Novel bio-sensing platform based on TFBG and multifunctional 3D nanoflower

Yuting Sun, Yujie Wang*, Yunting Du, Ming Chen, Haining Xu, Fang Wang,

Bowen Wang, Yang Zhang* and Wei Peng

College of Physics

Dalian University of Technology, Dalian, Liaoning

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Introduction

We presented a multifunctional refractive index (RI) bio-sensing platform based on tilted fiber Bragg grating (TFBG) modified with Zinc oxide nanoflower. TFBG mode coupling coefficient or the amplitude of cladding mode will vary sharply with the imaginary part of permittivity of the Zinc oxide nanoflowers. It has been demonstrated that the resonance intensity of the cladding mode decreases obviously with the addition of multifunctional nanoflower. In the experiments two self-assembly methods including silane coupler and polyelectrolytes were introduced to coat ZnO nanoflower on TFBG. By chosing different method and repeating dipping cycle, different thickness of the nanoflower layer could be achieved. Moreover, the refractive index sensitivities of ZnO coated TFBG sensors are respectively 18.4dB/RIU and 22.96dB/RIU, which are significantly improved 5 times compared to conventional bare TFBG. Benefting from strong electron transfer and adsorption as well as stability and high surface to volume ratio of ZnO, this ZnO coated TFBG RI sensor are significant and valuable for high-sensitivity and cost-effective biosensing applications.

Experiment Setup

Method one

A commonly used TFBG surface-modification method is to use a chemical linker, e.g., 3-aminopropyl triethoxysilance (APTES), which immobilizes the receptor and anchors to the silica sheath of the TFBG at opposite ends of the linker. Upon surface modification, APTES solution will form silicon-oxygen bonds with the hydroxyl groups on the surface of the fiber, while the other end of the APTES is an amino group. The amino group is ligated and chelated with the metal cation in ZnO, then the sensing platform is constructed.

Method two

the fiber is cleaned with a plasma cleaner and to make the surface negatively charged. Then, the optical fiber is immersed in a solution of positively charged polyallylamine hydrochloride (PAH) and negatively charged polystyrene sulfonate (PSS). Finally, positively charged zinc oxide is coated on the surface of the modified optical fiber.

Figure 1(a) is the SEM of the morphology of ZnO nanoflower, and (b) is the SEM of effect picture coated on optical fiber.

