Label-Free Optical Fiber Sensing Platform based on Lossy Mode Resonances Supported by Transparent Conducting Oxides

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Thin-film coated optical waveguides can support different types of resonances [1]. Among them, surface plasmon resonances (SPR) have focused the attention of the scientific community motivating hundreds of publications and sensing applications as a label free sensing platform [2]. Besides, optical fiber SPR configuration can overcome some of the limitations of the traditional Kretschmann-based SPR configurations such as the utilization of a prism and a monochromatic light source and permits remote sensing and multiplexing between multiple SPR-based devices [3]. A second type of resonance is known as lossy mode resonances (LMR) [4]. Even though LMR-based optical fiber sensors are independent of light polarization and can overcome some of the traditional limitations of SPR-based optical fiber sensors they have not been as widespread as SPR-based optical fiber sensors. Additionally, LMR-based devices permit to tune the sensitivity of the resonance in the spectral range by simply adjusting the absorbing thin-film fabrication parameters or by selecting the appropriate material. LMR-based devices also permit the utilization of an additional coating adhered to the metal layer in order to detect diverse substances or chemical compounds [5]. Indium tin oxide (ITO) coated optical fibers have been already studied in literature as LMR-based refractometers with a resonance wavelength in the infrared region [4-5].

Here, it is described the fabrication of LMR-based refractometers by means of the deposition of a thin aluminium doped zinc oxide (AZO) film onto the optical fiber core. The AZO film is deposited onto the optical fiber core as described elsewhere [6]. The deposition process basically consisted of a prior fiber cleaning process in order to remove the optical fiber cladding followed by a sol-gel dip-coating deposition process. The AZO film of thickness ~115 nm fabricated onto the optical fiber is shown in the SEM image of *Fig. 1*.

AZO coated optical fibers were connected in a typical transmission setup as it is represented schematically in *Fig. 2.* A halogen lamp (ANDO Inc.) was used as the excitation source at one end of the fiber and a spectrometer (HR4000, Oceanoptics Inc.) was used in order to collect the light at the opposite end of the fiber. Absorbance spectra (see *Fig. 3*) were obtained when the AZO sensitive region (see detail in *Fig. 1*) was immersed in different glycerin/water concentration solutions from 0% to 75% corresponding to 1.33, 1.35, 1.37, 1.39, 1.41 and 1.43 refractive index units (RIU) respectively, estimated at 20 ºC and 590nm. Here, the wavelength at maximum absorbance (resonance wavelength) is shifted to larger wavelengths as the external medium refractive index is increased. The resonance wavelength shift is represented in Fig. 4, showing a variation of approximately 1100 nm/RIU.

To sum up, AZO coated optical fibers have been fabricated and characterized as LMR-based refractometers in the visible spectral region in a simple and straigh-forward way. Finally, LMR-based devices presented here, could be the first step towards a vast field of applications in chemistry, or biology by the only addition of the specific outer coating in the same manner as SPR-based sensors already did.

References:

[1] Yang & Sambles, *J. Mod. Opt.*, **44**, 1155-1163, 1997.
[2] J. Homola, *Anal. Bioanal. Chem.*, **377**, 528-539, 2003.
[3] B. Lee, S. Roh, J. Park, *Sens. Actuators B*, **15**, 209-221, 2009.
[4] I. Del Villar, C. R. Zamarreño, M. Hernaez, F. J. Arregui, I. R. Matias, *J. Lightwave Tech.*, **28(1)**, 111-117, 2010.
[5] C. R. Zamarreño, M. Hernaez, I. Del Villar, I. R. Matias, F. J. Arregui, *Sens. Actuators B*, (in press)
[6] Keh-moh Lin y Paijay Tsai., *Mat. Sci. & Engineering B*, **139,** (2007) 81-87.

Figures:

