Flexible large-area plasmonic gold nanocheckerboard fabricated by cost-effective solution process for highly sensitive refractive index sensing in visible range

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Localized surface plasmon resonance (LSPR) based sensors have found wide applications in medical diagnosis [1], food safety evaluation [2], and environmental pollution monitoring [3]. LSPR sensors are capable of high-sensitivity, label-free, high-throughput, and real-time detection. However, the fabrication process of LSPR sensors is still complicated and expensive, which severely restricts the applications of LSPR sensors. On the other hand, most of the recent studies mainly focused on the fabrication of LSPR sensors on rigid substrates like glass or silicon. Plastic substrates featuring flexibility, high transparency, low cost, and light weight are desirable as they would offer great merits for detection on non-flat surfaces and enable practical consumer applications of LSPR sensors. In this research, a facile and cost-effective fabrication process of flexible SPR sensors on plastic substrates was demonstrated. The fabrication method is a vacuum-free, solution-processed strategy which combines lithography, electrodeposition, and imprint transfer, termed LEIT strategy. Moreover, the sensitivity of our fabricated LSPR sensors was determined to be 435.1 nm RIU^{-1}, which was among the best performance achieved in the visible range.

Figure 1 demonstrates the LEIT fabrication process of flexible LSPR sensors. After the photoresist is spin-coated on a cleaned indium tin oxide (ITO) glass substrate, interference lithography is conducted to create nanostructured patterns (Figure 1a). Then gold is electrodeposited inside the nanotrenchs (Figure 1b). Next, the photoresist is removed through immersing the substrate in acetone (Figure 1c). Thereafter, a thermoplastic film is placed on the gold nanostructures and heated to above its glass transition temperature. Pressure is then applied to press the gold nanostructures into the softened plastic film (Figure 1d). Finally, the gold nanostructures were fully transferred and embedded in the plastic film by a thermal imprinting process (Figure 1e). Figure 1f displays the embedded gold nanocheckerboard on the plastic film and the photo demonstrated the flexibility of the sensor. Figure 2 shows the refractive index sensing using the LSPR sensor. A relatively high sensitivity of 435.1 nm RIU^{-1} was observed from peak P1. We also observed excellent stability of our flexible LSPR sensors under repetitive bendings. The figure of merit decreases by only 30% for a radius of 3 mm up to 1000 times bending experiments.

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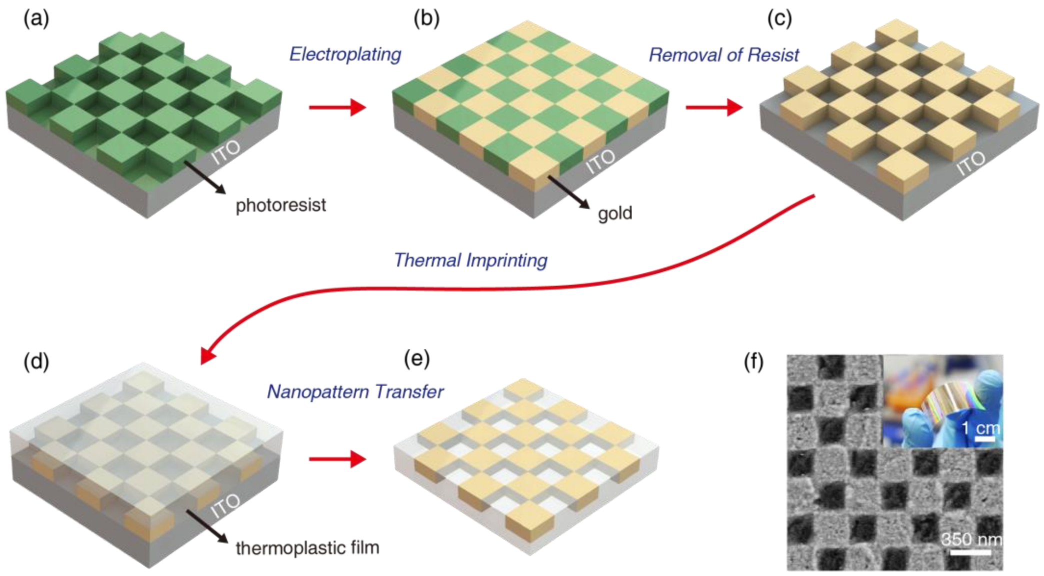

