Dual-Band Metalenses for Imaging and Absolute Temperature Detection

CNF Project Number: 3105-23
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Primary CNF Tools Used: Gamma, ASML DUV Stepper, Heidelberg 2000, Oxford 81/82, Anatech Strip Resist, SEM

Abstract:

The project focuses on developing a novel dual-band metalens system, engineered for precise detection and identification of unknown aerial objects, with potential military applications. The design incorporates two metalenses that operate in distinct mid-infrared bands designed using a hyperbolic phase profile for diffraction-limited focusing enabling maximum angle resolution [1]. The metalenses are integrated with wavelength-selective filters for enhanced performance and compactness.

Summary of Research:

Trip 1: 2/4/24 – 2/10/24

- Orientation and training on the Gamma, ASML DUV Stepper, Heidelberg 2000, E beam deposition tool and in general chemistry.
- Generated mask for two lenses and patterned multiple wafers.
- The process aimed to deposit a hard mask and perform lift-off at The Vanderbilt Institute of Nanoscale Science and Engineering (VINSE). However, due to the large diameter of the lens (20 mm), lift-off proved challenging, resulting in incomplete liftoff and rendering the samples unusable for further processing and testing as seen in Figure 1.

Trip 2: 3/11/24 – 3/21/24

- Training on Oxford 81/82, Oxford Cobra, Anatech Resist Strip, and Scanning Electron Microscope (SEM).
- Employed a new strategy of depositing mask material (SiO2) on wafer before patterning to avoid having to lift-off of the hard mask.
- Generated mask for two samples and patterned multiple wafers.
- Post-processed the wafers to etch the anti-reflective coating (ARC), etch hard mask using a CHF_3/Ar recipe, and then ash-etch the rest of the resist and ARC, preparing the sample for Si etch.
- Attempted to Si etch using multiple recipes on the Oxford Cobra; however, a straight edge etch was not achieved as seen in Figure 2.
- Using a CHF_3/O_2 etch recipe for the hard mask, samples were Si etched at VINSE, achieving a vertical edge etch as seen in Fig. 3.
- Characterization revealed significant reduction in the size of the fabricated pillars compared to the designed ones due to diffraction effects during exposure and edge etching during mask and Si etch. The smallest design features were not patterned, leaving empty spaces on the wafer, as seen in Figure 2 and Figure 3.

Trip 3: 5/16/24 – 5/22/24

- To account for the discrepancy between fabricated pillar and designed pillar sizes, a bias was added to the design to compensate for the shrinkage during patterning and etching.
- Generated new masks incorporating the bias and patterned multiple wafers.
- Post-processed the samples, preparing them for Si etch at VINSE.
- After Si etch at VINSE, the lenses were characterized, and pillars covered entire lens surface as seen in Figure 4.

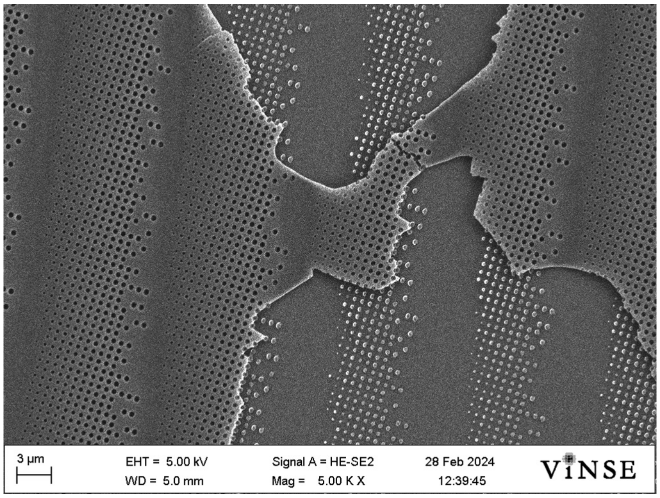

Figure 1: SEM images of the lens showing incomplete lift-off of the mask from the lens.

