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Lossy mode resonances supported by TiO2-coated optical fibers

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Abstract

An optical fiber refractometer based on lossy mode resonance (LMR) supported by a TiO2 coating has been designed and fabricated for the first time. The Layer by Layer (LbL) method, used to deposit the film, makes possible to tune the sensitivity and the operation wavelength of the device. The LMR absorption peak, located in the infra-red region, is highly sensitive to changes in the refractive index (RI) of the surrounding medium, showing a sensitivity of 2228 nm/RIU.

Optical fiber sensor, Refractometer, Layer by layer, Thin film, Electromagnetic resonance

1. Introduction

Optical fiber sensors have attracted the attention of many researchers in the last decades due to their optimal characteristics, such as low weight and size, immunity to electromagnetic fields, biocompatibility, capability of remote sensing, etc [1]. Many different sensing configurations have been developed in these years [3,4]. Among all those configurations, wavelength based sensors overcome the inconveniences produced by sensors based on optical power, as immunity to fluctuations in the optical source. Sensors based on surface plasmon resonance (SPR) are a good example of these devices [5,6]. Lossy mode resonances (LMR), a different electromagnetic phenomenon, has been applied recently in the fabrication of optical fiber sensors [7,8]. To generate the LMR, an indium tin oxide (ITO) coating was deposited onto the optical fiber core by means of the sol gel method, a technique which does not allow controlling the thickness of the deposited film.

In this work, TiO_2 nanoparticles have been deposited by the layer by layer (LbL) method in order to create the LMR supporting coating. This deposition technique permits to control the thickness of the coating with high accuracy [9] and, as a consequence, the number of generated resonances, the wavelength of the absorption peaks and the sensitivity of the device when it is subjected to changes in the external refractive index (RI). As an example, the device presented here shows a good sensitivity and a high dynamical range when the RI of the surrounding medium varies between 1.32 and 1.40.

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2. Experimental section

The fabrication process of the refractometer consists of two different steps. Firstly, a 4 cm fragment of a 200 μm-core multimode optical fiber (FT200-EMT, Thorlabs Inc.) is cleaned and perpendicularly cleaved in both extremes. The cladding of this portion is chemically removed and it is spliced to two multimode optical fiber pigtails. After that, the LMR supporting coating is deposited onto the optical fiber core by means of the LbL method. This multilayer technique is based on the consecutive deposition of a cationic and an anionic layer to form a bilayer. The process is repeated until the thickness and the structure of the coating reach the desired values. In this case, water solutions of TiO_2 nanoparticles and poly(sodium 4-styrenesulfonate) (PSS) have been used as cationic and anionic solutions, respectively. In Fig 1, a schematic representation of the final refractometer is shown. A scanning electron microscopy (SEM) analysis showed that the resultant thickness of the film after the deposition process was 1200 nm, as can be seen in Fig. 2.

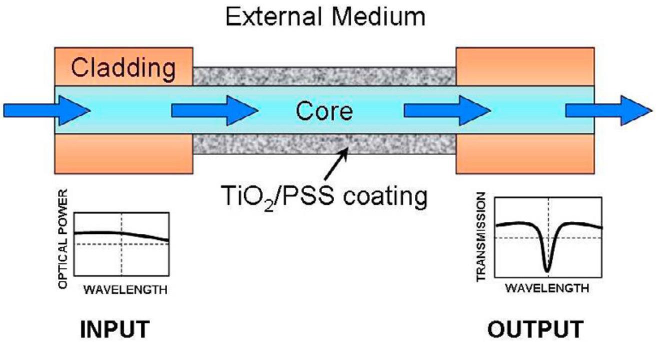

Fig. 1. Schematic representation of the optical fiber device

To characterize the optical response of the fabricated device, the typical transmission setup showed on Fig. 3 was used. A white light source introduces the optical power into the optical fiber pigtail. The light crosses the coated region, where the electromagnetic resonance is produced, and the other optical fiber pigtail, reaching a near infra red (NIR) spectrometer connected to a PC, which collects the transmitted optical power. The response of the device to changes in the external refractive index is measured by introducing the sensitive region into different water solutions of glycerine with RI from 1.32 to 1.38.

