Diffractive Optical Element Manufacturing Feasibility

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Primary CNF Tools Used: GCA 5x g-line Stepper, Oxford 100 Plasma Etcher, YES Eco-Clean Asher, KLA P7 Profilometer

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Abstract:

The purpose of this project is to investigate the feasibility of manufacturing a specific diffractive optical element (DOE) pattern using equipment available at both the Cornell NanoScale Facility (CNF) and at Applied Image, Inc. The pattern in question is a computer-generated hologram that acts as a high angle (170+ degrees) dot grid type beam splitter with 0.9 μm elements for use in an optical instrument.

Summary of Research:

Applied Image has set out to investigate whether it will be feasible to manufacture high quality DOEs using our current lithography equipment and resources like the Oxford 100 plasma etcher at CNF. Our test pattern that we are attempting to reproduce is a 49 x 49 0.900 μm binary pixel array with a pi phase shift, repeated over an entire 100 mm fused silica wafer.

Our first attempt to pattern our resist was using CNF. We used S1805 resist and a master made on our own lithography equipment with reticle markings for our GCA 5x G-Line stepper. Our stepper is nearly identical to the one at CNF, so we attempted to pattern our wafer using the stepper at CNF. The stepper at CNF is configured differently than ours and was unable to focus correctly on a clear substrate. The autofocus system on our stepper appears to be a completely different design, which allows it to focus properly.

One of our next tasks was to take the processes and training we received from CNF regarding resist spinning back to Applied Image. We completely redesigned the processes for our spin lab to mirror the best practices we learned during our training at CNF. Major changes were using pipettes for depositing resist, methods for depositing HMDS, increasing our accelerations and using a copper plate for cooling. Another important process related note, we have also launched a project to overhaul our safety procedures and documentation using CNFs safety manual as a gold standard.

After producing several wafers that were successfully patterned with AZ3312 resist, we took these back to CNF for processing in the Oxford 100 Plasma Etcher. We used two etch processes CHF_3/O_2 oxide etch (etch rate:150nm/min Selectivity 2.5:1), and C_4F_6/high He oxide etch (etch rate:225nm/min selectivity 4:1) [1]. An etch depth of 690 nm was targeted to create a pi phase shift in 632.7 nm He/Ne laser light.

An attempt was made to measure the etch depth of the pattern with the KLA P7 Profilometer. This did not turn out to be successful as the features were not quite big enough to get a good reading from the stylus. Most readings with the profilometer returned 125-275 nm etch depths. It was difficult to line up larger features (2 μm x 6 μm) as the viewing lens did not resolve these features very well. For better process control test patches with a larger cross-sectional area of at least 50 x 50 μm would need to be added to make better measurements on either a profilometer or an ellipsometer.

Despite the inability to measure or control the etch depth, reliance on the suggested etch rates seemed to be good enough to produce favorable results. Both etch methods produced an acceptable diffraction efficiency of around 90%. Although diffraction efficiency in terms of zero order energy to total beam energy were high, some undesirable artifacts were present in the form of lines between the desired dots in the resulting diffraction pattern. More investigation will be ongoing to attempt to resolve this issue.

Further work is being done to optimize the process including switching to ChemLab 5305 High-Resolution resist, that has so far shown superior resolution to Shipley S1805, AZ1505 and AZ3312 resists.

References:

[1] CNF Users. "Oxford 100 ICP Dielectric Etcher." Cornell NanoScale Science & Technology Facility. Etch Baseline Data. Accessed July 2, 2024.

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