Figure 1. (a-e) Schematic illustration of the fabrication of a flexible LSPR sensor through LEIT strategy. (f) SEM image and photo of a flexible LSPR sensor.

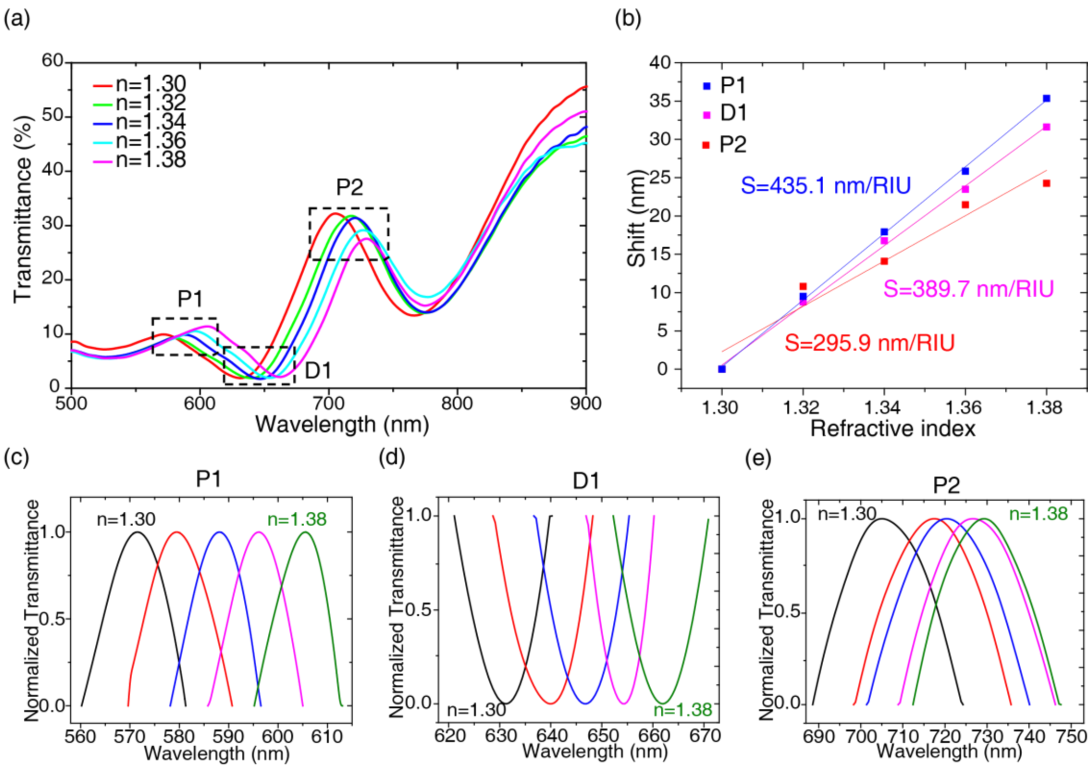

Figure 2. Refractive index sensing using the flexible LSPR sensor. (a) Transmission spectra of the film when surrounded by liquids with different refractive indices at normal incidence. (b) Plot of spectral shift versus surrounding refractive index. The lines are linear fitted, with the refractive index sensitivities of P1, D1 and P2 are determined to be 435.1 nm RIU^{-1}, 389.7 nm RIU^{-1} and 295.9 nm RIU^{-1}, respectively. (c – e) Normalized transmission spectra of (c) P1, (d) D1 and (e) P2 in the spectral region indicated with the dashed boxes in a.