Squeezed Hollow Core Photonic Bragg fiber for surface sensing applications

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Abstract: We demonstrate theoretically and confirm experimentally that squeezing a section of the Bragg fiber core increases overlap between the optical fields of the core-guided modes and the modes bound to the sensing layer, which, in turn, enhances surface sensitivity of the fiber sensor.
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1. Introduction

Photonic crystal fibers, in particular hollow-core photonic Bragg fibers, have enormous potential for chemical and biological sensing applications, owing to a number of unique advantages such as high sensitivity, fast response, small volume requirement of samples, ease of fabrication, and potential for detection of specifity [2]. In this work, we propose and demonstrate a hollow-core Bragg fiber for surface sensing applications.

2. Hollow core photonic Bragg fiber

The Bragg fiber used in our sensor features a large hollow core (D~600μm) surrounded by a period sequence of high and low refractive index layers, namely polystyrene (PS)/poly-methacrylate (PMMA) Bragg reflector. As a demonstration of the Bragg fiber for surface sensing, we undertake the study of dissolution dynamics of a thin analyte film deposited on the fiber core inner surface. A thin layer of Polyvinyl butyral (PVB) layer is first deposited on the inner surface of the fiber using a solution-based method [1]. The cross section of the Bragg fiber with a PVB layer is shown in Fig. 1. The thickness of the PVB layer is estimated to be ~500nm.

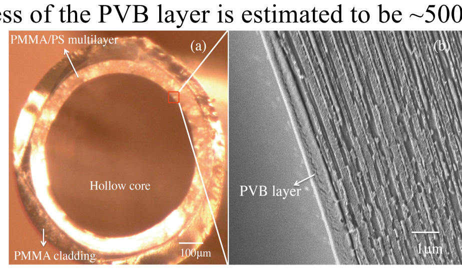

Fig. 1. Cross section of the fiber under microscope (a) and SEM (b).

3. Characterization of dissolution dynamics of the PVB analyte layer

First, we characterize the surface sensitivity of the Bragg fiber sensor without squeezing. The time varying transmission spectra are acquired every minute after introducing ethyl alcohol into fiber. As shown in Fig. 2, with the dissolution of the PVB layer, a blue shift is observed with the decrease of PVB layer thickness. By comparing the transmission peaks of the fiber measured before and after the dissolution allows us to calculate the surface sensitivity of the Bragg fiber. The obtained surface sensitivity is ~0.05nm/nm when the fiber is filled with water.

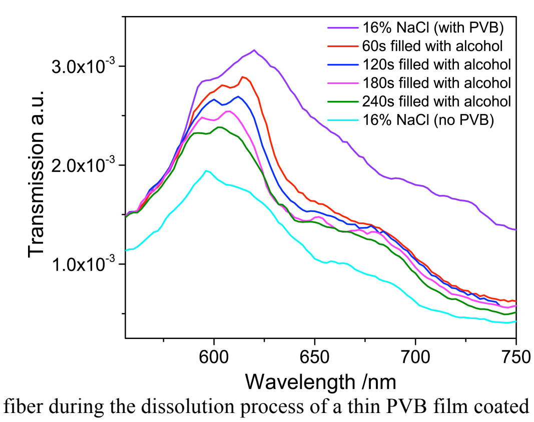

Fig. 2.Transmission spectra of the fiber during the dissolution process of a thin PVB film coated on the inner surface of the fiber core.

4. Enhancement of the surface sensitivity by squeezing the Bragg fiber

Due to the large core of the Bragg fiber (significantly larger than the wavelength of light and the analyte layer thickness), only a small fraction of the power of the core-guided mode is present in the vicinity of the inner surface of the fiber core, thus leading to a poor modal overlap with the PVB analyte layer; therefore, only a moderate surface sensitivity is observed experimentally. In order to enhance the surface sensitivity, we propose squeezing a section of the Bragg fiber using a metalic rod fixed on the micropositioning stage. Squeezing of the fiber in one dimension effectively enhances the modal overlap with the analyte layer [1]. We choose the same Bragg fiber, as well as the same recipe for the PVB film deposition. We then characterize the surface sensitivity using the same method presented in Section 3. As shown in Fig. 3, the surface sensitivities of the squeezed fiber are enhanced by ~35% and ~30% when the fiber is filled with distilled water and 16% NaCl solution, compared to that of a non-squeezed fiber. The mechanism of sensitivity enhancement is due to increased overlap between the core modes and the PVB film when the fiber is squeezed.

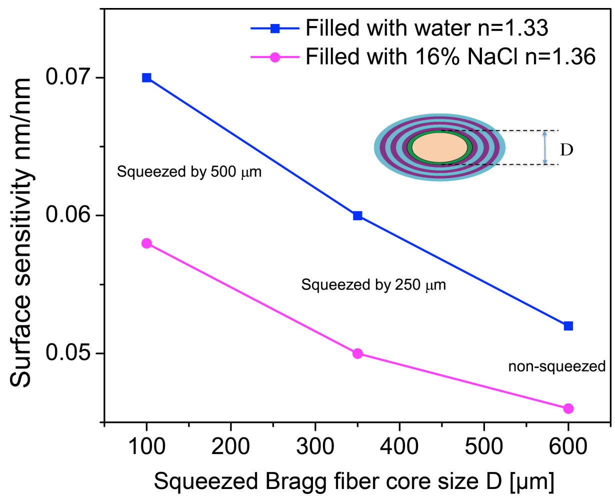

Fig. 3. Surface sensitivities of the hollow-core Bragg fiber sensor filled with water and NaCl solution at various degrees of squeezing.

5. Conclusion

In summary, we study, both theoretically and experimentally, the use of hollow-core Bragg fibers for surface sensing applications. The fiber sensor operates using a spectral sensing modality to monitor changes in the thickness of an analyte layer deposited on the inner surface of the Bragg fiber core. As a practical demonstration, we have applied this sensor to monitor the dissolution dynamics of a thin PVB layer coated on the fiber inner surface. A surface sensitivity of 0.052nm/nm is experimentally achieved with aqueous analyte. Moreover, we have also experimentally demonstrated that squeezing a section of the Bragg fiber effectively increases the overlap between the core-guided modes and the analyte layer, thus enhancing the surface sensitivity of the fiber sensor. The highest surface sensitivity achieved in our work is 0.07nm/nm with the squeezed fiber core size of 100µm. The experimental observations are validated by theoretical simulation based on the transfer matrix method. The proposed liquid-core Bragg fiber sensor is applicable to a wide range of surface sensing applications including molecular recognition, bacteria detection, and monitoring of the biolayer thickness variation and others, with the advantages of simplicity in sensing mechanism, short response time, ease of fabrication, and relatively high sensitivity

6. References

[1] J. Li, H. Qu, M. Skorobogatiy, "Squeezed hollow core photonic Bragg fiber for surface sensing application," Optics Express **24,** 15687-15691 (2016).

[2] J. Li, H. Qu, M. Skorobogatiy, "Simultaneous monitoring the real and imaginary parts of the analyte refractive index using liquid-core photonic bandgap Bragg fibers," Optics Express **23,** 22963-22976 (2015).