Direct Nanoimprint of Chalcogenide Glasses for Optical Applications

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Chalcogenide glasses are attractive optical materials due to their high transmittance, high refractive index, high optical nonlinearity, and low optical losses. Many applications of these glasses require their surface patterning with micro-/ nano- strictures, such as diffraction gratings, antireflection morphologies, or waveguides. Up to date, such patterning was possible by laser writing, which provides, however, low throughput and limited resolution. Alternatively, the surface of chalcogenide glasses can be nanoimprinted, since their glass transition temperature ranges between 100 ^{o}C to 300 ^{o}C, depending on their composition. However, the high temperature and pressure applied during the imprint would also deform the shape of the substrate itself, and damage its optical functionality. Thus, optical components made of chalcogenide glass cannot be directly patterned by standard nanoimprint.

Here, we demonstrate two novel approaches for the direct surface nanoimprint of As_2Se_3 - a chalcogenide glass with the glass transition temperature of 165 ^{o}C. Both approaches yielded full pattern transfer into the glass surface, without deforming the substrate. The first approach is based on a nanocomposite mold made of carbon nanotube matrix and Polydimethylsiloxane PDMS resin. To allow nanoimprint, the mold and As_2Se_3 are confined between two elastic membranes, pneumatically pressed against each other, and controllably radiated by an infrared bulb (Fig. 1a). As_2Se_3 is transparent to infrared radiation, and the radiation is mostly absorbed in the mold due to the embedded carbon nanotubes. By this method, only As_2Se_3 surface that contacts the mold is heated above its glass transition temperature and nanoimprinted, while cold As_2Se_3 bulk is not deformed.

In the second approach, As_2Se_3 solution is applied onto As_2Se_3 substrate by spin coating and baked. Here, we tuned baking conditions to evaporate most of the solvent, and obtained a “softened” As_2Se_3 film whose glass transition temperature is below that of pristine As_2Se_3 (Fig.1b). In this case, a standard nanoimprint with PDMS mold was done by applying conductive heating and mechanical pressure, to yield the full pattern transfer with no damage to the substrate shape, similarly as in the first approach (Fig. 1 c and d). To demonstrate the applicability of our novel approaches for optics, we imprinted diffraction gratings onto the As_2Se_3 surface, and characterized it in the reflection mode (for visible wavelength, Fig.1 d) and in the transmission mode (for near infrared wavelength). In overall, our work presents two novel, unconditional approaches for the direct micro-/ nano-structures of chalcogenide glasses, and paves the way to their numerous applications in the future optical components.

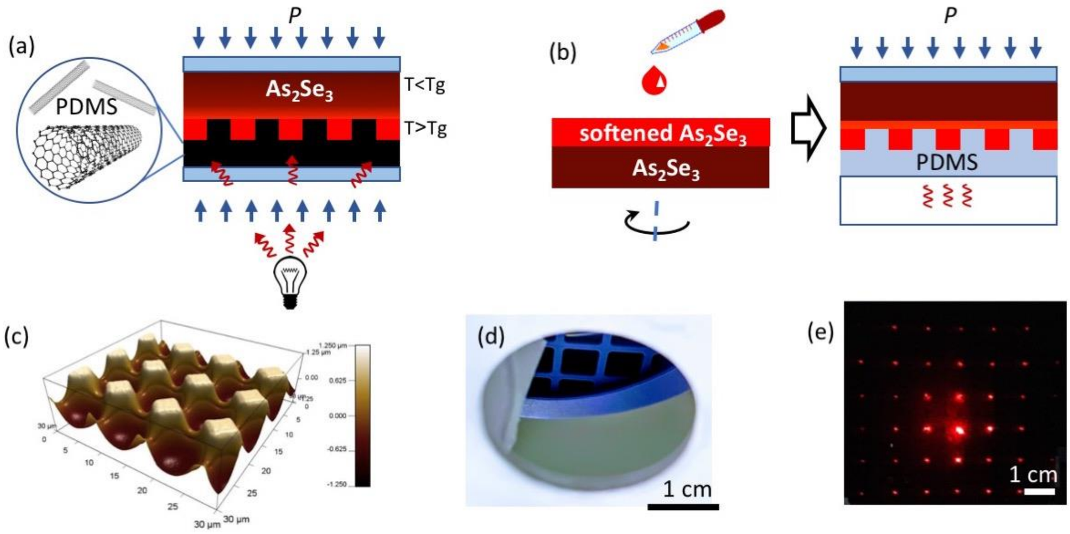

Fig.1. (a) Imprint with carbon-nanotube reinforced PDMS mold by radiative heating. (b) Imprint of softened chalcogenide glass. (c) Imprinted pattern on the surface of chalcogenide glass (d) Backside of the imprinted substrate showing no deformation. (e) Diffraction patted if the imprinted grating.