Refractive Index and Temperature Sensing Using a Plasmonic Optical Fiber Probe Fabricated by Double-Transfer Nanoimprint Lithography

Shijie LI and Wen-Di LI*

Department of Mechanical Engineering, Univ. of Hong Kong, Hong Kong, China

*liwd@hku.hk

Surface plasmon resonance (SPR) on periodic subwavelength metallic structures has drawn much attention on sensing applications because of its strong sensitivity to surrounding refractive index changes.[1] Integrating SPR nanostructure on optical fiber can realize more accessible and versatile plasmonic sensing applications especially in field-based systems, owing to desirable features of optical fiber e.g. small size, low cost and good compatibility.[2] Among all the nanofabrication techniques[3], nanoimprinit lithography(NIL) exhibits great merits in low cost and high throughput and thus it is exploited to fabricate plasmonic nanostructure on fiber facet.

In this work, we use double transfer UV-NIL to transfer metal nanostructures from a cyclic olefin copolymer (COC) mold to the fiber facet with 200μm diameter core size. Once a COC mold carrying pillar array is fabricated by thermal embossing, gold was deposited on it by thermal evaporation. Then the metal nanostructure is transferred onto fiber facet by cross-linked UV-cured resist, as shown in Fig.1. The transferred metallic nanostructures feature closely spaced double layers of disks and holes. The electric field is enhanced in between the metal disk and hole and generates resonant dip in reflection spectra.

The plasmonic fiber probe was connected to halogen light source and spectrometer by bifurcated fiber when nanostructured fiber end was inserted into liquid under test, as shown in Fig.2 (a). Index liquid with refractive index ranging from 1.40 to 1.45 was measured and plotted in Fig.2 (b-c). In order to investigate the temperature sensitivity of this plasmonic fiber probe, the nanostructured fiber end was put into hot water to record its resonant dip shift during cooling. Refractive index of water has negative correlation of its temperature variation when resonant wavelength shift captured from fiber probe showed same trend in Fig.2 (d-e).

FDTD simulation was performed based on SEM observation of the double layer structure and its calculated reflection meets well with experimental result. The electric field distribution was also investigated and it showed sensitivity increased when electric field enhancement located close to detected index environment.

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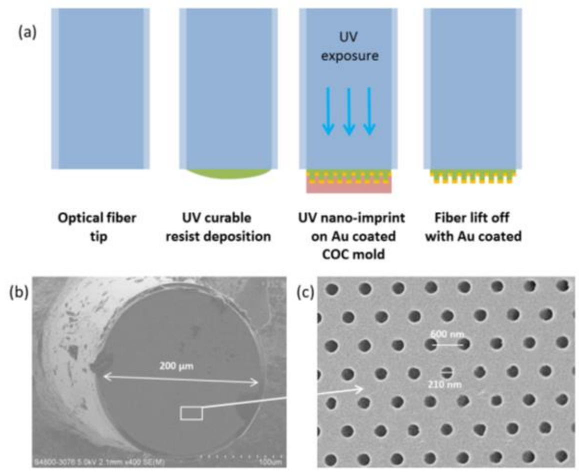

Fig. 1. (a) Schematic of double-transfer nanoimprint lithography on optical fiber facet. (b) SEM image showing fiber facet after metallic nanostructure NIL. (c) Zoom-in SEM image of corresponding area in (b), showing 600nm period hexagonal hole array pattern

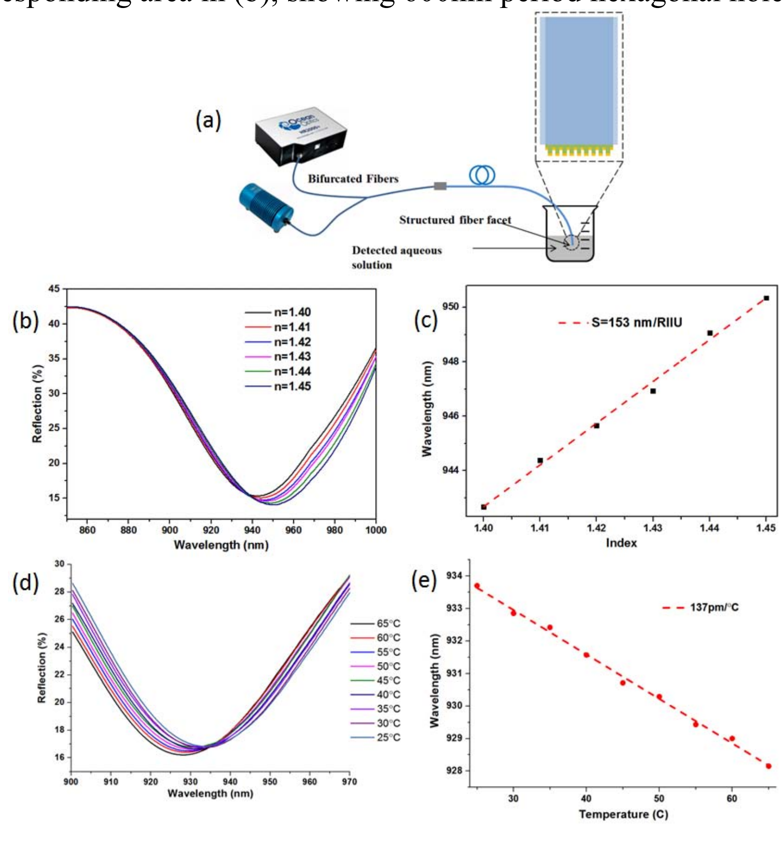

Fig.2. (a) Optical setup for the plasmonic fiber probe based on reflection spectra measurement. (b) Measured reflection spectra for the fiber probe in different index liquid. (c) Relative wavelength shifts of the reflection dips as a function of the refractive index. (d) Measured reflection spectra for the fiber probe in water with different temperature. (e) Relative wavelength shifts of the reflection dips as a function of the temperature