MICROFLUIDIC FABRICATION OF HIERARCHICAL PHOTONIC CRYSTAL MICROSPHERES AND THEIR APPLICATIONS

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ABSTRACT

We report a robust method to fabricate hierarchical photonic crystal microspheres (HPCs) with tailored multi-scale structures, versatile surface topologies, and tunable optical properties. These produced HPCs consist of well-distributed gold nanoparticles (AuNPs) (as 3rd-tier) anchored on close-packed silica (SiO_2NPs) nanopatterns (as 2nd-tier), which are assembled by SiO_2NPs confined into micrometer spherical templates (1st-tier). These HPCs possess both photonic stop band (PSB) and surface plasmon resonance (SPR) properties. Thus, these microspheres can be applied in biochemical sensors, superwetting and surface enhanced Raman spectroscopy (SERS).

KEYWORDS: Droplet microfluidics, dewetting, photonic stop band (PSB), surface plasmon resonance (SPR)

INTRODUCTION

Although photonic crystals (PCs) and noble metal nanoparticles have been reported in literature for their specific optical properties and highly flexible controllability, few works have reported on the combination of the PCs with noble metal nanoparticles [1,2], providing synergistically functional properties. The distribution of AuNCs on the PC structures was still random, being lack of a method to well control the combination of both materials and structures to tune the synergistic interaction of the PSB and SPPR properties. In this work, we report a robust and facile method to fabricate HPCs with tailorable multi-scale structures, versatile surface topologies, and controllable optical properties, *via* combining droplet microfluidics with metal thin film deposition and thermal annealing process.

EXPERIMENTAL

An aqueous suspension of SiO_2NPs (with varying diameter from 200 nm to 300 nm) is used to generate uniform droplets (Figure 1a). After SiO_2NPs self-assembly and solidification by thermal evaporation, two-tier PCs of approximately 20 μm in diameter were obtained (Figure 1b). Subsequently, a thin Au film was deposited on the surface (Figure 1c), followed by thermal annealing (Figure 1d), thus yielding three-tier PCs with varying surface topologies.

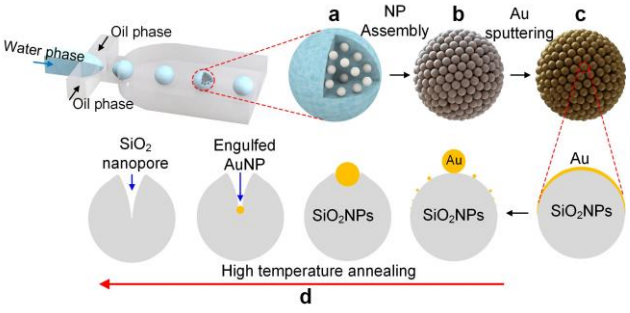

Figure 1: Fabrication procedure of HPCs. (a) Monodispersed microdroplet generation via a droplet generator, (b) Two-tier PCs featuring close-packed SiO_2NPs nanopatterns, (c) Thin Au film deposition on the as-prepared two-tier PCs; (d) Thermal annealing resulting in three-tier PCs with different surface topologies.

RESULTS AND DISCUSSION

The surface topologies of the three-tier PCs are found to depend on the Au film thickness and annealing programs, as shown in Figure 2. It turned out that the optical properties of these fabricated HPCs can be tuned by varying the SiO_2NP size and Au film thickness. Figure 3 shows application of the produced HPCs for superwetting, refractive index sensing, and SERS.

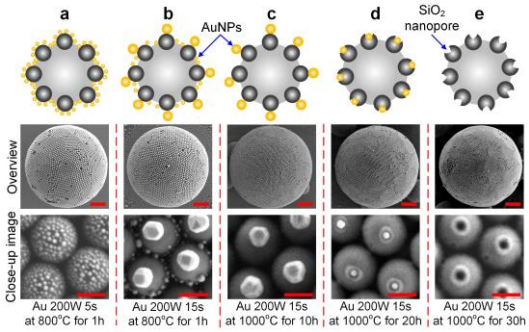

Figure 2: (Bottom) Top-view HR-SEM images (scale bar: 2 μm) of three-tier PCs with various surface topologies (close-up images, scale bar: 200 nm), and (Top) their corresponding schematics. Topologies differ depending on the thermal annealing protocol.

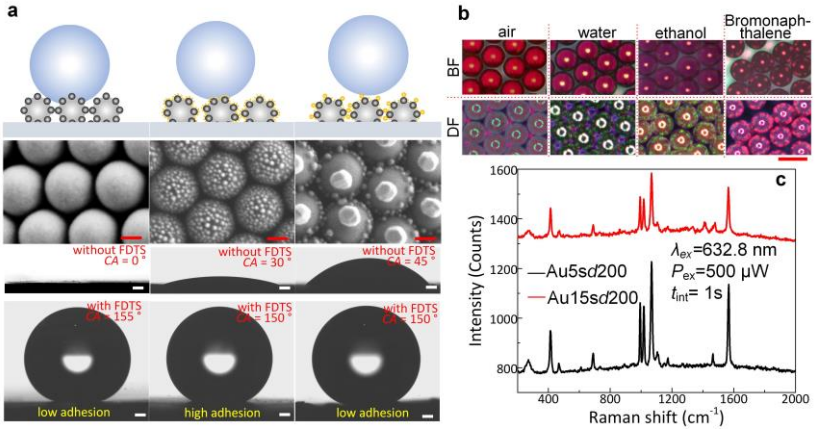

Figure 3: Application demonstration of the HPCs for (a) superwetting, (b) refractive index sensing, (c) SERS detection. The produced HPCs used above consist of different size SiO_2NPs and AuNPs. The thermal annealing condition is the same: in N_2 at 800°C for 1 h in a tube furnace. Perfluorodecyltrichlorosilane (FDTS) was used for surface coating. Scale bars in (a) 100 nm and 200 μm, respectively and in (b) 25 μm.

CONCLUSION

In conclusion, HPCs featuring both SiO_2NP and AuNC nanopatterns and possessing both PSB and SPR properties have been successfully fabricated. Their properties can be easily tuned by varying the SiO_2NP size and thickness of Au film. We furthermore demonstrated their superwetting, refractive index sensing and SERS properties.

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