Fabrication of subwavelength high aspect-ratio tapered fused silica nanostructures for transparent photophilic material

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Subwavelength structures have been developed years in order to fabricate antireflective surfaces [1]. Due to the smaller size of the structures than wavelength of visible light, the structure behaves as an effective medium with gradually varying index of refraction. Such a surface therefore has suppressed Fresnel reflection, allowing broadband wavelength light with wide incident angles to pass through without reflection losses. These functional surfaces have been prepared by some methods, for example, Electron beam lithography [2], Nano imprint with replication from the mold [3], and deposition of multilayer porous films [4].

However, most of the recent work on antireflection structures are based on absorptive materials (e.g., Si, GaAs, carbon nanotube, etc.), which only reduce the reflection from the surface. Here, we present the fabrication of subwavelength nanostructure in fused silica to produce a surface with enhanced transparency, rendering the surface “photophilic.” There have been few efforts to produce such highly transparent photophilic structures, utilizing techniques such as replication method using polymer and reactive ion etching with colloidal lithography [5]. However, it is difficult to make high aspect ratio structures with replication, because the modulus of those polymers is not strong enough to persist from detaching process compared to crystal material (e.g., silicon and silicon oxide). Furthermore, colloidal lithography has limited spatial-phase coherence, resulting in non-perfect periodic/quasi random structures that scatter light.

We introduce a novel method to fabricate high aspect ratio subwavelength fused silica nanostructures that are over 99% transparent with no scattering for broadband wavelength and wide angle. The proposed processes combine interference lithography and a double-hardmask etch process to achieve 180 nm period tapered nanostructure over 1 um tall with ~10-20 nm radius of curvature directly on a fused silica substrate. These have stronger mechanical properties than other polymer based high-transmission surface so that they can sustain from surface tension from any liquid or drop impact. And, perfectly periodic structures eliminate undesirable scattering of light.

These structures are fabricated by Interference lithography and reactive ion etching following with the fabrication process in Figure 1. A cross-section micrograph of the surfaces patterned with 180 nm period subwavelength tapered structure is shown in Figure 2. The structures with high aspect ratio of ~8 have been fabricated using the proposed process. Based on the effective medium theory and geometry of the structures, it acquires smooth transition of refractive index from that of the air and that of the fused glass.

In this work we describe the fabrication process for high aspect-ratio subwavelength nanostructures in fused silica substrate. We will present the detailed fabrication process, theoretical modeling using rigorous coupled wave analysis (RCWA), and experimental testing of broadband, large incident-angle reflection and transmission.

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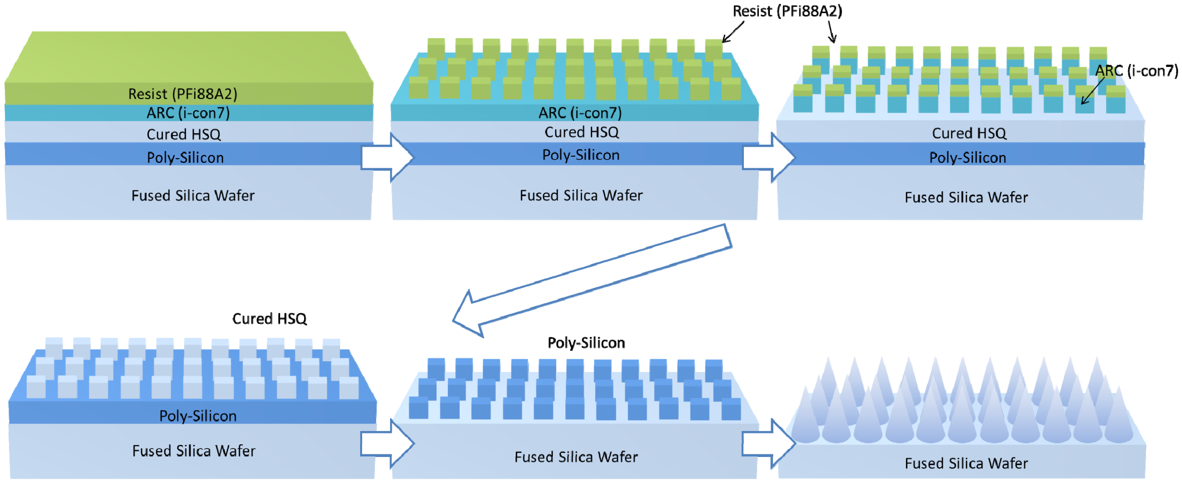

Figure 1 *Schematic of the fabrication process for high aspect ratio subwavelength fused silica nanostructures*

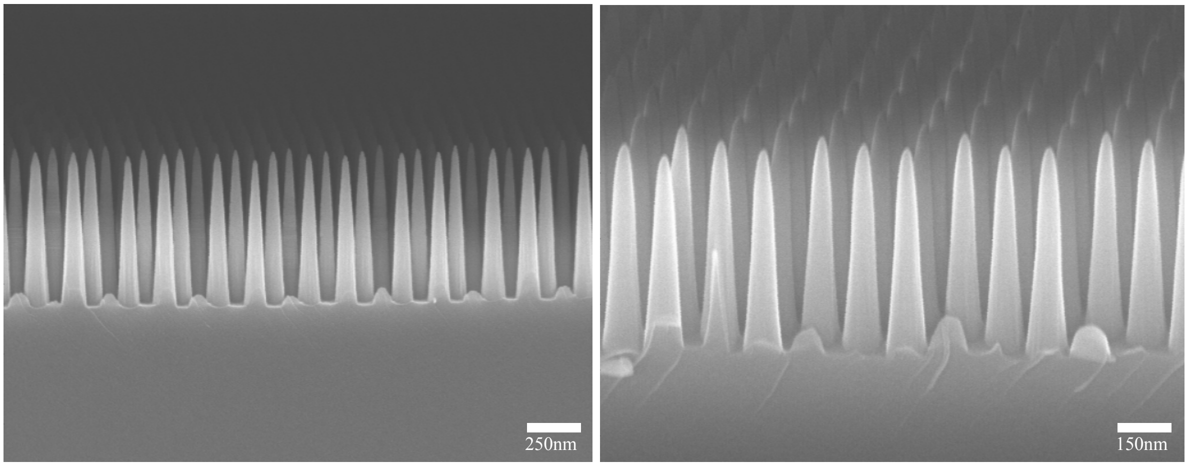

Figure 2 *Cross-section SEM micrographs of fabricated high aspect ratio subwavelength nanostructures in fused silica.*

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