Results and Discussion

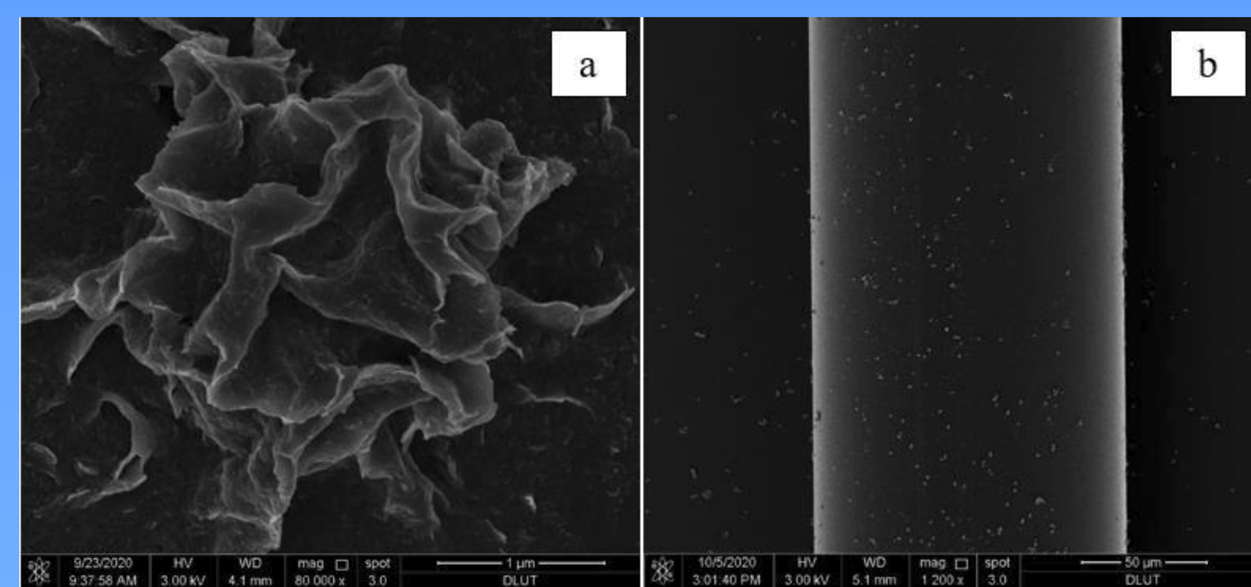

Figure 1. (a) and (b) are SEM images of ZnO morphology and the effect of coating on optical fiber

Figure 2 is the experimental spectra of ZnO using the this method. It can be clearly seen that the resonance intensity of the cladding mode decreases obviously with the addition of the number of coatings. The testing results revealed that this method is more suitable for 2D materials.