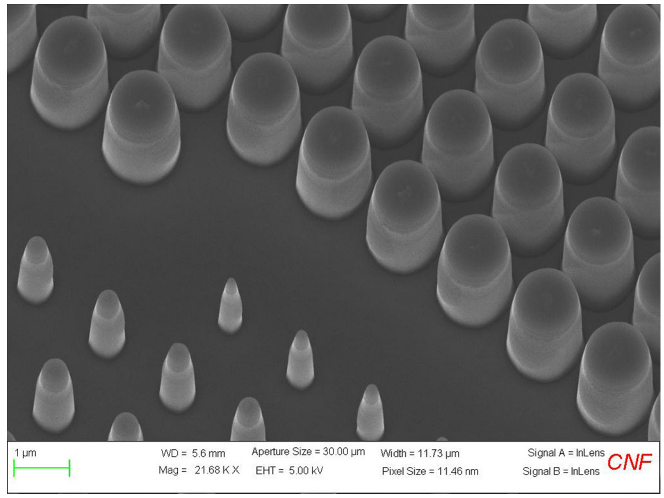

Figure 2: SEM image of the lens after Si etch at CNF showing pillars without perfectly vertical side walls. Rows of missing pillars visible.

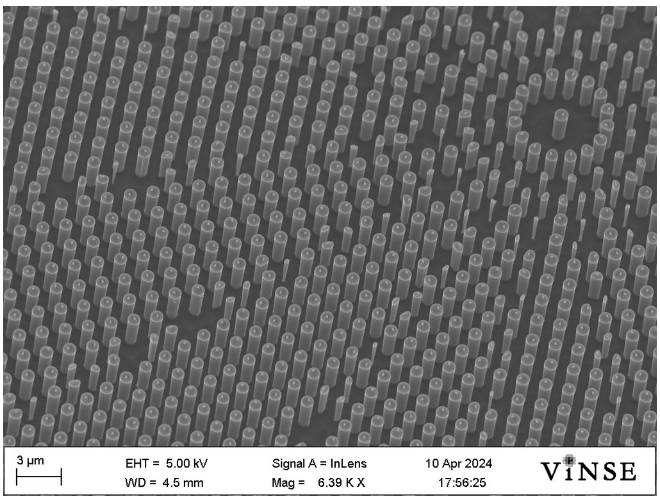

Figure 3: SEM image of the lens after Si etch at VINSE using a different mask etch recipe, showing improved side wall profile. Rows of missing pillars visible.

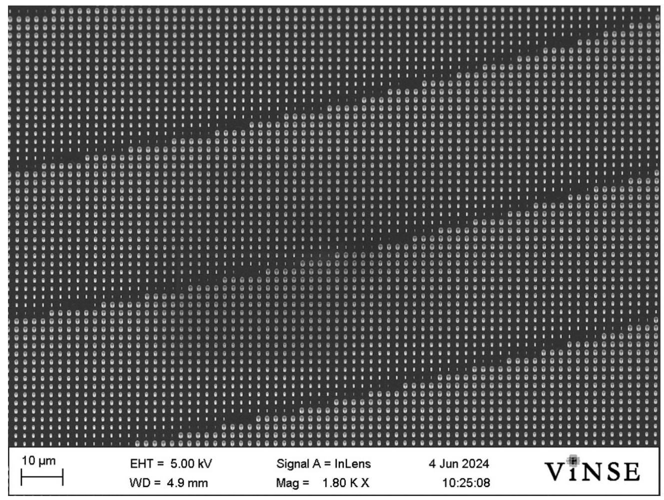

Figure 4: SEM image of the lens patterned after biasing, and after Si etch at VINSE with complete lens surface covered with pillars.

Conclusion and Future Steps:

The two lenses are designed to operate at a narrow band, and to ensure optimal performance, both lenses need to be equipped with a narrow band filter. We aim to design and fabricate a distributed Bragg reflector (DBR)-cavity-DBR based band pass filter on one side of the wafer and pattern and etch the lens on the other side of the wafer to achieve a seamless, compact design for our metalens. After fabrication and characterization, the lenses will undergo extensive testing to ensure they meet the necessary performance standards for the desired application.

References:

[1] Mohammadreza Khorasaninejad, et al., Metalenses at visible wavelengths: Diffraction limited focusing and subwavelength resolution imaging. Science352,1190-1194(2016). DOI:10.1126/science.aaf6644.