Scalable Metasurfaces for Ultrasensitive Biosensing

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Building upon a long-established history of plasmonic and nanophotonic biosensors, the recent advancements in metasurfaces have brought to light exciting new possibilities, such as tailor-designed high-Q resonances, spectrometer-less and imaging-based sensing[1]. However, there is still a major challenge towards the widespread implementation of metasurface technology, for either sensing or wavefront engineering: optical metasurface manufacturing largely relies on top-down lithographic techniques such as electron beam lithography (EBL), focused ion beam (FIB), which provide high resolution at a price of low throughput, making it very difficult for high-volume production or large area metasurfaces. Here, we demonstrate scalable manufacturing of metasurfaces using the self-assembly approach of nanosphere lithography, which is versatile in terms of material selection, nanopattern geometry and dimension tunablity.

Taking gold nanohole arrays as an example, the metasurface geometric parameters are tuned by the following: the period is determined by the original PS bead size, the nanohole diameter is determined by the Oxygen plasma etching, while the thickness is determined by electron beam deposition. We started with 600 nm PS beads assembly on glass coverslips, and etched the diameter to 320 nm for gold deposition of 50 nm (Fig. 1a). For the optofluidic integration, a polydimethylsiloxane (PDMS) chamber was formed in a mold, and then bonded on top of the metasurface after Oxygen plasma treatment (Fig. 1b). In the medium of DI water, a transmission resonance dip was found near the wavelength of 735 nm using a spectroscopy setup. By changing media with different refractive indexes (RI), the bulk RI sensitivity was measured as 498 nm/RIU, with a limit of detection (LOD) down to 6.28×10^{-4} RIU (Fig. 1c). It matches well with simulations, and approaches that of the state-of-the-art devices fabricated by EBL[2] or FIB[3]. The metasurface sensor was functionalized to detect biomolecules (e.g., streptavidin, IgG) with a LOD ~3 pM (Fig. 1d), which can be further customized for various biosensing targets. Overall, using the self-assembly approach of nanosphere lithography, our scalable meta-sensors achieved sensing performance comparable to devices manufactured by top-down lithographic techniques. While gold nanohole arrays were demonstrated as an example, our method can be applied to other dielectric metasurfaces, and broad biosensing applications.

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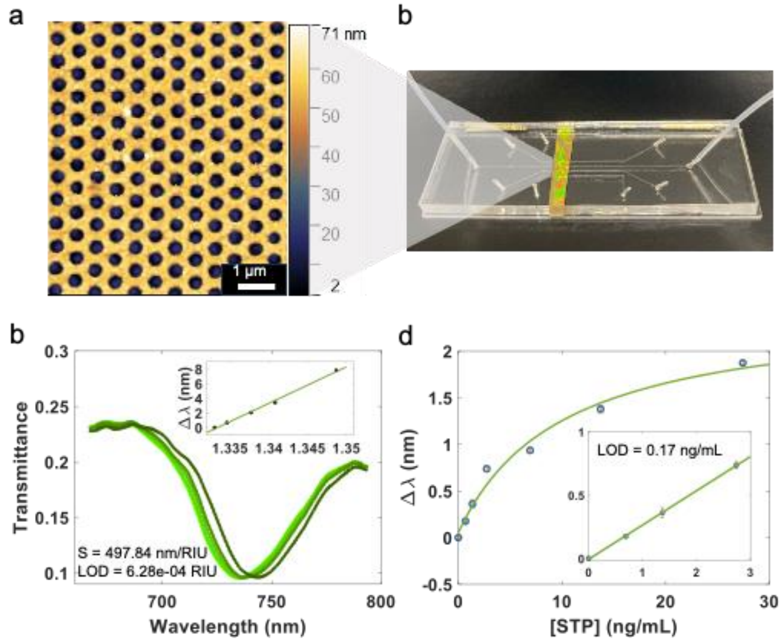

Figure 1: (a) Atomic force microscope (AFM) image of the fabricated gold nanohole array. (b) An integrated sensor composed of scalable metasurfaces and microfluidics. (c) Refractive index sensing. (d) Biomolecular detection demonstrated by streptavidin.