Nanoscale Periodic Features with a 5x Autostep i-line Stepper

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Primary CNF Tools Used: ASML 300C DUV stepper, GCA 5x Autostep i-line stepper

Abstract:

Lithography with the ASML 300C DUV stepper has been used in previous years to produce pillar and hole features with diameters including 232 nm, 306 nm, 408 nm, and 446 nm, and with backside auto alignment on fused silica wafers. This past year, work has been furthered with the GCA 5x Autostep i-line stepper to pattern the larger of these hole features with diameters of 408 nm and 446 nm on fused silica wafers.

Summary of Research:

In previous years a process for patterning nanophotonic pillar and hole structures was developed at CNF that used the ASML 300C DUV stepper. These features were etched into the substrate material using the patterned resist as an etch mask. The ASML 300C DUV stepper process has been used to pattern 4-inch borosilicate float glass wafers ("borofloat"), 4-inch fused silica wafers, and 4-inch silicon wafers. Pillar features like those shown in Figure 1 were fabricated with diameters of 232 nm, 270 nm, 306 nm, 408 nm, 612 nm, and 816 nm. Hole features like those shown in Figure 2 were fabricated with design diameters of 306 nm, 408 nm, and 446 nm. Optimal depth of focus (DOF), exposure dose, and etch time were determined for nanophotonic patterns in fused silica by varying these parameters incrementally and examining the resultant features. Photonic crystal geometry was examined in the SEM and photonic crystal performance was assessed optically via extraction of waveguided light.

The DUV process previously developed to pattern fused silica wafers with nanophotonic pillar and hole structures was expanded to include automated backside alignment on the ASML 300C DUV stepper. Work done to enable backside alignment was achieved for up to three out of four ASML alignment marks etched into bare fused silica to a depth of 150 nm.

In previous years preliminary work was done with the GCA 5x Autostep i-line stepper to adapt the ASML 300C DUV stepper process which patterns 4-inch fused silica wafers minimum hole feature sizes of 408 nm and 446 nm. The best results of a coarse DOF and exposure dose variation study on the GCA 5x Autostep i-line stepper are shown in Figures 3 and 4. DOF and exposure dose were determined for nanophotonic patterns in fused silica by varying these parameters incrementally and examining the resultant features. The optimal etch depth used was determined in previous work making the same features using the ASML 300C DUV stepper. Photonic crystal geometry was examined in the SEM and photonic crystal performance was. Although, there is a deformity in the holes pictured in Figures 3 and 4, the optical performance of the resultant photonic crystal pattern was comparable to those seen from the DUV lithography process.

This past year a finer DOF and exposure dose variation study on the GCA 5x Autostep i-line stepper was done focusing in on those exposure parameters which gave the best performance during the coarse study. This work was focused on the hole feature sizes of 446 nm. The resultant photonic crystal patterns are being assessed via extraction of waveguided light and the best performing of these will be further examined in the SEM to determine their geometric quality.

In summary, the process previously developed to pattern fused silica wafers with nanophotonic hole structures using the ASML 300C DUV stepper was adapted to use the GCA 5x Autostep i-line stepper for hole sizes of 408 nm and 446 nm. A coarse DOF and exposure dose variation study on the GCA 5x Autostep i-line stepper resulted in photonic crystal patterns with some geometric deformation but with comparable performance to that of those made with the DUV stepper when assessed optically via extraction of waveguided light. The results of a finer DOF and exposure dose variation study on the GCA 5x Autostep i-line stepper for hole sizes of 446 nm is currently being assessed.

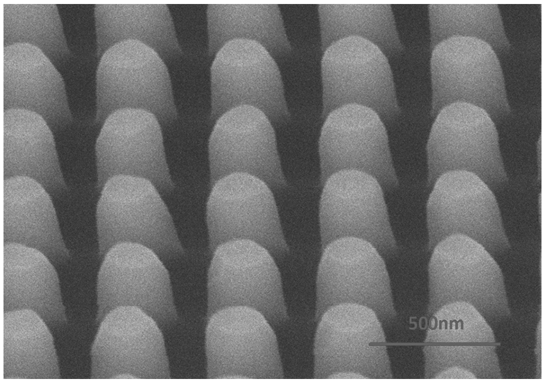

Figure 1: SEM image of photonic crystal pattern, nominally with 270 nm pillar features, fabricated fused silica with process developed with ASML 300C DUV stepper.

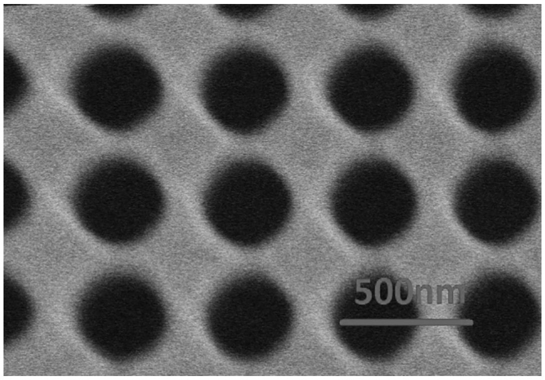

Figure 2: SEM image of photonic crystal pattern, nominally with 306 nm hole features, fabricated in fused silica with a process developed with ASML 300C DUV stepper.

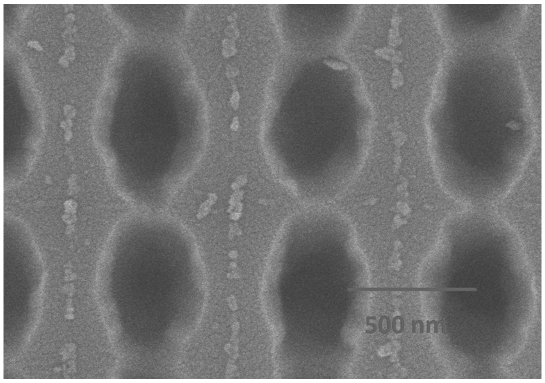

Figure 3: SEM image of photonic crystal pattern, nominally with 408 nm hole features, fabricated in fused silica with a process developed with GCA 5x stepper.

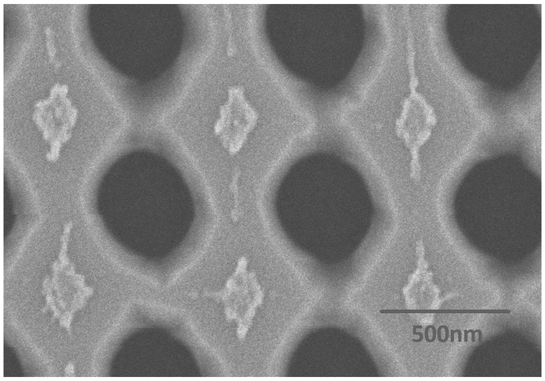

Figure 4: SEM image of photonic crystal pattern, nominally with 446 nm hole features, fabricated in fused silica with a process developed with GCA 5x stepper.