NanoScale Hole Patterns Etched into Glass for Spectral Sensing

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Primary CNF Tools Used: ASML 300C DUV, GCA 5x Autostep i-line stepper, Oxford 81 / Oxford 100 etchers

Abstract:

Over the past several years the ASML 300C DUV and GCA 5x Autostep i-line stepper have been used to produce pillar and hole features with diameters ranging from 232 nm to 816 nm on fused silica and silicon wafers as part of an academic account. These wafers have been further processed to include front and backside patterned metals layers in an academic cleanroom in New York City and then sent to our contract manufacturer to process them into spectral sensors. This report details how this process has been exported over to a complete manufacturing process for scale. This manufacturing process is split into parts. The first part consists of contract work at CNF where nanoscale hole features are patterned with the ASML 300C DUV and etched with the Oxford 81 and Oxford 100 etchers on an industrial account created this past year. The wafers are then further processed by a series of contract manufacturers to ultimately produce spectral sensors at scale. The initial results of the process have produced near identical results to the older process with a small decrease in throughput.

Summary of Research:

In previous years, a process for patterning nanophotonic pillar and hole structures was developed at CNF which used the ASML 300C DUV stepper as well as the GCA 5xAutostep i-line 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" borosilicate float glass wafers (“borofloat”), 4" fused silica wafers, and 4" silicon wafers. Pillar features like those shown in Figure 1 were fabricated with diameters ranging from 232 nm to 816 nm. Hole features were fabricated with design diameters ranging from 306 nm to 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.

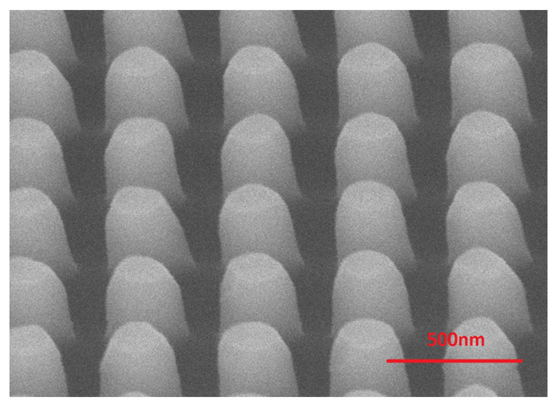

Figure 1: SEM image of photonic crystal pattern, nominally with 270 nm pillar features, fabricated fused silica with process developed with ASML 300C DUV stepper.

For recent applications, nanophotonic patterning is mainly focused on holes versus pillars because pillars are more likely to become damaged in a way that renders them useless for our spectral application during further processing and wafer handling.

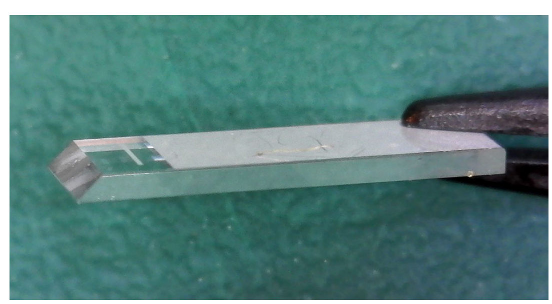

Figure 2: Diced and polished fused silica die with pattered Al reflectors on both sides in addition to the nanophotonic pattern and 45° edge polish.

In recent years, processing steps have been added to the wafer after nanophotonic crystal pattering to include both front and back side aluminum reflector layers which were developed in an academic cleanroom in New York City. These added layers are combined with single edge angled polishing after die singulation as shown in Figure 2, which is done in Asia. Additional front and backside

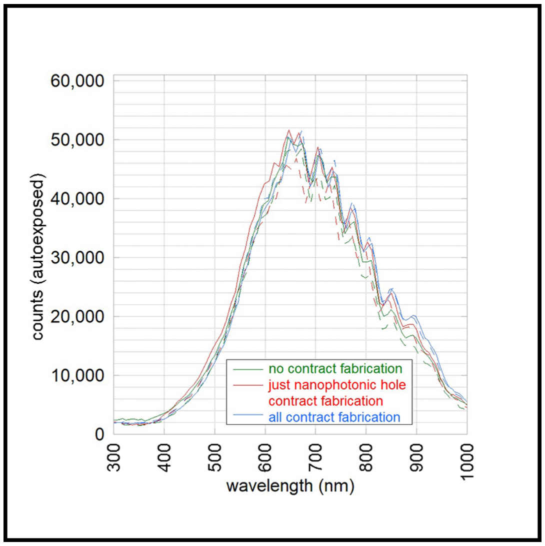

Figure 3: Overlay plot comparing dies with different amounts of contract manufacturing. Data has been normalized to they have the same peak values.

Figure 4: Example of spectrometer batch made with contract manufacturing process that includes fabrication steps at CNF.

patterned black absorber layers were also added to the process in Asia for better light handling. The dies are then built into spectral sensor housing with commercial off-the-shelf linear detectors to make spectrometers.

This last year, the complete process was exported to contract manufacturing, which utilizes the CNF ASML 300C DUV for submicron patterning of the photonic holes that are then etched using the Oxford 81 and Oxford 100 etchers. The nanophotonic patterning that is etched into fused silica wafers at CNF is done by a local CNF user who does contract work. The wafers are then transferred over to a local foundry for front and back side metal patterning. The wafers are then sent to our contract manufacturer in Asia where the additional patterned absorber layers are applied to the front and back side, the wafers are diced, and the die edges are polished at an angle. These dies are then built into spectrometers. Each 4" wafer produces just over 200 dies, allowing in turn which can be built into 200 spectrometers. This process allows for ease of spectrometer scale production into the thousands.

Comparisons were made between wafer dies that had nanophotonic patterns and metal that been made completely without contract manufacturing, dies that had only the nanophotonic patterns made by contract manufacturing, and dies that had both the nanophotonic patterns and metal done by contract manufacturing. Figure 3 shows an overlay of the spectrums produced with all these three different categories of without, partial, and complete contract manufacturing responding to a halogen lamp. The data was taken at differing integration times so that the peak value for each spectrum is normalized to the same value. It was found that the dies made without contract manufacturing had integration times of 0.12-0.14 ms, while the dies with just the nanophotonic pattern made by contract fabrication had integration times of 0.20 ms, and the dies made completely with contract manufacturing had integration times of 0.20-0.22 ms. So there is some small decrease in the brightness of the dies made with contract manufacturing that could be related to small variation in the process. This small variation in brightness is small enough to not be a concerning issue.

The use of the DUV capabilities at CNF has allowed high resolution, robust production of nanophotonic patterns for commercial quantities. Ideally all of Chromation's wafer fabrication would be done at a single foundry, but the DUV lithography capability that CNF has is hard to find elsewhere. Furthermore, the additional layers added to the wafers at our contract manufacturer in Asia was a process specialty designed for our applications that could not be achieved in a conventional cleanroom. A commercial process that includes contract work at CNF is an effective way of producing Chromation's nanophontic spectrometer at scale. Figure 4 shows a batch of spectrometers made with this manufacturing process.