Reversal Nanoimprinted Highly Sensitive Plasmonic Sensor around Microposts for DNA Detection

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Plasmonic sensors based on localized surface plasmon resonance (LSPR) are widely used for label-free, real-time biomolecules detection, including DNA analysis. Conventional LSPR sensors rely on two-dimensional nanopatterns and typically exhibit sensitivities below 500 nm per refractive index unit (RIU). Although multiple-layer three-dimensional (3D) plasmonic photonic crystal biosensors with sensitivity up to 1376 nm/RIU have been reported, their multiple-step fabrication, stringent layer alignment, and limited analyte binding surfaces restrict scalability for practical biosensing. In this study, Au nanopillars were formed around microposts using reversal nanoimprint. Introduction of microposts increases the available plasmonic surface area significantly and enhances light-matter interaction, thereby increasing sensing performance.

Figure 1 illustrates the fabrication technology. First, SU-8 nanopillars were nanoimprinted on a silicon (Si) substrate. 10% (weight by volume) polyvinyl alcohol (PVA) solution was cast over the nanopillars and cured at 25 °C for 48 h, forming a flexible PVA stamp with the SU-8 nanopillars. In addition, a Si micropost stamp was fabricated by photolithography and deep reactive ion etching, and replicated into an intermediate polymer stamp (IPS). Using this IPS, SU-8 microposts were imprinted on glass. The nanopillars were then conformally transferred around the microposts via reversal nanoimprint using the PVA stamp, follow by dissolution of PVA in deionized water for 5 h. Finally, 2 nm thick chromium (Cr) and 20 nm thick gold (Au) were deposited by thermal evaporation to form Au nanopillars around the microposts. Micrographs of Au nanopillars around 5 and 10 μm tall microposts are shown in Fig. 2.

The extinction spectra and resonance wavelength shift for solutions with different refractive index (RI) are presented in Figs. 3(a1–a2) for Au nanopillars on flat surface. The Au nanopillars, with width, pitch, height, and Cr/Au thicknesses of 280, 535, 500, and 2/20 nm, respectively, exhibited a resonance peak at 1067 nm and a sensitivity of 430 nm/RIU for solutions with RI values between 1.30 and 1.39. When these nanopillars were wrapped around 5 μm tall microposts, the resonance peak near 1060 nm showed an enhanced sensitivity of 633 nm/RIU, as indicated in Figs. 3(b1-b2). For 10 μm tall microposts, the resonance peak occurred at 1245 nm, and the sensitivity reached 1216 nm/RIU, as shown in Figs. 3(c1-c2). These results indicate that forming 3D plasmonic sensor around microposts could be used to enhance plasmonic sensor detection sensitivity substantially by increasing the density of nanopillars that was reverse nanoimprinted over microposts.

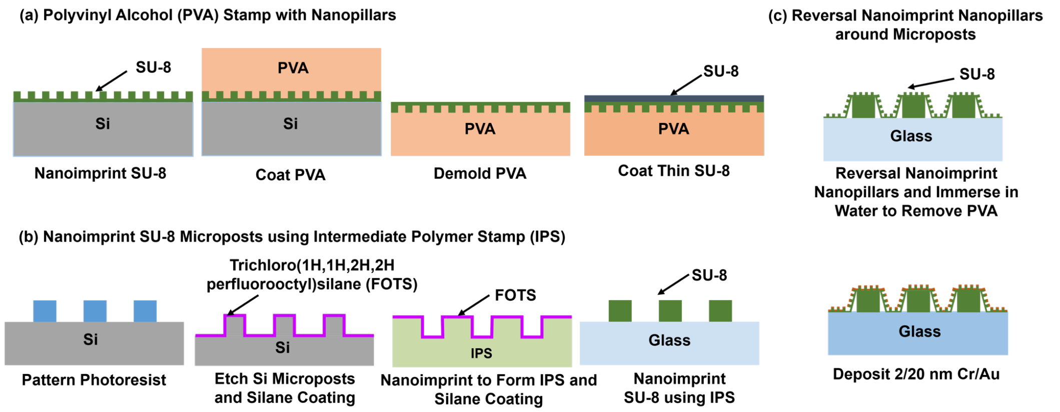

Figure 1: Schematics of fabrication technology for Au nanopillars around microposts.

