cross patterns with diameter/linewidth of 20 nm were patterned in 60-nm thick hydrogen silsesquioxane (HSQ) resist on a Si substrate by electron beam lithography (EBL). Next, gold with the same thickness was deposited using an electron beam evaporator. Finally, the sample was heated on a hot plate set at 400°C, gold would dewet and form apertures with diameters corresponding to template dimensions. Figure 1(a) shows the schematic of the fabrication process. Figure 1(b) shows that apertures with ~20 nm diameters can be fabricated by using the dot pattern as previously shown. Interestingly, apertures with larger diameters of ~130nm can now be formed using the cross template.

Initial results show that the grain boundary positions can also be controlled by HSQ structures. Figure 2(a) shows that the grain boundaries in gold terminate close to where the ends of the cross meet with gold. Statistical analysis in Figure 2(b) shows that 40% of the boundaries terminate within 5 nm of the HSQ template, showing the relation between template shape-size and grain-boundary control. Along with larger grain size, engineering the grain boundary position could allow the minimization of loss from grain-boundary scattering, thus reducing damping of surface plasmon resonances. We will present results from different template geometries and processing conditions.

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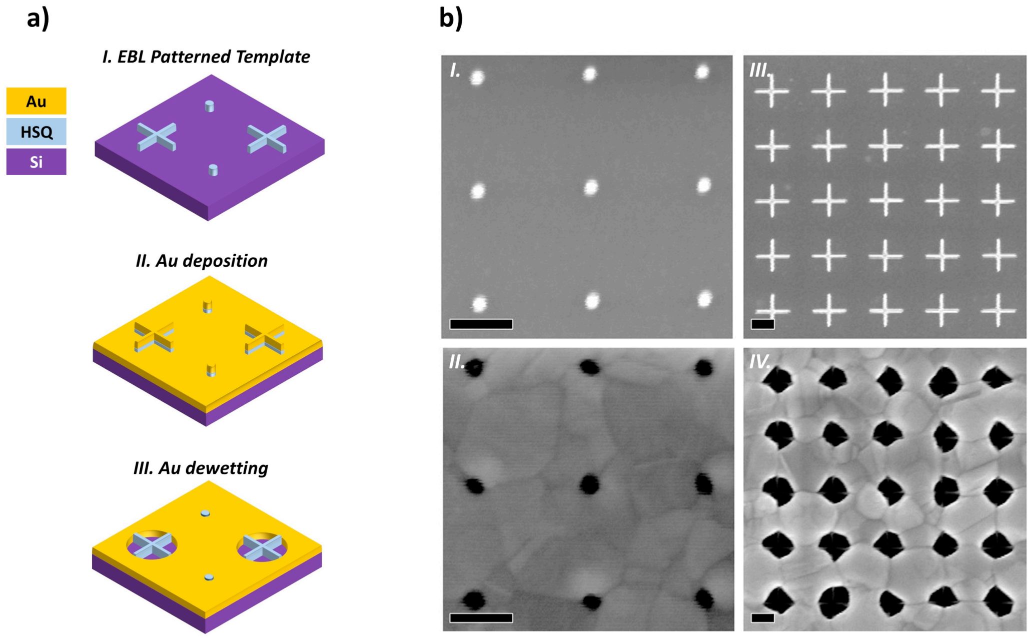

Figure 1: (a) Schematics demonstrating the fabrication process. First, dot/cross shaped HSQ (thickness= t= 60nm) are patterned using EBL on Si substrate. Next, gold with thickness t is deposited using electron beam evaporator. Finally, by heating at 400^{o} C on a hot plate, metal sitting on top of HSQ will dewet away from the nanostructure, and form apertures as a result of capillary-assisted diffusion. (b) SEM images of (I) dot template, (II) ~20nm diameter aperture arrays, (III) cross template, and (IV) ~130nm diameter aperture arrays.

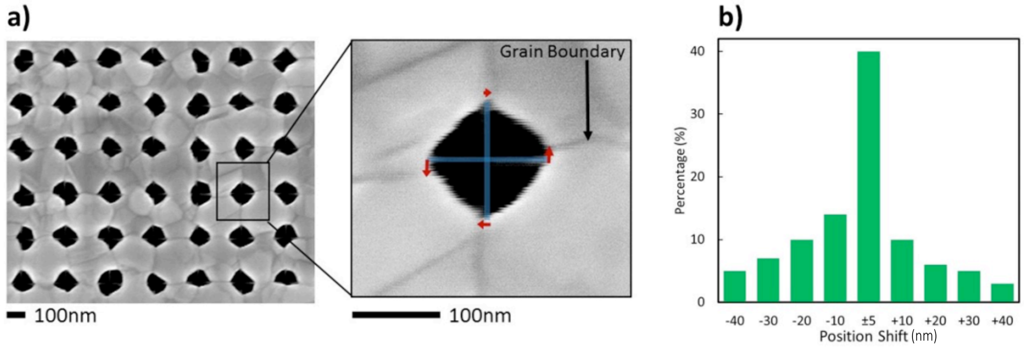

*Figure 2:(*a) SEM image of ~130nm diameter aperture fabricated using the cross template (blue cross overlaid on SEM). Interestingly grain boundaries in gold follow the template shape, and end near the edges of the crosses. Red arrows show the distance between the grain boundary and the ends of a representative HSQ cross. (b) Histogram shows the shift of grain boundary from template edge. Forty percent of the boundaries are within 5 nm of the template, showing the potential of this method to be used as a grain boundary engineering platform.