Sub-Wavelength Optical Functionalities Directly Imprinted on Chalcogenide Glasses

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Chalcogenide glasses are attractive materials for infrared optics. However, their applications are often hampered by signal losses due to the high surface reflection. Traditional thin-film-based antireflective coatings are hardly applicable on chalcogenide glasses, as they often generate mechanical stresses that result in the film delamination. An attractive alternative to the film-based coatings are surface-pattered moth-eye subwavelength structures, which are made of the same material as the bulk, and thus do not generate stress. Among various methods of the surface patterning of chalcogenide glasses, thermal nanoimprint is the most attractive due to the low their low glass transition point – around 200 ^{o}C. Still, one major challenge remains – how to directly imprint the surface of chalcogenide glass without deforming the shapes of the substrate?

Here, we present three novel approaches for the direct soft imprint of chalcogenide glasses without deforming the shape of the imprinted substrate. The *first approach* is based on the imprint with IR radiative heating using a soft mold. Here, the mold is produced from PDMS reinforced with carbon nanotubes, making it a good radiation absorber. Since chalcogenide glasses are transparent in IR, only a thin layer at the mold-glass interface is sufficiently heated above the glass transition point during the radiative imprint. At the same time, the rest of the bulk remains below its glass transition point and therefore is not deformed [1]. Using this approach, we demonstrated the full pattern transfer of micron and sub-micron-sized features on flat surfaces, as well as on a lens.

The *second approach* is based on soft imprinting of a solvent-plasticized glass layer formed on the glass surface. Here, we established a methodology for surface plasticizing by controlling its glass transition temperature through process conditions. This control allowed us to imprint the surface of chalcogenide glass with features sized down to 20 nm and achieved an unprecedented combination of full pattern transfer and complete maintenance of the shape of the imprinted substrate. We demonstrated two applications of this approach: a diffraction grating and a multifunctional pattern with both antireflective and highly hydrophobic water-repellent functionalities – a combination that has never been demonstrated for chalcogenide glasses [2].

The *third* recently explored and still unpublished approach is based on elastomeric stamps soaked in an organic solvent, which diffuses into the imprinted chalcogenide glass, plasticizes its surface, and thereby allows its imprint at the temperature below its glass transition point. Using this approach, we imprinted features at the 20-nm scale, which is comparable to that demonstrated by convention nanoimprint techniques. Here, we again illustrated the applicability of our approach by producing functional antireflective nanostructures onto flat and curved optical polymeric substrate[3].

Overall, these three approaches open a new route for the nanofabrication of optical devices based on chalcogenide glasses and pave the way to numerous future applications for these important optical materials.

[1] N. Ostrovsky, D. Yehuda, S. Tzdaka, E. Kassys, S. Joseph, and M. Schvartzman *Adv. Opt. Mater*.,1900652 (2019)
[2] S. Tzadka, N. Ostrovsky, E. Toledo, G. Le Saux, E. Kassis, S. Joseph, and M. Schvartzman ,*Opt. Express*, 28 (19), 28352 (2020)
[3] S. Tzdaka, M Schvartzman – in preparation

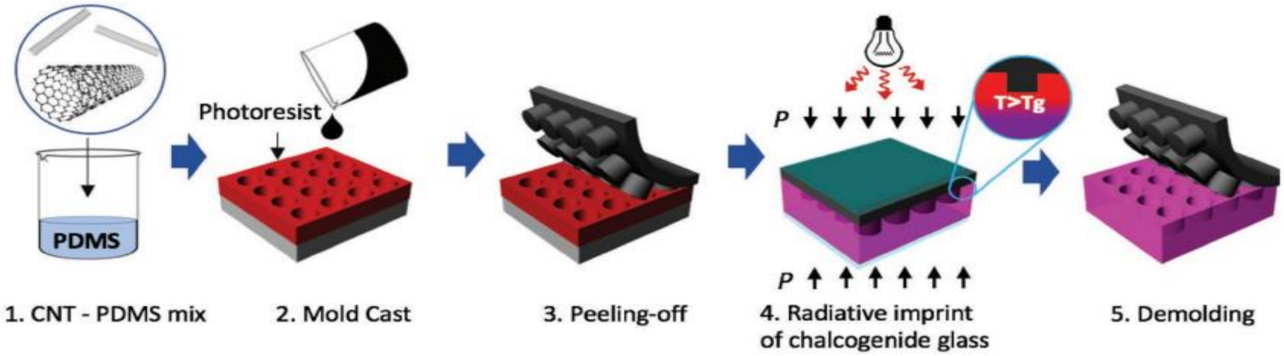

Figure 1. Schematic process flow of direct radiative imprint of chalcogenide glass[1]