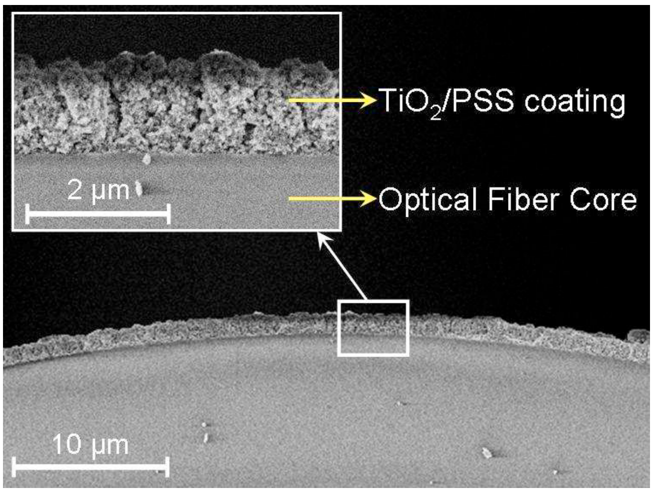

Fig. 2. SEM image and detail of the coated optical fiber core

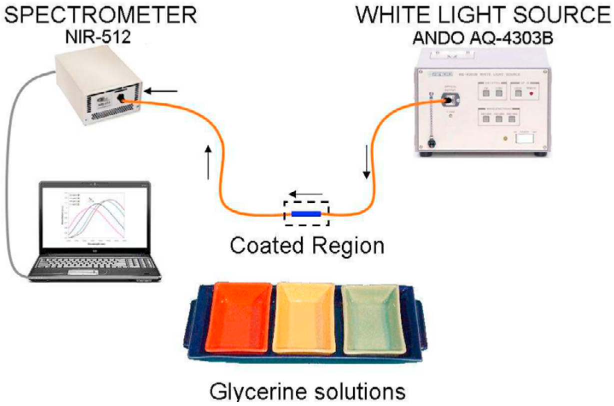

Fig. 3. Optical fiber transmission setup used to characterize the refractometer response

3. Results

In this section, the results obtained in the characterization of the refractometer are presented. The absorption peak generated by the LMR can be observed in fig 4. This peak is centered at 1430 nm when the device is immersed into ultrapure water (refractive index 1.32). If this value is increased by adding glycerine to the water solution the peak shifts to higher wavelengths. This way, when the refractive index of the external medium is 1.34 (15% of glycerine) the absorption peak is located at 1480 nm, when the RI is 1.38 (45% glycerine) the peak is at 1560 nm and when its value is 1.4 (60% glycerine) the peak reaches the 1590 nm. These data can be clearly observed in Fig. 5.

This refractometer shows a dynamical range of 157 nm in the studied range of RI, a sensitivity of 1987 nm/RIU and a high repetitivity. To our knowledge, this is the first time that an optical fiber refractometer based on LMR is fabricated using TiO_2 nanoparticles, opening a wide range of applications in the field of optical fiber sensors based on electromagnetic resonances.

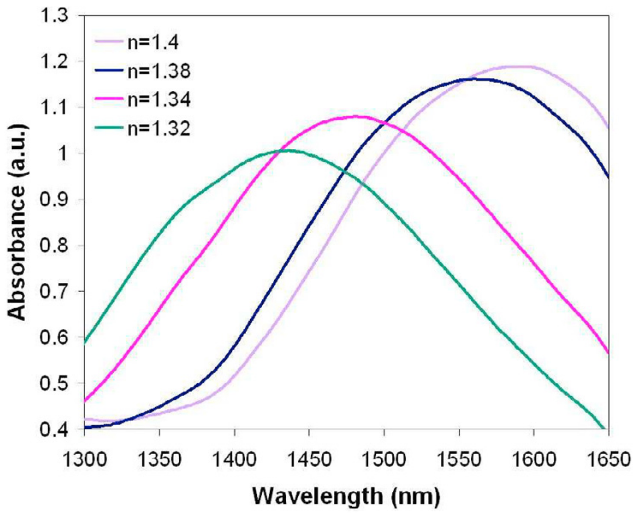

Fig.4. LMR absorption peak in the NIR region and variation with the external refractive index

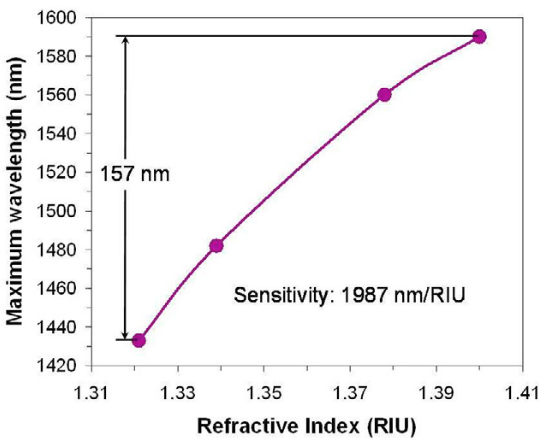

Fig.5. Variation of the maximum absorbance wavelength as long as the refractive index of the external medium changes

4. Conclusions

An optical fiber refractometer based on LMR has been presented in this work. The LbL method has been applied to fabricate a coating of TiO_2 nanoparticles onto the multimode optical fiber core. This device shows an absorption peak in the infra red region which shifts to higher wavelengths when the refractive index of the surrounding medium becomes higher. The sensitivity of this refractometer is 1987 nm/RIU, reaching a dynamical range of 157 nm when the external refractive index varies between 1.32 and 1.40.

Acknowledgements

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