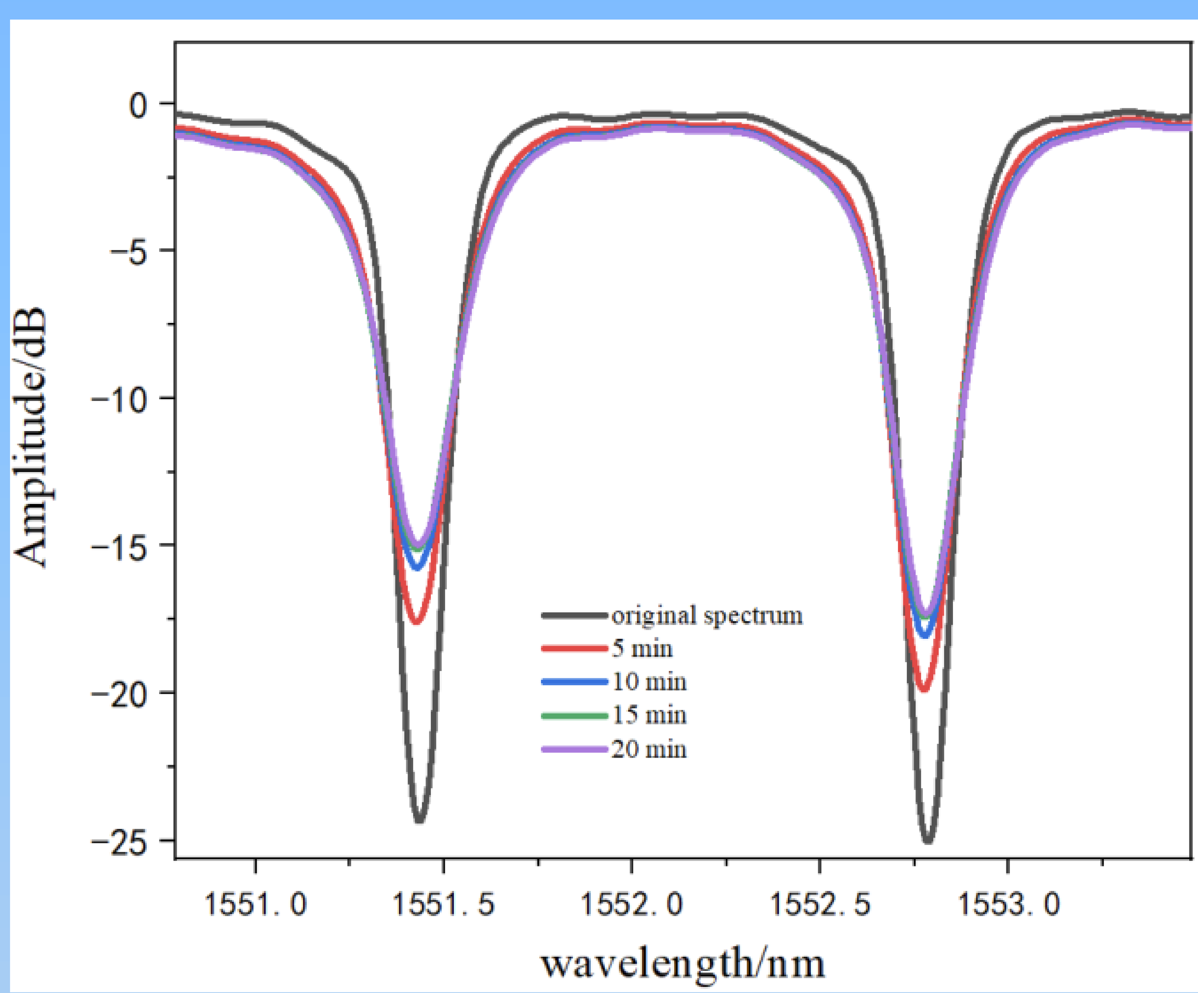

Figure 2. TFBG-APTES-ZnO platform experimental spectrum

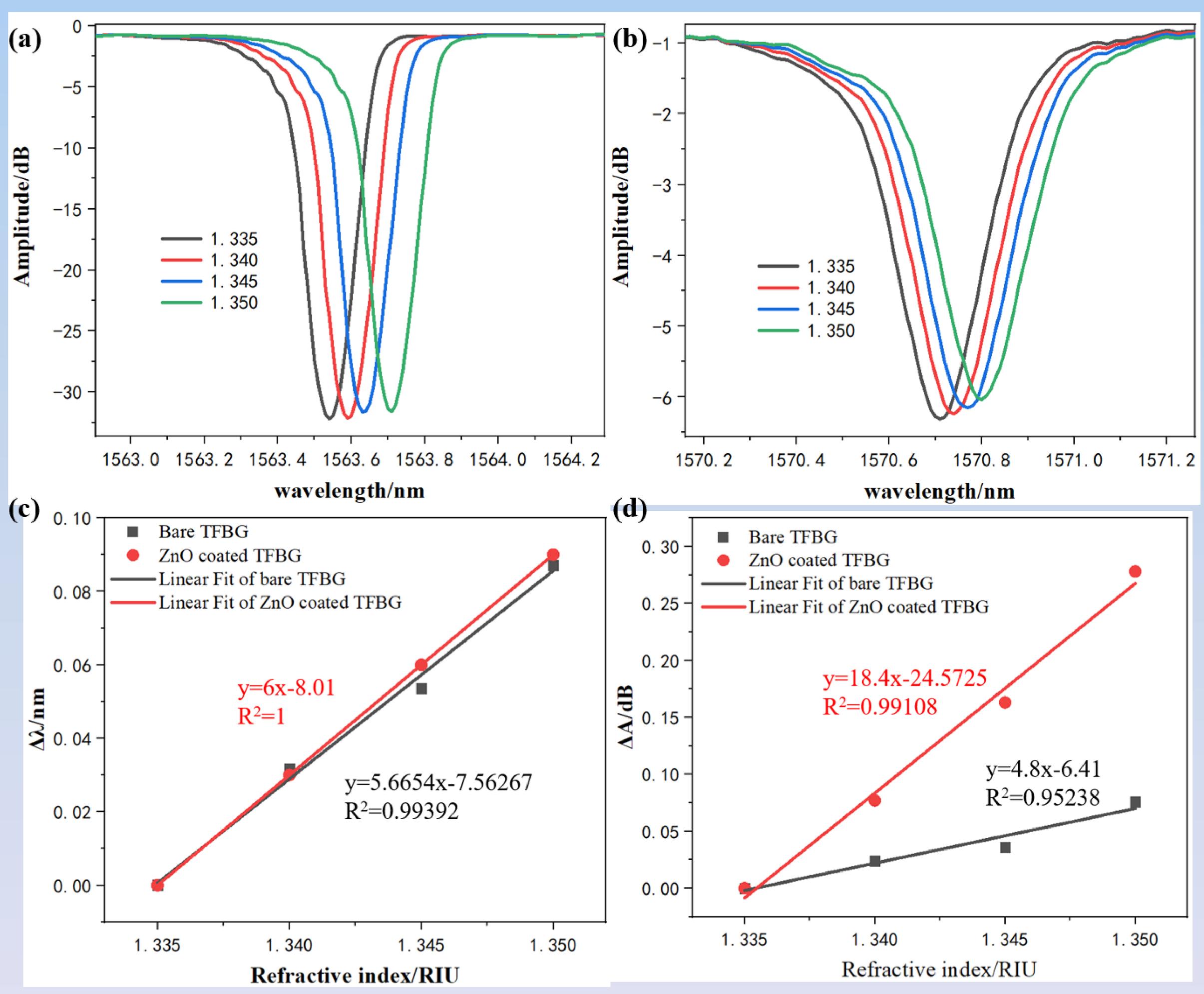

Figure 3. Sensor sensitivity (a) refractive index spectrum of bare fiber (b) Refractive index spectrum of zinc oxide sensing platform (c) wavelength variation linear fitting graph and (d) intensity variation linear fitting graph

The spectral responses of bare TFBG and TFBG coated with 2D ZnO material with different refractive indices, as shown in Fig. 3. (a) and (b).

