Study of Gold nanoparticles In Situ Synthesis

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The use of gold nanoparticles (AuNPs) in the field of fiber optic sensors has presented promising results for detection of different chemical, physical and biological variables. One of the principal challenge is the improvement of the sensitivity of this type of sensors and to make it will be interesting the study of other gold deposition techniques. One example of this is the use of In Situ Synthesis (ISS) as an efficient tool of post-fabrication to immobilize AuNPs on the optical fiber. This technique was previously used in an investigation that allowed the enhancement of the contrast of the optical response of nano Fabry–Perot interferometric (FPI) cavities and to tune this optical response from the VIS to NIR, making possible the adjustment of their interferometric parameters. This same technique is used in the study of Tilted Fiber Bragg Gratings (TFBG), making possible to obtain interesting and novel spectral transmission response, which would be useful for the adjustment of sensitivity parameters.

Introduction

The use of gold nanoparticles (AuNPs) as sensitive material offers interesting advantages for optical detection applications [1], due to its stability, compatibility with the aqueous medium, easy functionalization and its optical properties. When gold nanoparticles interact with the light, there is a resonant coupling of light-matter energy known as Localized Surface Plasmon Resonance (LSPR) that can be used as a detection signal [2]–[5]. Nowadays the incorporation of AuNPs to the optical fiber has allowed the development of interesting sensors. There are different methods of AuNPs deposition, however, the use of the In Situ Synthesis (ISS) technique can be used as an efficient tool of post-fabrication to immobilize AuNPs in the optical fiber.

This technique was apply to two investigations. One of them in the immobilization of AuNPs on the optical fiber tip Fabry–Perot interferometric (FPI) cavity after the polymer film fabrication. With the incorporation of AuNPs not only enhance the contrast of the optical response of nano-FPI cavities, also we can to tune this optical response from the VIS to NIR. The ISS technique was also applied in the study of Tilted Fiber Bragg Gratings (TFBG), making possible to obtain interesting and novel spectral transmission response, which would be useful for the adjustment of sensitivity parameters.

ISS Technique to obtain an Optical Fiber Tip Interferometer sensor using AuNPs

It is possible to create Fabry–Perot interferometric (FPI) cavities creating a thin film at the end-face of an optical fiber [6], [7]. However, the most of FPI-sensors base his detection mechanism in two principal functions: one of them is the use of the polymers to support other sensitive element like metallic nanoparticles, doing possible to have more flexibility for the design fiber optic sensors and, another alternative is the simple use of the detection mechanism of the polymer itself. In the last case, they present a low contrast due to their refractive index is similar to that of fiber.

With the objective to enhance the contrast of the optical response of nano-FPI cavities created at the end-face of optical fibers, the fabrication process has been performed in two steps (Fig.1). Firstly (Step A), a polymeric coating was fabricated using the Layer-by-Layer (LBL) assembly by the deposition of oppositely charged polyelectrolyte of PAH and PAA, respectively, and secondly (Step B), gold cations (Au^{3+}) have been immobilized into the previous polymeric matrix obtained by the LBL assembly. Afterwards, the gold loaded into LBL polymeric coating has been reduced by using dimethylamine borane complex solution. This reducing agent (DMAB) makes possible the in situ synthesis (ISS) of the AuNPs.

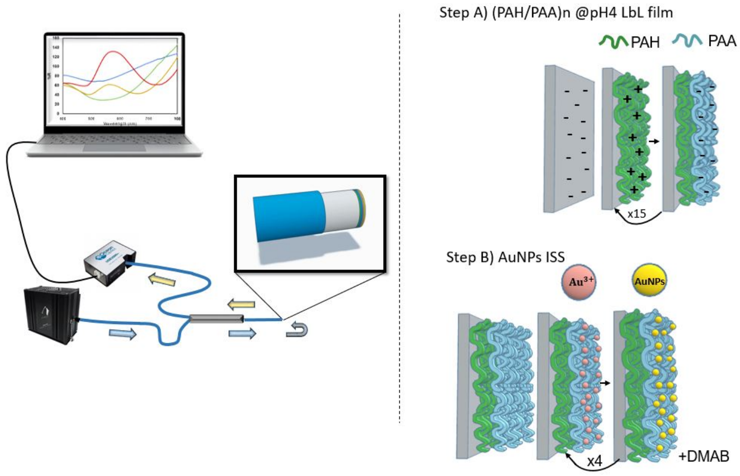

Figure 1. Schematic illustration of the Layer-by-Layer nano-assembly and a further *In Situ Synthesis (ISS)* of the gold nanoparticles into the previously created LbL films.

In Figure 2A is possible to observe the result of the reflected light due to FPI of the LBL-$(PAH/PAA)_{15}$ thin-film without AuNPs on the fiber tip, which evidence that only with the use of the polymeric thin-film a response with a low contrast was obtained. For that reason AuNPs were incorporate with the ISS technique and in Figure 3 B is shown the spectra evolution with every (L/R) cycles showing an improvement in the contrast of the optical response of nano-FPI cavities. Using the combinations of $(PAH/PAA)_{15}$+$(L/R)_4$ was possible to observe the improvement of low finesse enhancement with the use of ISS AuNPs in respect to the polymeric coating only.