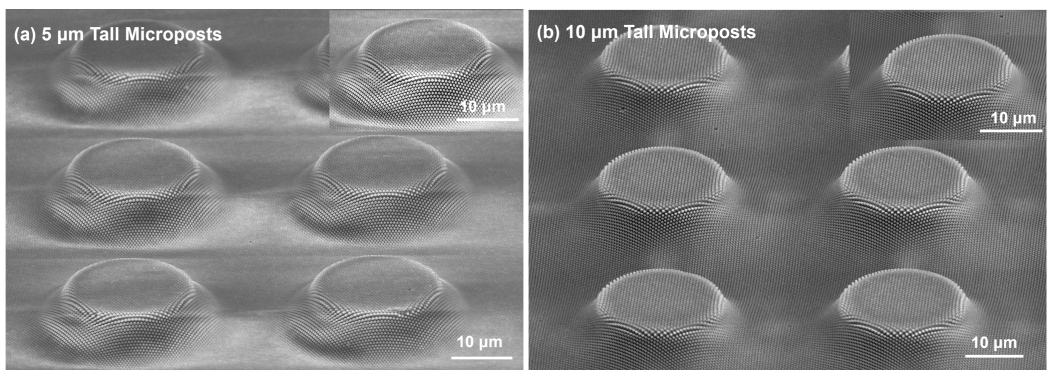

Figure 2: Micrographs of Au nanopillars around 5 and 10 µm tall microposts.

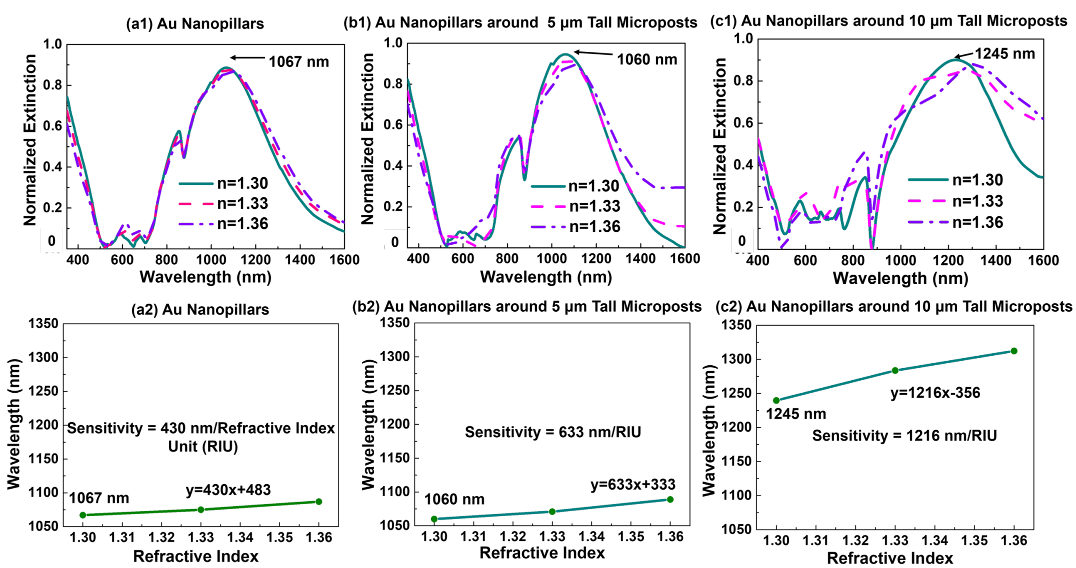

Figure 3: Extinction spectra and resonance peaks as function of refractive index of certified solutions.