Direct Nanoimprinting of Functional Inorganic Layers for Nanophotonic Chip Devices

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The direct imprinting of functional inorganic materials has been performed to fabricate high quality nanophotonic chip devices. A variety of titanium dioxide (TiO_2), aluminum oxide (Al_2O_3) and zirconium dioxide (ZrO_2) inorganic precursors have been investigated as inorganic resist materials for thermal nanoimprint lithography (NIL). The reactivity of the inorganic precursors was correlated with the NIL requirements and their mechanical properties. Among the studied materials, a new type of metal-organic precursor based on alkanoate chemistry was identified as the best choice for high quality thermal imprinting and good optical properties.

The patterning was performed by a novel process developed to imprint crack-free inorganic films and control the shrinkage of the patterned nanostructures. The inorganic precursor films were pre-annealed and thermally patterned with a flexible bilayer-PDMS stamp. The fabrication of the soft-PDMS stamp has been optimized to keep its thermal stability during the imprinting step. After imprinting, the patterned films were annealed to achieve desired optical properties as calibrated by ellipsometry.

The alkanoate-based precursor titanium di-n-butoxide bis(2-ethylhexanoate) presented the best properties to produce high quality inorganic patterns by thermal NIL. Post-annealing of this precursor at high temperatures allowed the generation of pure titanium oxide films with high refractive index. In addition, it was found that titanium di-n-butoxide bis(2-ethylhexanoate) material possesses low enough viscosity to achieve an easy imprinting under low applied pressures.

Ellipsometry measurements were performed on titanium di-n-butoxide bis(2-ethylhexanoate) thin films annealed at different temperatures T in order to measure their refractive index. Refractive indexes (at 1 µm) up to 2.04 (see Figure 1b) were measured for the annealed samples.

It was also found that the TiO_2 material presents high mechanical integrity which helps avoid pattern breaking or collapse during mold release. In addition, relatively low shrinkage induced by a post-annealing process was demonstrated for this inorganic precursor since the lateral dimensions decreased only from 300 nm to 240 nm after annealing (see Figures 1c and 1d).

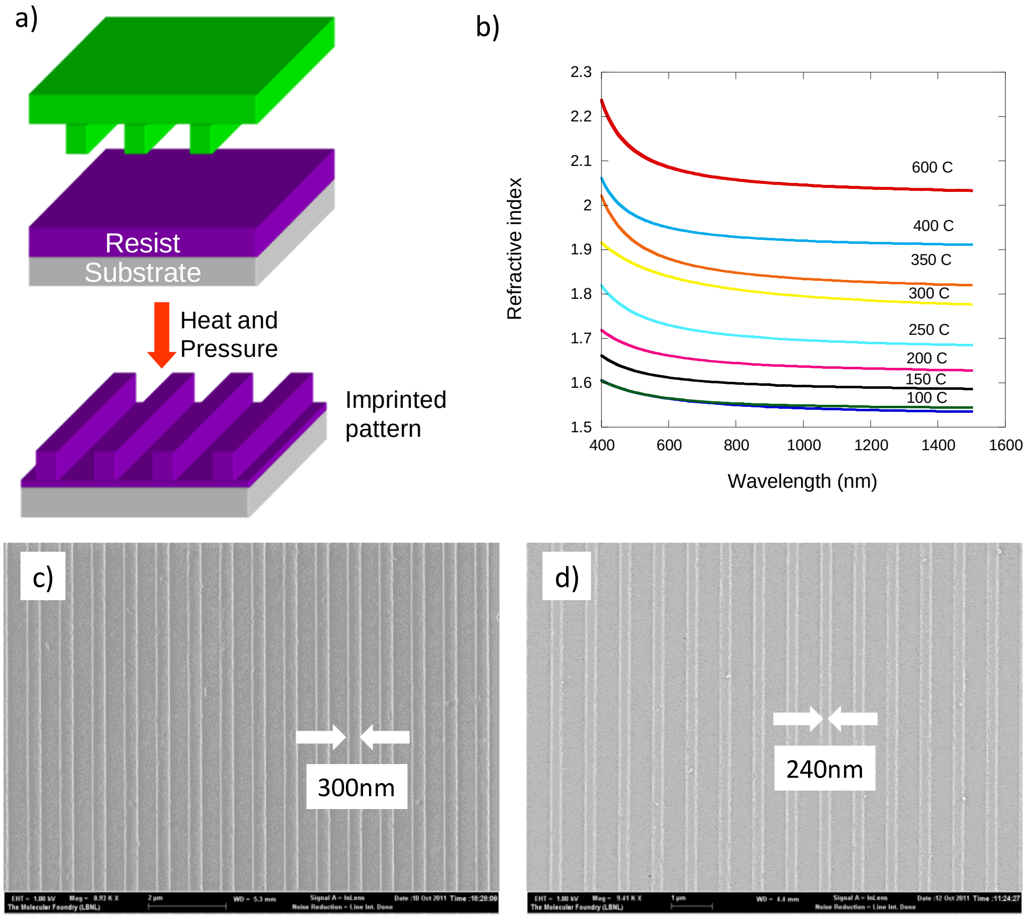

Figure 1: (a) Schematics of the imprint lithography process; (b) ellipsometry measurements of the refractive index of TiO_2 films for various annealing temperatures; (c) SEM of titanium di-n-butoxide bis(2-ethylhexanoate) sample after imprinting and (d) after annealing.

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