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Procedia Engineering 25 (2011) 499 – 502

Procedia Engineering

www.elsevier.com/locate/procedia

Proc. Eurosensors XXV, September 4-7, 2011, Athens, Greece

Optical Fiber Refractometers based on Indium Tin Oxide Coatings with Response in the Visible Spectral Region

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Abstract

This work presents the fabrication of optical fiber refractometers based on indium tin oxide (ITO) coatings with response in the visible spectral region. ITO thin-films have been sputtered by employing a rotating mechanism that enables the fabrication of smooth homogeneous coatings onto the optical fiber core. The ITO coated optical fiber devices present several resonances in the visible and infra-red region. These resonances show high optical power attenuations (more than 10 dB) in the visible spectral region, which produces changes in the colour of the output visible light. Therefore, since these resonances shift as a function of the surrounding medium refractive index (SMRI), it is feasible to determine the refractive index of the outer medium in contact with the ITO coating by simply monitoring the chromatic coordinates of the visible output light.

Keywords: Optical fiber; refractometer; Lossy Mode Resonances; indium tin oxide; sputtering; refractive index;

1. Introduction

ITO, as well as In_2O_3 and TiO_2 coated optical fiber devices have been studied by our group and recently presented in the literature as novel refractometers based on lossy mode resonances (LMRs) [1-3]. LMRs have been obtained for both TE and TM polarizated light, whereas surface Plasmon resonances (SPRs) are only obtained for TM polarized light. Moreover, several LMRs can be generated as a function of the coating thickness [4-5]. However, in most cases, the fabrication of these devices is very tedious and time-consuming. Furthermore, the resonances do not show generally high power attenuations, which is mainly attributed to the fabrication procedures. In order to produce high attenuation resonances it is employed the sputtering method, which enables the fabrication thin homogeneous ITO coatings onto the core of optical fibers.

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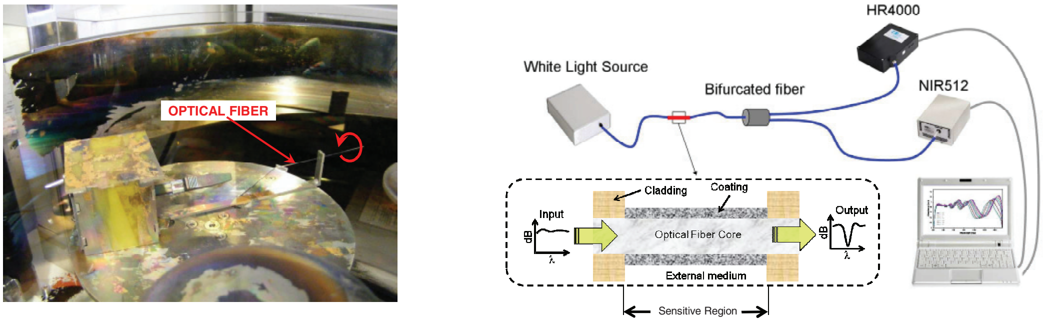
doi:10.1016/j.proeng.2011.12.124

2. Experimental

2.1. ITO coating fabrication

ITO thin films with an estimated thickness of 250 nm were fabricated onto a 4 cm. portion of uncladded optical fibers (FT200EMT 200/225 core/cladding diameter from Thorlabs Inc.) by sputter coating deposition as explained elsewhere [6]. A rotating mechanism has been employed to spin the fiber at constant speed inside the chamber during the deposition (Figure 1a). This enables the fabrication of homogeneous coatings all around the cylindrical core.

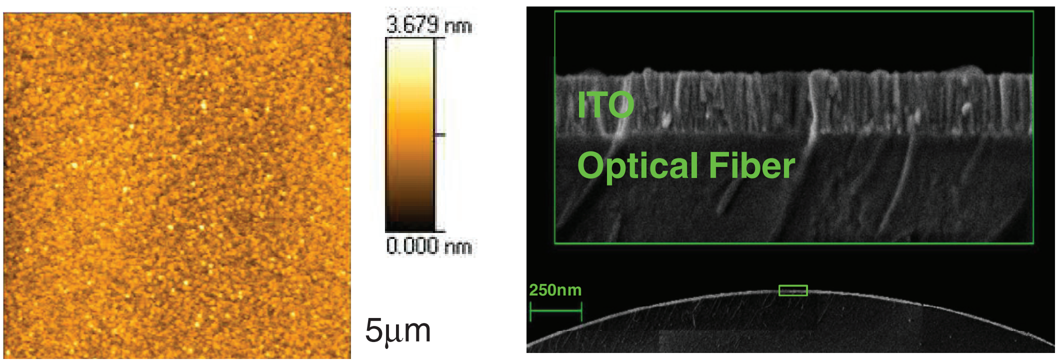


(a) (b)

Fig. 1. (a) Rotation mechanism introduced into the sputtering vacuum chamber for the deposition of ITO over the optical fiber.; (b) Schematic representation of the experimental setup.

