Scalable Nanofabrication of High Index Optical Components Using Nanoimprint Lithography

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Applications in photonics such as augmented reality waveguides and metalenses can comprise of high refractive index (>1.9) nanostructures of complex geometries[1,2] (aspect ratios approaching 10:1 and critical dimensions approaching 1/10th the operational wavelength). Current manufacturing processes of the aforementioned applications typically include fabrication of nanostructures with lower index organic resist (1.5-1.7), or high index inorganic nanostructures etched using ion beam milling[3] that is defect prone and prohibits 3D nanoshapes and smaller critical sizes whereas certain processes use e-beam lithography[4]. All these processes are unable to meet the requirements of throughput and optical performance simultaneously.

In this paper, we have introduced a scalable process of fabricating of high index nanostructures with complex geometries. As shown in Fig. 1, a detackable[5] adhesive is coated on a bare substrate. In this study, a water-soluble polymer coat has been used. Wafer-scale nanoimprint lithography is then performed using MonoMat™ resist by Canon Nanotechnologies (CNT). It is followed by deposition of an adhesion promotor layer (TranSpin™ by CNT). High index silicon nitride (index of 1.9) is deposited at 50 °C using PECVD until the trenches of the patterned resist are completely filled and a flat layer of nitride is obtained on the top. Another layer of TranSpin™ is then dispensed. This processed substrate with high index nitride in the trenches is bonded to a bare fused silica wafer using MonoMat as a bonding adhesive where the bonding processes is performed using a nanoimprint equipment. This bonded stack is then kept in a water bath for the detacking adhesive to dissolve completely. This transfers the high index nanostructures to the fused silica substrate (i.e. final device substrate). An oxygen plasma etches all remainder organic resist and reveals the high index silicon nitride nanostructures on the fused silica substrate. Fig. 2 shows the process results and SEM of the transferred silicon nitride nanostructures. This experimental results validate that high index nanostructures can be fabricated using high throughput processes like nanoimprint lithography and while avoiding defect-prone nanoscale etch steps thereby possibly meeting the requirements of manufacturing throughput and optical performance simultaneously.

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[1] Kress, B.C. et al. 2021. Nanophotonics, 10(1), pp.41-74

[2] Chen, W.T., et al. 2020. Nature Reviews Materials, 5(8), pp.604-620.

[3] Eibelhuber, M. et al., 2021, March. In Optical Architectures for Displays and Sensing in Augmented, Virtual, and Mixed Reality (AR, VR, MR) II (Vol. 11765, pp. 103-108). SPIE.

[4] Khorasaninejad, M. et al., 2016. IEEE Journal of Selected Topics in Quantum Electronics, 23(3), pp.43-58

[5] ability to significantly reduce the tackiness of an adhesive on-command

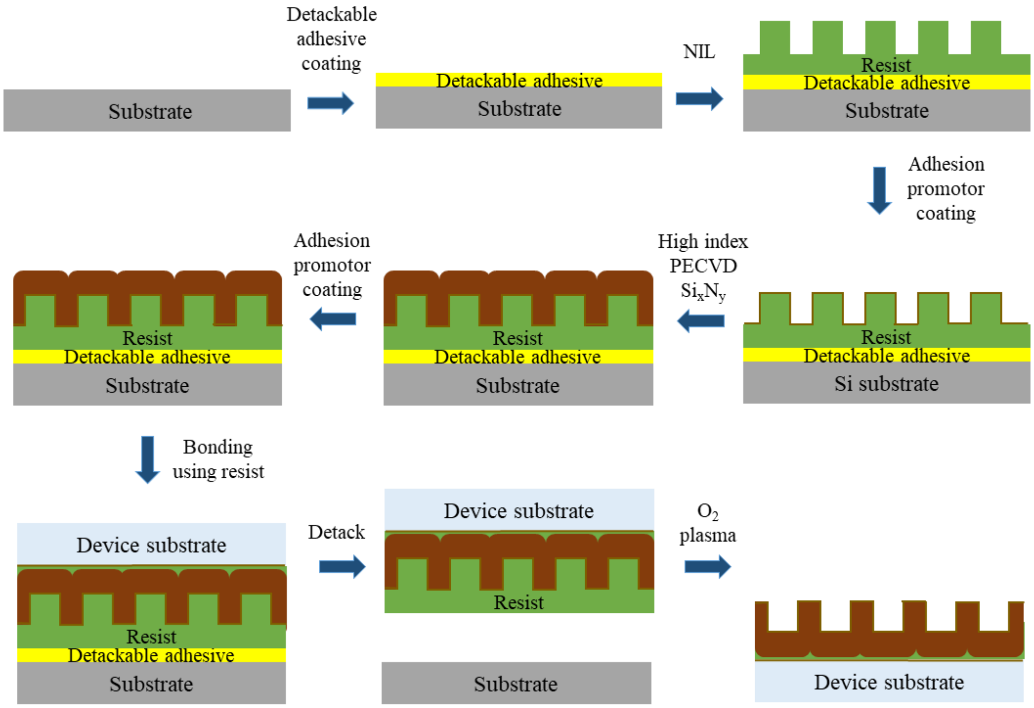
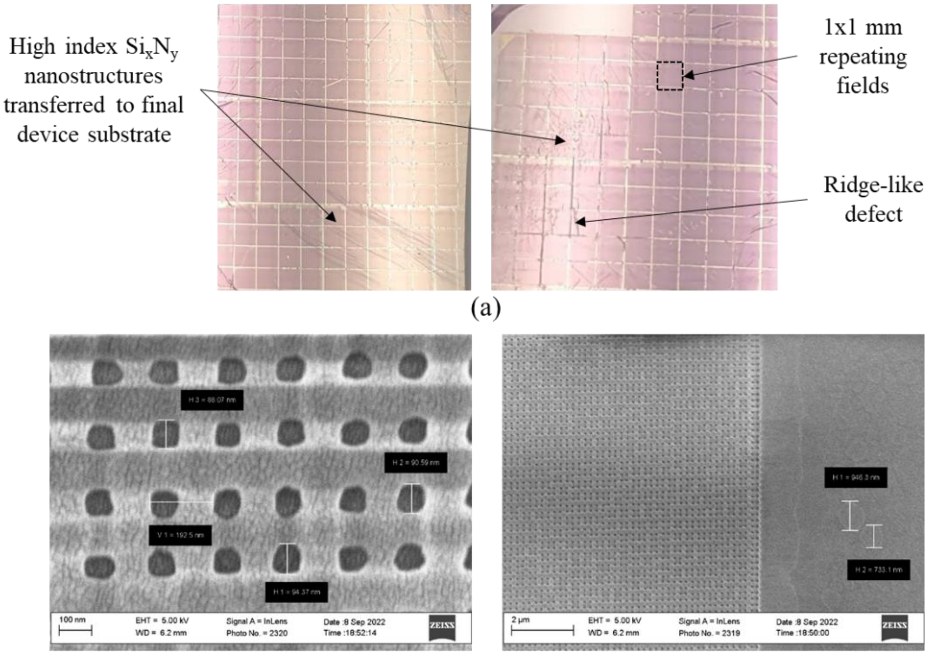


Figure 1: Process flow: Transferring nanostructures made of silicon nitride to a final device substrate using nanoimprint lithography and a detackable adhesive



(a)

(b)

Figure 2: Process results: a) Transferred high index Si_xN_y nano-holes (100 nm diameter) on final device substrate, b) SEM of transferred Si_xN_y nano-holes