Patterning Chalcogenide Glass with Thermal Nanoimprint

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Chalcogenide glasses are inorganic materials with important optical properties. Those superior optical properties have enabled many practical applications such as optical memories and nonlinear optical components. However, the application of chalcogenide glasses in integrated optical circuits is limited, mainly due to the lack of a low-cost technique to create micro- and nanopatterned structures in chalcogenide glass thin film. In this work, we employ thermal nanoimprint to directly emboss chalcogenide glass into device structures. This essentially combines lithography and etching into one step for fast fabrication of micro- and nanodevices based on chalcogenide glasses. Since nanoimprint is a low-cost, high-resolution and high-throughput technique, we expect this method can potentially speed up the applications of chalcogenide glasses in integrated optical circuits.

Arsenic trisulfide glass (As_2S_3), being a member of chalcogenide glass family, is a promising material which is transparent from visible to the far infrared (8µm) range. Photonic devices such as infrared optical fibers and optical waveguides as well as infrared lenses have already been fabricated using As_2S_3 [1]. Due to its low softening temperature (208°C), As_2S_3 is a suitable material for thermal nanoimprint. As_2S_3 is deposited on bare silicon wafer from high purity targets using RF sputtering technique. The nanoimprint mold was prepared from thermal oxide and was coated with FDTS surfactant. Due to high viscosity of As_2S_3 melt, nanoimprint was carried out at 250°C and at a pressure of 5 MPa. Well defined mesa, hole and grating patterns from tens of micron to sub-micron have been achieved (figure 1).

Though polymer nanoimprint has been well characterized, the research on nanoimprint of inorganic glasses such as As_2S_3 remains primitive. Many factors, such as high melt viscosity, interfacial adhesion, large thermal expansion coefficient difference between mold and As_2S_3 [2], can contribute to defect generation as shown in figure 2. Optimal processing conditions need to be identified to reduce defects. Since patterned As_2S_3 structure will be part of the optical component, its surface roughness has significant impact on device performance. The surface roughness and methods to control it will be explored in this work. Another significant issue in imprinting chalcogenide glasses is the high processing temperature (typically greater than 250^{o}C). Since widely used nanoimprint surfactants such as OTS and FDTS experience thermal degradation at this temperature range, new surfactants with better thermal stability will be evaluated to enhance process yield.

[1] S.K. Sundaram, B.R. Johnson, M.J. Schweiger, J.E. Martinez, B.J. Riley, L.V. Saraf, J.N.C. Anheier, P.J. Allen, and J.F. Schultz. *Chalcogenide glasses and structures for quantum sensing*. in *Quantum Sensing and Nanophotonic Devices*. 2004. San Jose, CA, USA: SPIE.
[2] J. W. Robinson, *Practical Handbook of Spectroscopy*, CRC Press, 1991.

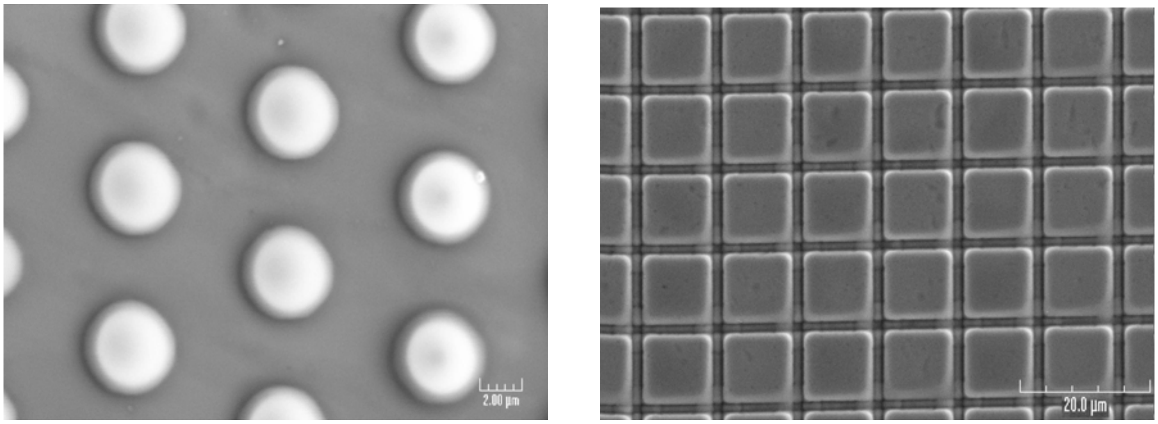

Figure 1. Nanoimprinted arsenic sulfide structures (a) 2μm circular mesas; (b). 10 μm squares

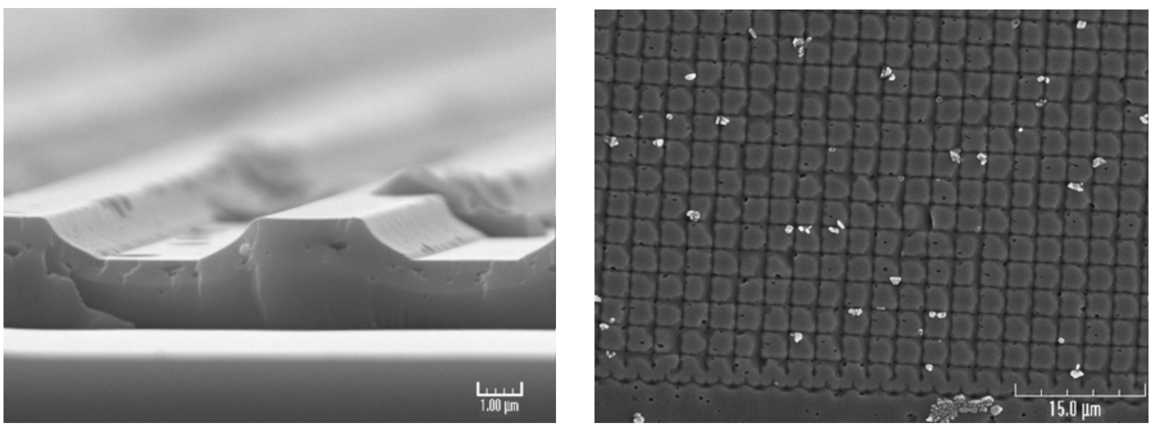

Figure 2. Defects and surface roughness in imprinted As_2S_3 structures. (a) chipped edges in As_2S_3 gratings; (b) part of the square pattern (white particles) peeled off and re-deposited on surface.