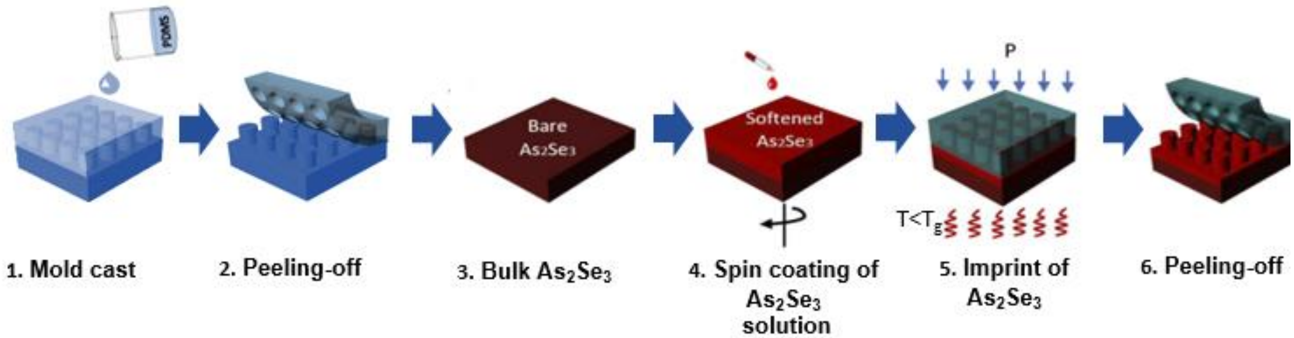

Figure 2. Schematic process flow of direct imprint of chalcogenide glass via surface plasticizing[2]

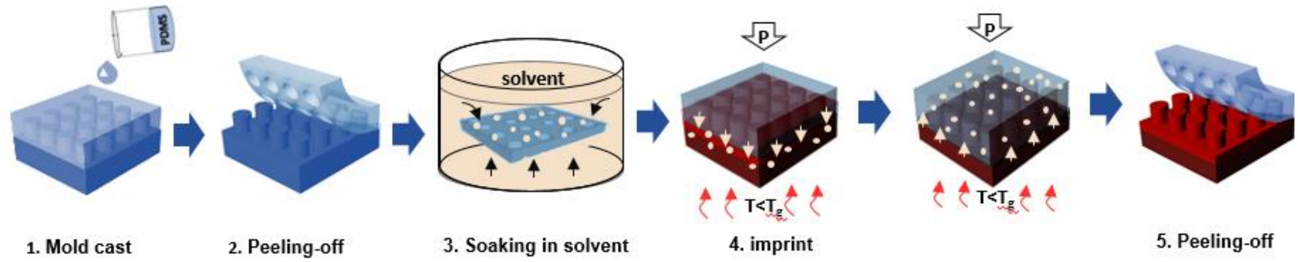

Figure 3. Schematic process flow of direct imprint of chalcogenide glass via surface dissolving[3]

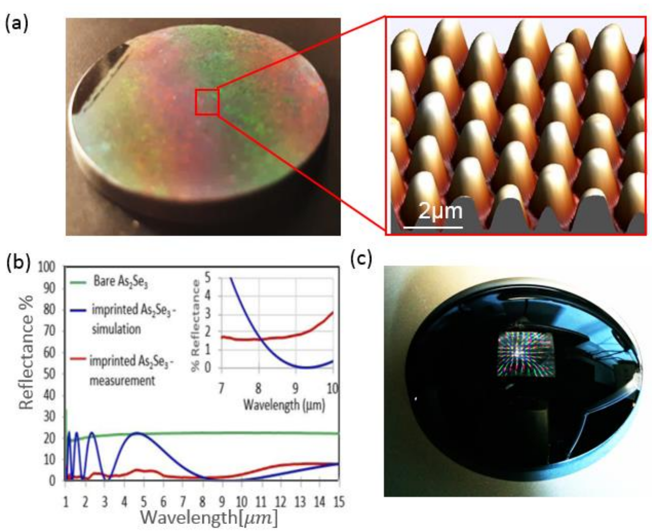

Figure 4. (a) As2Se3 substrate fully imprinted with antireflective moth-eye microstructures, (b) The reflectance spectrum of surface imprinted with antireflective (red), compared to that of bare As2Se3 surface (green), and a simulated spectrum (blue), (c) Diffraction grating imprinted on the surface of As2Se3 lens