Curved Metalens Fabrication on Objective Lens of Si Cooke Triplet for Aberration Corrected IR Imaging

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Metasurfaces are periodic two-dimensional nanoscale structures, which can be used to control and manipulate the properties of electromagnetic waves. In the case of an optical system, metalenses are specially designed metasurfaces that behave similarly to diffractive optical elements, focusing and manipulating the properties of light, including phase, amplitude, and polarization. Metalenses can also be designed to correct various aberrations found in traditional optical lens systems [1]. A key benefit of metalenses is their compact lightweight formfactor compared to traditional multi-element refractive optics [2]; however, these two-dimensional metalenses are also constrained to small areas (< $10mm^2$), planar substrates, and fabrication techniques that require planar processing. While hybrid diffractive refractive optical systems incorporating metalenses have been demonstrated [3], incorporating large-area (>$10mm^2$) phase-engineered metalenses onto the curved faces of traditional refractive optics is an ongoing and yet-to-be-demonstrated area of research exploring complementary benefits of traditional refractive elements combined with the focusing and aberration correction capabilities of metalenses.

In this work, we demonstrate novel fabrication of nanostructured metalenses on curved silicon refractive lenses to form hybrid diffractive refractive optics on a Cooke triplet lens. Optical simulations have been carried out to generate the phase profile and corresponding nanostructured layout for the metalens integrated on a 25 mm silicon objective lens. Electron Beam lithography (EBL) is used to pattern the metalens, followed by RIE etching of silicon to fabricate the final nanostructure, as shown in Figure 1. Results of this work include comparisons between the simulated optical performance of the standard refractive lens (non-patterned) and patterned hybrid diffractive refractive lens with corresponding experimentally measured imaging performance of the fabricated lens system with an IR camera and source.

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[1] N. Yu and F. Capasso, "Flat Optics with designer metasurfaces," *Nature Materials,* pp. 139 - 150, 2014.

[2] S. Shrestha, A. Overvig, M. Lu, A. Stein and N. Yu, "Broadband achromatic dielectric metalenses," *Light: Sciences & Applications,* vol. 7, p. 85, 2018.

[3] R. Sawant, D. Andren, R. J. Martins, S. Khadir, R. Verre, M. Kall and P. Genevet, "Aberration-corrected large-scale hybrid metalenses," *Optica,* vol. 8, no. 11, p. 1405, 2021.

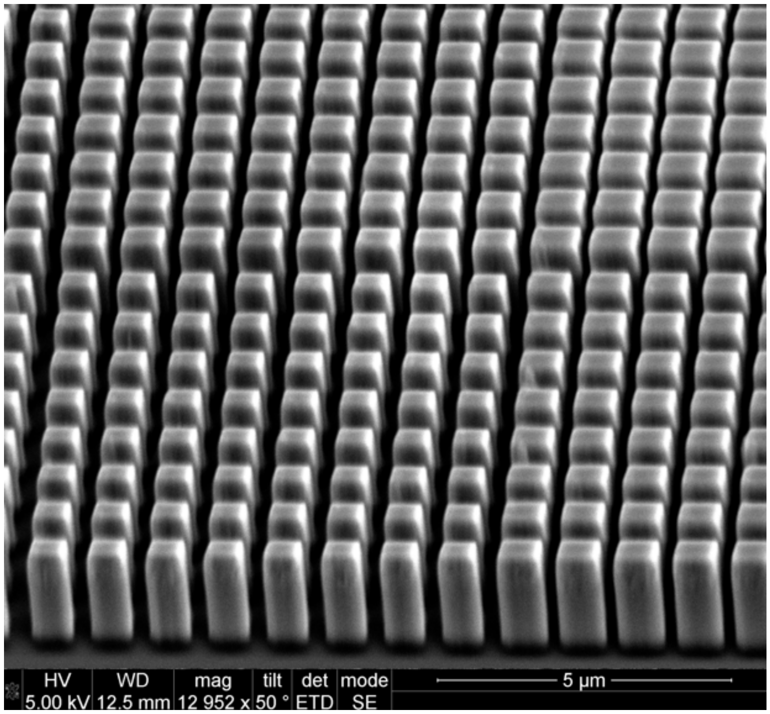

Figure 1. Tilt view SEM image of etched nanostructures which make up the silicon metalens.

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