Lab-on-a-fiber Sensors with Nanoimprinted Nanostructures on Fiber Sidewall

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Nanoimprint lithography (NIL) is a promising method that can fabricate nanostructures with high resolution, high throughput and low cost [1]. Since this technology was developed, it has been used in many different fields such as photonics[2], bio-sensing[3], etc. Integration of NIL or other fabrication technology with optical fiber results in a new concept “lab-on-fiber” [4].

In this work, we proposed a fabrication method to create nanoscale structures on the sidewall of a plastic optical fiber (POF) to demonstrate a new form of “lab-on-fiber” for light-matter interaction. We then used this fiber sensor to detect the environment refreactive index (RI) as an application demonstration. And a theoretical model was developed to explain the experimental phenomenon.

Fig. 1a showed the schematic of experimental setup for nanoimprinting on the sidewall of POF. The imprinting temperature was controlled by a hot wind gun. A copper stick was used to press POF into a silicon mold carrying grating patterns with period of 278nm, depth of 110nm and duty cycle of 1:1. Images of the POF after nanoimprint from top, side, and bottom view were provided in Fig. 1b. The transferred pattern was on the bottom side, and corresponding SEM images were showed in Fig. 1c. Thermal expansion and contraction of POF caused a little distortion of the grating lines.

In Fig. 2a, the reflection measurement setup (top) was illustrated. Light from a broadband source or a laser was guided into POF through a Y-shape fiber, the reflected light was collected by a spectrometer or a photodetector. Bottom figure showed the schematic of the model we developed to simulate the reflection caused by the imprinted region of POF. The measured and simulated reflectance of POF in air was plotted, and they agree well with each other. To construct a highly sensitive RI sensor, 30 nm gold was deposited on the POF for RI detection. The reflection spectrum in media with different RI was plotted in Fig. 2c with a schematic of the gold coated grating inserted. Linear fit and original peak positon (blue) with RI was plotted in Fig. 2d. Besides this peak position method, another method was to measure reflection intensity with a 650nm laser as light source, and corresponding intensity (red) was also plotted in Fig. 2d.

In summary, we propose a NIL method to fabricate structures on sidewall of fibers, and a model was developed to explain the reflection at imprinted region. Finally, RI detection was conducted using this fiber as a probe.

[1] S. Y. Chou, P. R. Krauss, and P. J. Renstrom, Applied Physics Letters **67**, 3114 (1995).

[2] W.-D. Li, F. Ding, J. Hu, and S. Y. Chou, Optics Express **19**, 3925 (2011).

[3] R. Alvarez-Puebla, B. Cui, J.-P. Bravo-Vasquez, T. Veres, and H. Fenniri, The Journal of Physical Chemistry C **111**, 6720 (2007).

[4] M. Consales, A. Ricciardi, A. Crescitelli, E. Esposito, A. Cutolo, and A. Cusano, ACS Nano **6**, 3163 (2012).

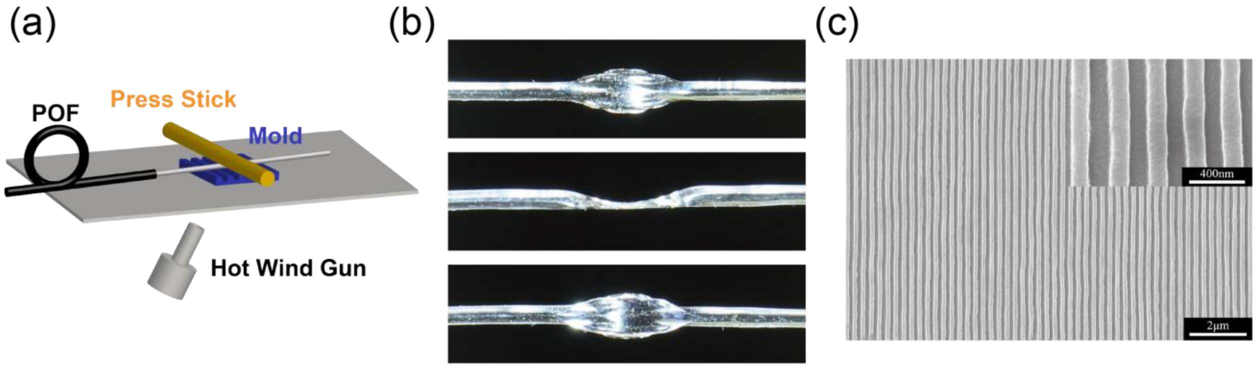

Fig.1 (a) Schematic of thermal nanoimprint setup for POF; (b) Images of POF after imprint from top, side and bottom view; (c) SEM images of the transferred grating pattern on the bottom of the POF

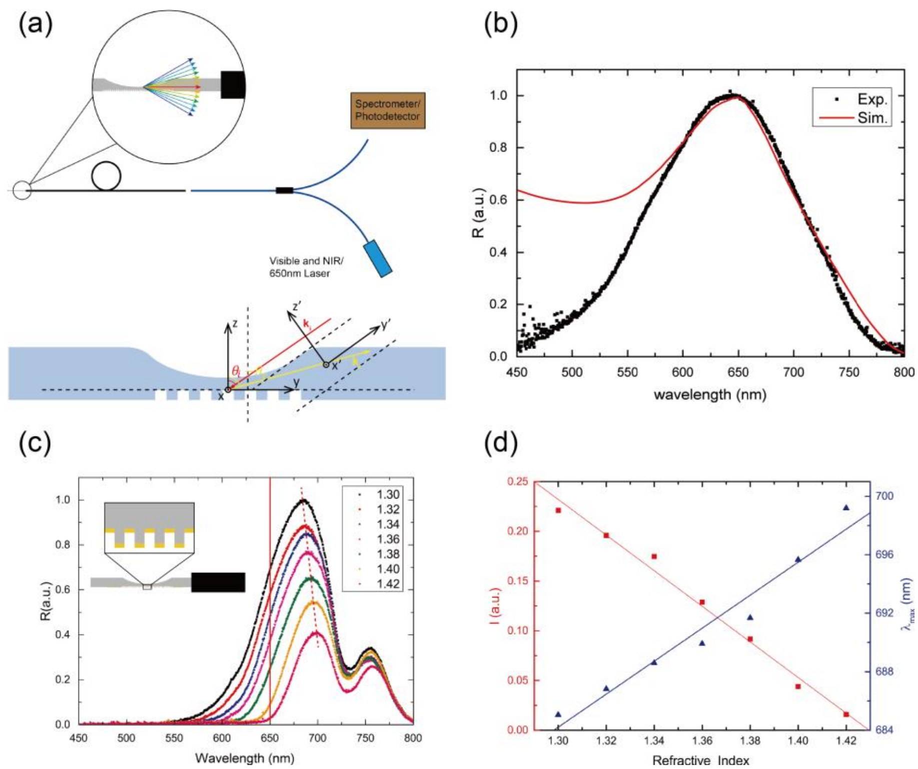

Fig.2 (a) Schematic of reflection measurement setup (top) and an analytical model used to investigate the reflection nature (bottom); (b) Measured and simulated reflectance of imprinted POF in air without any metal coating; (c) Reflection spectrum of POF after 30nm Au layer deposition, inset picture is a schematic of the gold deposited grating; (d) Refractive index detection result of monochromatic intensity method and peak position method.