Thermal nanoimprinting of mid-IR antireflective moth-eye nanostructures on chalcogenide glass windows

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Chalcogenide glasses are known for their exceptional ability to transmit infrared light, boasting a large transparency range spanning from the near infrared (~1 µm) and into the far infrared (~20 µm).[1] However, regardless of their low optical losses these glasses still suffer from a significant optical power loss due to Fresnel reflection at the glass-air interface. While dielectric coatings effectively reduce this reflection loss, studies have shown that surface reliefs can achieve similar results without significantly hampering the power handling capability of the glass, an unfortunate side effect from using dielectric coatings.[2] In this study we report on the progress towards patterning antireflective moth-eye nanostructures designed to operate in the mid infrared on the surface of bulk chalcogenide glass (As_2Se_3) windows using a thermal nanoimprinting technique.

The master stamp was fabricated using an etch mask defined by a deep ultraviolet lithography step followed by a dry etching process using inductively coupled plasma reactive ion etch to define the nanostructures. From the silicon master we then fabricated a nickel shim by a metallization and electroforming step and a subsequent KOH bath to etch away the silicon master, such that only the nickel shim remained. We then proceeded to use the shim to nanoimprint chalcogenide discs 25 millimeters in diameter (example in Figure 1(a)). Pattern pitches between 0.9-1.6 µm were replicated as simulations based on Rigorous Coupled-Wave Analysis predicted these would produce the best antireflection results in the mid infrared (2.5-4.5 µm). To characterize the imprinted windows we used a scanning electron microscope to evaluate the replication of the structures (shown in Figure 1(b)) and an FT-IR Spectrum 100 to characterize the transmittance of the windows in order to determine the improvements to the transmittance given by the nanoimprint as illustrated in Figure 2.

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[1] J. S. Sanghera et al. Development and Infrared Applications of Chalcogenide Glass Optical Fibers. *Fiber and Integrated Optics* 19, 2000.
[2] Hobbs, Douglas S. Laser Damage Threshold Measurements Of Anti-Reflection Microstructures Operating In The Near UV And Mid-Infrared. *Laser-Induced Damage in Optical Materials: 2010*.

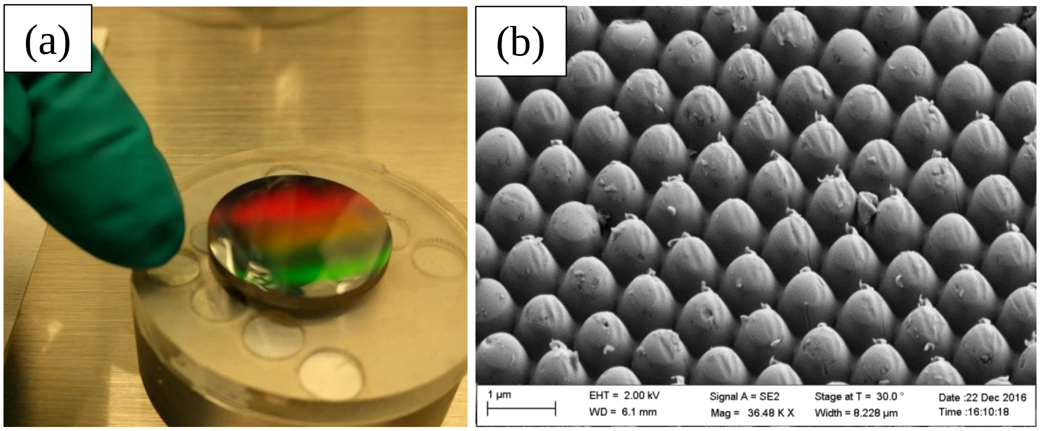

Figure 1: (a) Picture of a chalcogenide window post nanoimprint illustrating how visible light is diffracted at the surface - a quick and clear indication that a pattern has been successfully transferred. (b) SEM image taken of the imprinted surface showcasing the antireflective moth-eye nanostructures.

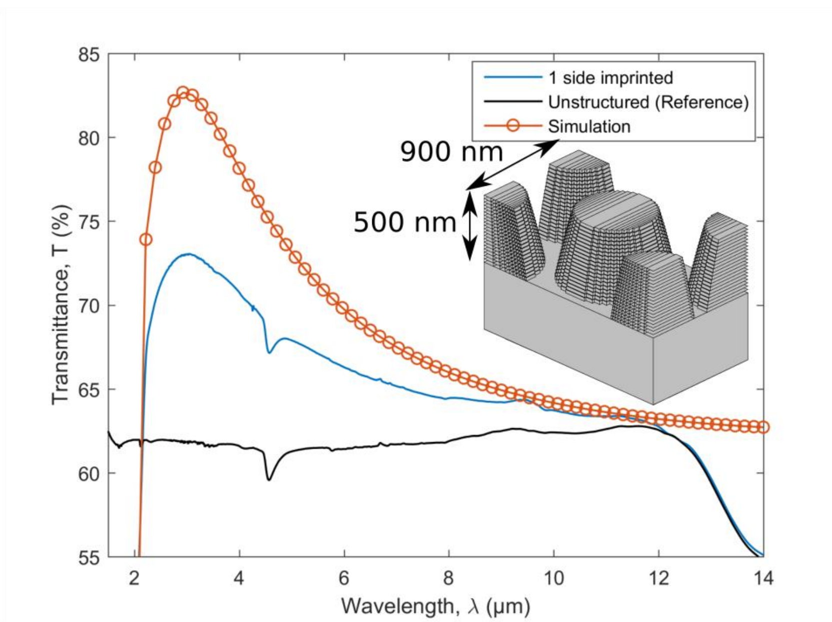

Figure 2: FT-IR transmittance measurements of a window with and without an imprinted moth-eye nanostructure relief with a pattern pitch of 900 nm and the corresponding RCWA transmittance simulation result. (Insert: The half-ellipsoidal nanostructure model used by the simulation software GD-Calc.)