The intensity sensitivity of the bare fiber is 4.8dB/RIU, and the intensity sensitivity of the sensing platform constructed of the two-dimensional material zinc oxide is 18.4dB/RIU. Figure 3 (c) and (d) show the comparison of wavelength and intensity sensitivity of bare fiber and zinc oxide sensing platform and its linear fit.

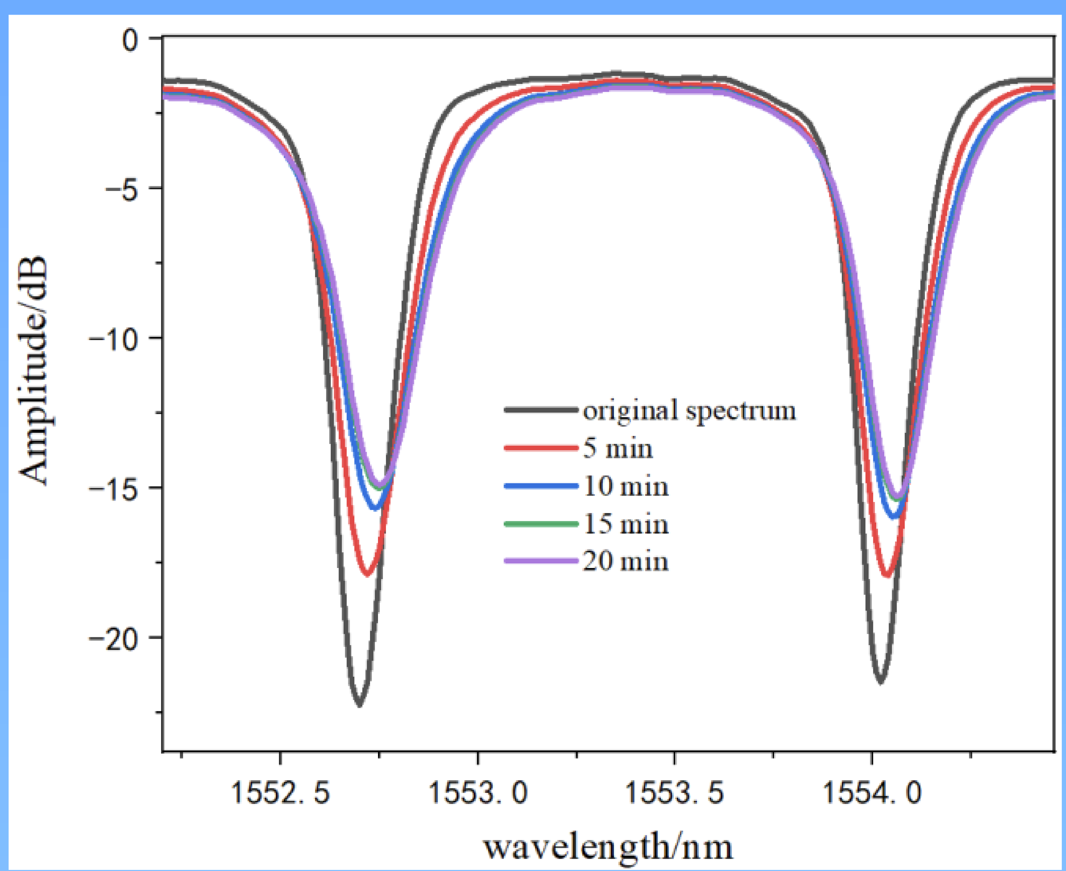

Figure 4. experimental spectra of TFBG-polyelectrolytes-ZnO constructed with ZnO nanoflowers