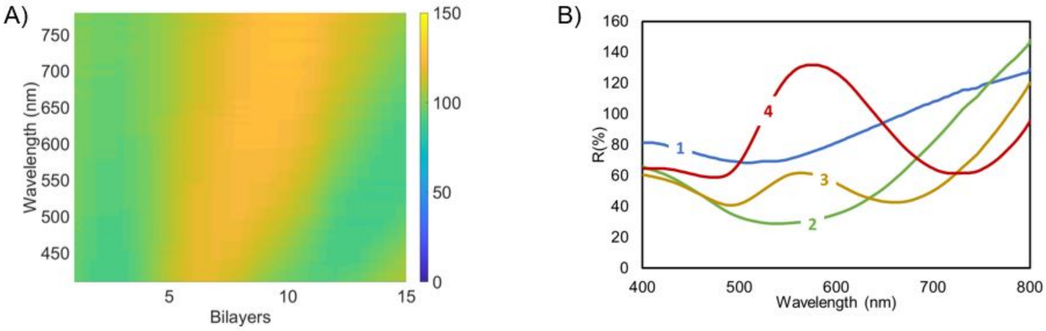

Fig.2 **A)** Evolution of the spectral characteristic of the reflected light due to white light interferometer of the LBL-$(PAH/PAA)_{15}$ thin-film. **B)** ISS of gold nanoparticles into LBL films for 1 to 4 (L/R) cycles.

The sensor obtained was characterized by measuring changes in relative humidity (RH), obtaining a 30 nm shift in the wavelength of the interferometric response of 20 to 80% RH changes (Figure 3).

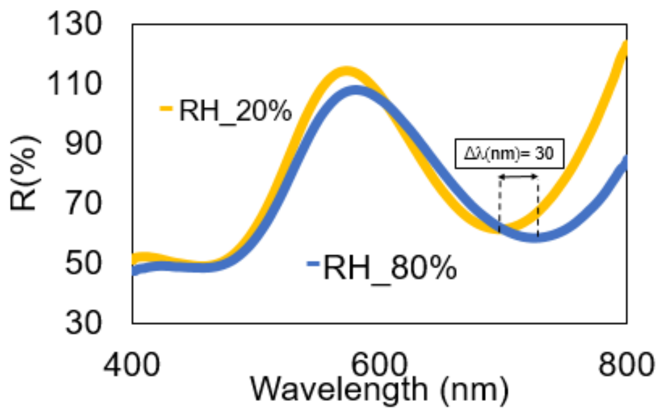

Fig.3 Spectral response of $(PAH/PAA)_{15}$+$(L/R)_4$ thin-film fabricated onto the end of the fiber tip for 20 and 80% values of relative humidity (RH).

ISS Technique applied to Tilted Fiber Bragg Gratings (TFBG)

The same technique (ISS) was used in the study of TFBG. In Figure 4 is possible to observe (in gray) the response of the TFBG manufactured, using the phase-mask technique. Was used a phase mask of 1100 nm period and 8° tilt angle. In the same figure is possible to observe (in yellow) the response of the same fiber after the deposition of $(PAH/PAA)_6$+$(L/R)_5$.

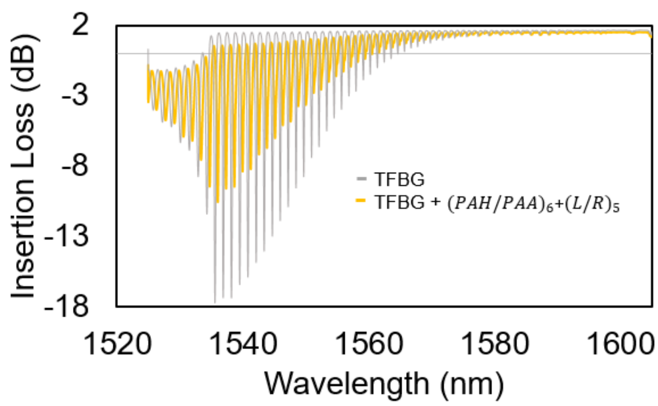

Fig. 4 TFBG transmission spectra with the use of ISS technique.

This sensor was exposed to different refractive index and every mode was analyzed. In the figure 5 is shown the mode with the best response to the different refractive index and his wavelength displacement, obtained a wavelength variation of 0.177124 nm between the index refractive of 1.331 and 1.334.

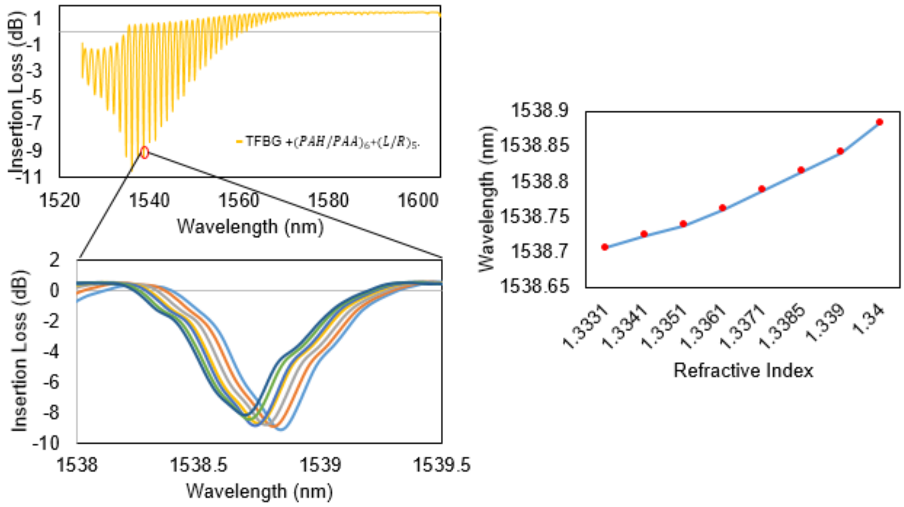

Fig. 5 Refractive index study of TFBG with AuNPs deposited by ISS technique.

Conclusion

In this study, the ISS technique represents an efficient post-fabrication tool to immobilize AuNPs in the optical fiber. It is important to highlight how with different configurations and fabrications of optical fiber, it was possible to adjust the sensitivity parameters with the increment of (L/R) cycles

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