LARGE-AREA FABRICATION OF SUB-30 NM PERIODIC NANOSTRUCTURES
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ABSTRACT
We demonstrate a robust and high-yield fabrication method without deep-UV laser source by combining displacement Talbot lithography (DTL) using a monochromatic UV beam with dry-etching techniques to pattern sub-30 nm periodic nanostructures over large-areas. Using this fabrication method, we fabricated 30-100 nm nanocolumns arrays of photoresist and sub-30 nm gold (Au) nanoparticle arrays.

KEYWORDS: PhableR 100, Displacement Talbot Lithography, Photoresist Shrinkage

INTRODUCTION
Recently, displacement Talbot lithography (DTL) has been introduced, providing high-resolution photo-lithography for rapid patterning periodic nanostructures, i.e. regular patterns of lines, holes or dots in photoresist, over large-areas [1]. However, for patterning sub-100 nm periodic nanostructures with this technique, a deep-UV source is needed, i.e. an ArF laser at 193 nm. Here, we report and demonstrate an alternative approach without laser use to fabricate size-tunable large-area periodic nanostructures, which have many potential applications in photonics, electronics, biosensors, smart surfaces, catalysis, and biomedical analysis [2, 3].

EXPERIMENTAL
An 3×3 cm² array of photoresist nanocolumns (102±4 nm diameter, 250 nm pitch) was patterned by DTL (PhableR 100C, EULITHA) in a layer of PFI88 photoresist (Figure 1b-d), and subsequently transferred to a bottom anti-reflection layer coating (BARC) layer (AZ® BARLi® II 200) by using different plasma etchings (Figure 1e). These BARC nanocolumns were then used to fabricate sub-30 nm Au nanoparticle arrays using ion beam etching (Figure 1f-g).

RESULTS AND DISCUSSION
The photoresist nanocolumns (Figure 1d) can be even shrunk to smaller high aspect-ratio BARC nanocolumns by subsequently using reactive plasma etching with a O2/N2 (40/50 sccm) gas mixture (12 mTorr, 25 W). Using this recipe for 135 s, photoresist nanocolumns (102±4 nm diameter) were transferred to BARC nanocolumns (30±2 nm diameter), as shown in Figure 2(a). The etching of
BARC using different plasma etchings versus etching time is shown in Figure 2(b). It is highly remarkable that the verticality of these nanocolumns remains during N₂/O₂ plasma shrink-etching. By controlling this shrink-etching process, BARC nanocolumn arrays can be produced at diameters ranging from ~100 nm to ~30 nm, enabling the large-footprint fabrication of size-tunable periodic nanostructures such as supported metal nanoparticle arrays for catalysis.

Figure 2: (a) HR-SEM images of shrink-etching of BARC at different etching times, using reactive plasma etching with O₂/N₂ (40/50 sccm) gas mixture, 12 mTorr, and 25 W. (b) Etching of BARC versus etching time.

Figure 3 shows an array of Au nanoparticles (24±4 nm diameter, 250 nm pitch) supported on cone-shaped fused-silica features fabricated by over inclined IBE of the fused-silica substrate for 10 min (Figure 1g). The Au nanoparticle diameter can be tuned from ~90 nm to ~30 nm by adjusting the ion beam etching parameters, i.e. etching time and the incident angle of the beam.

Figure 3: (a-b) AFM and (c) HR-SEM images of an array of Au nanoparticles (bright spots) supported on cone-shaped fused-silica features (inclined ion beam etching).

CONCLUSION
A robust fabrication method has been reported combining DTL using a monochromatic UV beam with dry-etching techniques, enabling the fabrication of large-area arrays of 30-100 nm periodic nanostructures. With easy operation, this method is suitable for batch-production at low-cost.

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