2.2. Device Characterization

ITO coated optical fibers were cleaved perpendicularly (LCD-200 Vytran Inc.) at both ends. Then, both ends were spliced to optical fiber cords (FITEL S176, Furukawa Co. Ltd.). Finally, fabricated devices were characterized by using a typical transmission setup (see Figure 1b), that consisted of a white halogen light as the excitation source and two spectrometers (HR4000 and NIR 512 from Oceanoptics Inc.) connected at the output of the optical fiber. The response of the device was recorded when the sensitive region was immersed in different RI solutions. The RI of the solutions used was 1 (air), 1.333 (water), and 1.447 (80%w glycerin) [7]. All the measurements were performed at room conditions (20 ºC).



(a) (b)

Fig. 2. (a) AFM image of the ITO coating. (b) SEM micrograph of the ITO coating.

3. Results and Discussion

ITO coatings fabricated onto the optical fibers were characterized by using an atomic force microscope (AFM) (Innova AFM, Veeco Inc.) and a scanning electron microscope (SEM) (FESEM, Carl Zeiss Inc.). AFM images of the coatings revealed a smooth surface (see Figure 2a) with a RMS roughness of 0.34 nm. Additionally, SEM micrographs showed a homogeneous coating with an approximate thickness of 250 nm.

The spectral response of the device when it is subjected to variations of the surrounding medium refractive index (SMRI) is plotted in Figure 3 (left). The device presents a transmission band in the studied region that shifts to the red when the EMRI is increased. Furthermore, the attenuation between the transmission and rejection bands is higher than 10 dB in all cases. This high attenuation, and the narrow bandwidth if compared to other works developed with ITO [1] enables to observe a different colour at the output of the fiber as it is shown in Figure 3 (right) for each SMRI. The colour change is produced because of the high attenuation of visible light at certain wavelengths. In particular, the colour changes from yellow to orange and purple when the SMRI is air (n=1), water (n=1.333) and 80% glycerine (n=1.447) respectively.

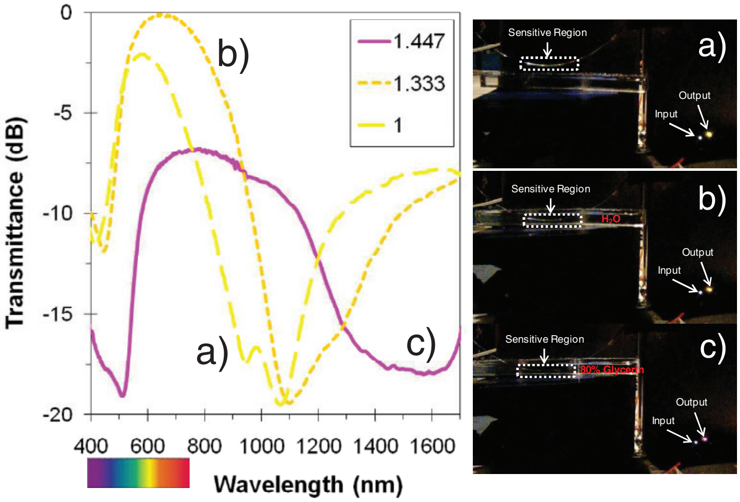


Fig. 3. Spectral response (left) and output colour (right) when the external medium refractive index of the ITO coated optical fiber refractometers is varied from a) air (n=1), b) water (n=1.333) and c) 80% glycerine (n=1.447).

The change in colour of the visible output light and hence the SMRI variation can be represented by means of the chromatic coordinates (x,y). In Figure 5 are depicted the chromatic coordinates in each case. The chromaticity coordinates of the output light are (0.471, 0.463), (0.507,0.445) and (0.445,0.392) for air, water and 80% glycerin respectively. Consequently, refractive index detection can be carried out by monitoring the colour change at the output of the optical fiber by using sputtered ITO coatings. Furthermore, it could be possible to tune the colour gamut in the appropriate working range by adjusting the ITO coating thickness.

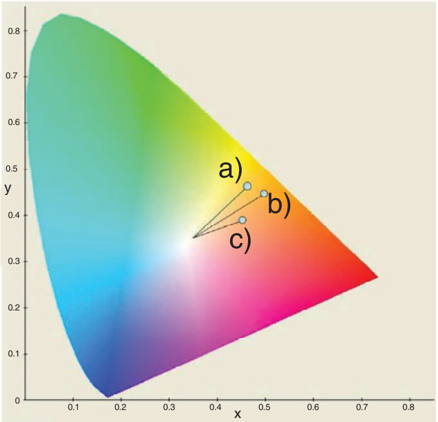


Fig. 4. Chromaticity coordinates of the output signal for different external medium a) air, b) water and c) 80% glycerin.

4. Conclusions

LMR-based optical fiber refractometers with high attenuation bands have been fabricated by means of sputtered ITO coatings. These devices present an optical response to SMRI variations in the visible spectral region. Moreover, fabricated devices are suitable to be used as optical filters.

Acknowledgements

This work was supported in part by the Spanish Ministry of Education and Science-FEDER TEC2010-17805 and Government of Navarra research grants. Special thanks to FIDENA for the utilization of the SEM.

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