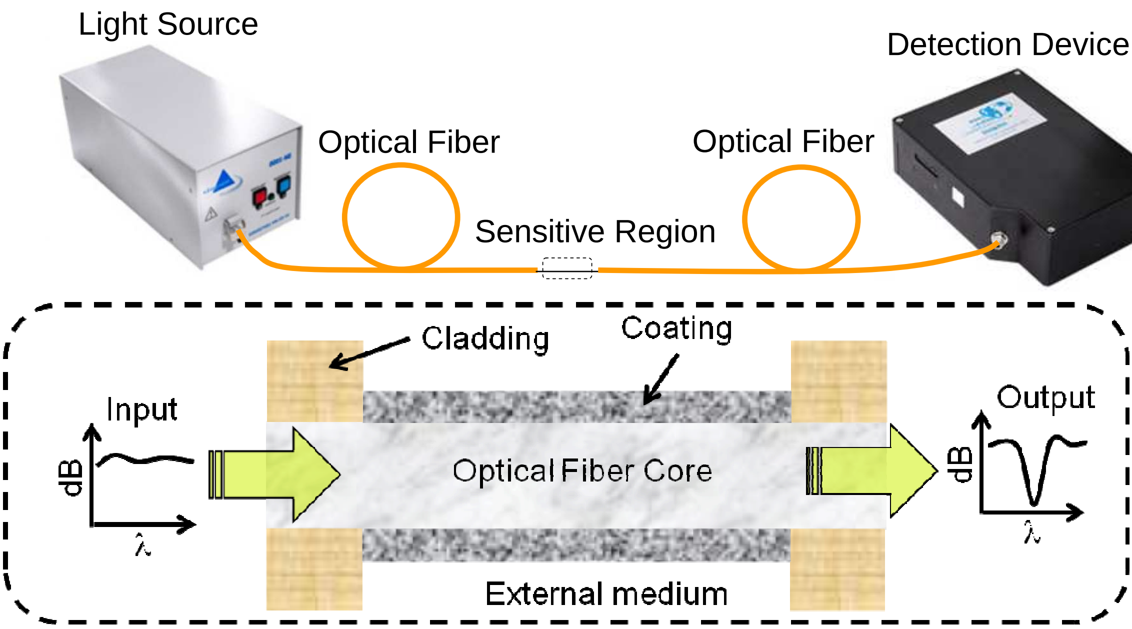

Fig2: Optical fiber transmission setup and detail of the sensitive region.

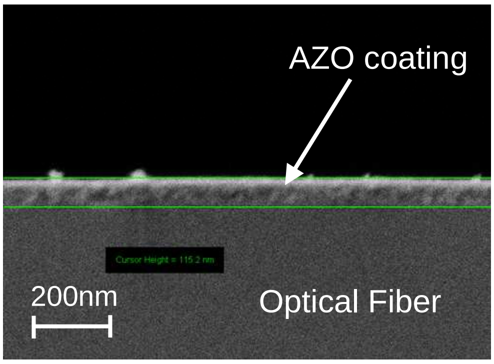

Fig1: SEM image of an AZO coated optical fiber.

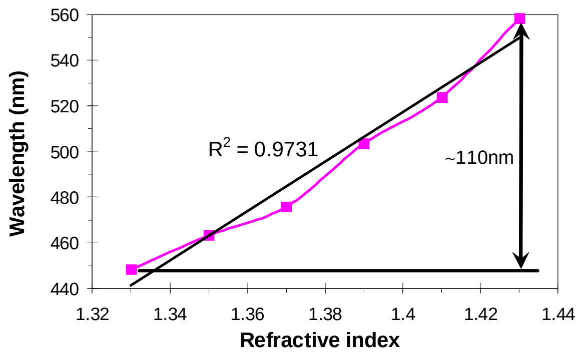

Fig4: Resonance wavelength shift as a function of the external refractive index.

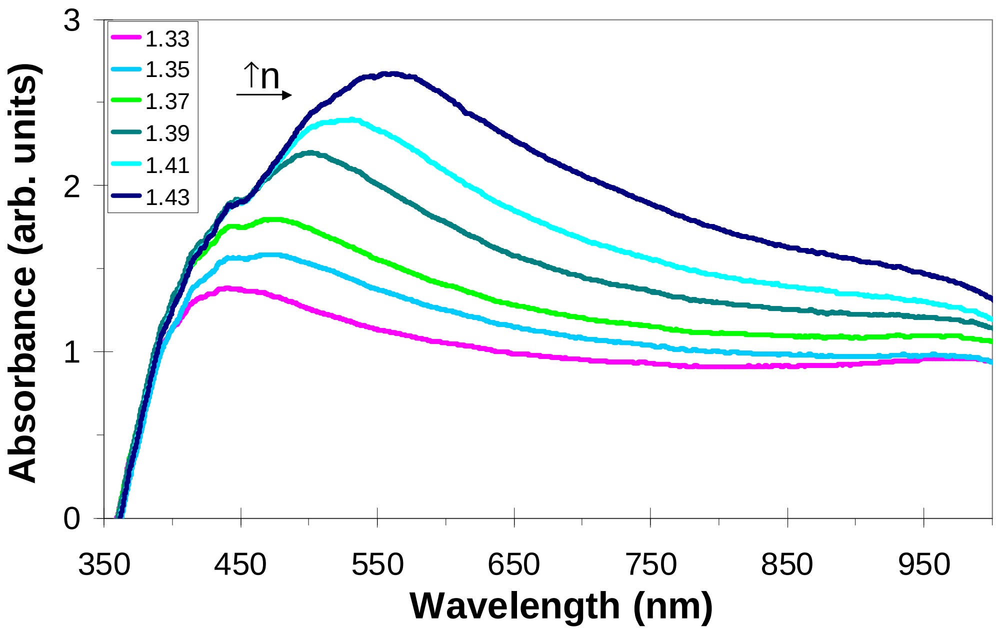

Fig. 3: Absorbance spectra obtained when the sensitive region was immersed in different glycerin/water concentration solutions of refractive indices 1.33, 1.35, 1.37, 1.39, 1.41, 1.43.