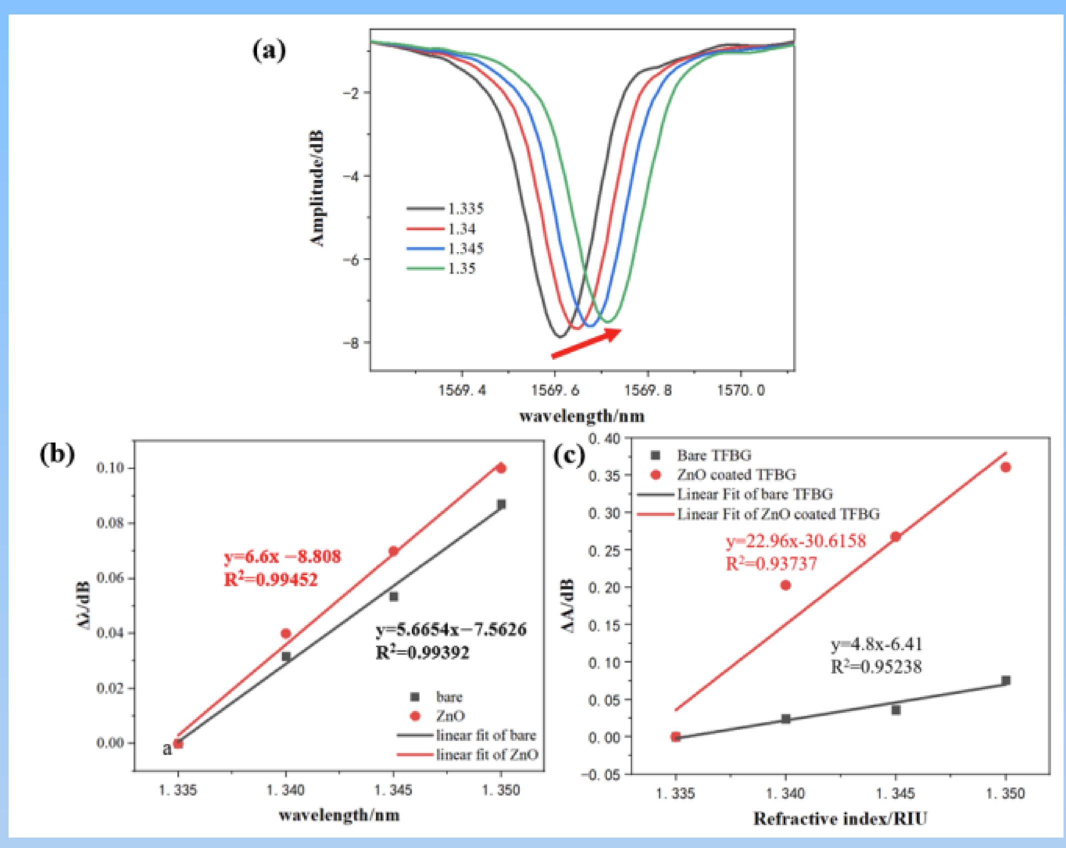

Figure 5. Sensor sensitivity (a) refractive index spectrum of ZnO sensing platform (b) linear fitting graph of wavelength change and (c) linear fitting graph of intensity change

Conclusions

The spectral characteristics of ZnO coated TFBGs have been experimentally investigated in order to verify interesting perspectives in refractive index sensing applications. Two different methods were used to coating 3D ZnO material onto TFBG. Using the APTES method, the number of coating layers is easy to reach saturation. Using the polymer method, it is easy to form a multilayer film structure, and its intensity sensitivity is larger. We demonstrated that the overlay deposition can be used to move desired sensitivity values towards higher SRI values than the uncoated structure. Hence ZnO coatings confirms its capacity to act on the cladding modes distribution, increasing their interaction with the external medium.