Exploiting Several Buffer Layers in SPR D-Shaped POF Sensors Based on Gold Film for Different Applications †

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† Presented at 7th International Symposium on Sensor Science, Napoli, Italy, 9–11 May 2019.

Published: 18 December 2019

Abstract: We present a comparative study of three optical sensing platforms based on surface plasmon resonance (SPR) in plastic optical fibers (POFs). The proposed sensors consist of a D–shaped POF sensing area, where the exposed core is covered by a photoresist layer, used as intermediate layer between the fiber’s core and the metal (gold) film. The photoresist deposited on the exposed core in the D–shaped POF region, is pivotal in order to improve the performances of the sensor in terms of sensitivity. In particular, we have compared the performances of three different buffer layers based on the following photoresist: Microposit SU-8 3005, Microposit S1813 before and after the expiry date.

Keywords: optical sensors; plastic optical fibers; surface plasmon resonance; photoresist; refractive index measurement

1. Introduction

Surface plasmon resonance bio–chemical sensors in optical fibers are suitable for on-site and real-time monitoring of different analytes, then they play an important role in many research fields [1–5]. Many solutions have been proposed in order to optimize the performances of the SPR sensors in terms of throughputs, reliability, robustness and miniaturization [6–11]. Whatever the application, the improvement of the sensitivity with the aim to observe small variations of refractive index of the analyte under investigation is one of the critical point to be addressed [6]. In the SPR D–shaped POF sensors described in this work the use of a buffer layer based on photoresist is a successful solution for increasing the sensitivity of the device. However, the selection of the photoresist depends on the specific application and on the region of refractive index of interest [11]. The SPR sensing platforms were fabricated by removing the cladding of a POF along half circumference, spin coating on the exposed core a buffer layer of photoresist, and finally sputtering a thin gold film [8]. We report about the SPR sensor’s performances variation when the photoresist buffer layer changes. In particular, to obtain three different buffer layers, we have used Microposit SU-8 3005, Microposit S1813 before the expiry date, and Microposit S1813 after the expiry date. The interesting results are discussed hereafter.
2. Plasmonic POF Sensors

The procedure for the fabrication of the D-shaped POF platforms includes several steps [11–14]. The plastic optical fiber (PMMA core of 980 µm and fluorinated polymer cladding of 10 µm) without protective jacket was embedded in a resin block and the cladding was removed by two different polishing papers along half circumference, giving the desired D–shaped to the device [13]. Then, the photore sist (in all three cases) was spun at 6000 rpm for 60 s, and, finally, a thin gold film sputtered on the top by using a sputtering machine (Bal-Tec SCD 500). In particular, the sputtering was repeated three times with a current of 60 mA for 35 s (20 nm per step). The final thickness of the gold film was 60 nm showing a good adhesion to the substrate. The process is resumed in Figure 1 together with the outline of a typical SPR D–shaped POF optical sensor. The realized D-shaped sensing region was about 10 mm in length.

![Figure 1](image1.png)

**Figure 1.** The figure shows the SPR sensor platform based on D–shaped POF, photoresist buffer layer and gold film.

In this work we tested three different SPR sensors based on this D-shaped POF platform. The first one was fabricated by using a Microposit SU–8 3005 as buffer layer between the POF core and the gold film. The second one, a Microposit S1813 photore sist before the expiry date, and, in the third case, we have used a Microposit S1813 photore sist longer (about 3 years) after the expiry date. The Microposit SU–8 3005 and S1813 are both manufactured by MicroChem Corp (Westborough, MA USA). In the bio-chemical applications, the selectivity is obtained by overlapping the gold surface with a very specific medium (receptor) for the considered analyte [12,14].

The experimental arrangement used for the measurements consists of a halogen lamp (HL–2000–LL, Ocean Optics) illuminating the SPR-POF sensor and a spectrum analyzer (USB2000+UV–VIS spectrometer, Ocean Optics) connected to a computer [13]. Figure 2 shows the outline of the setup.

![Figure 2](image2.png)

**Figure 2.** The experimental arrangement consists of a halogen lamp (HL–2000–LL, Ocean Optics) illuminating the SPR-POF sensor and a spectrum analyzer (USB2000+UV–VIS spectrometer, Ocean Optics) connected to a computer.
3. Results

Figure 3 shows the experimental measurements performed on the SPR–POF sensing platform with SU–8 3005 photoresist layer between the D–shaped POF core and the gold layer. The SPR transmission spectra were normalized to the spectrum achieved with air as the surrounding medium. The measurements were performed by using different water-glycerin solutions, with refractive index ranging from 1.332 to 1.393 as displayed. It is worth to note that when the refractive index increases the resonance wavelength increases (red shift). Figure 4 refers to the experimental spectra obtained by using the SPR-POF sensors with both the S1813 photoresist configurations. We named “new” the S1813 photoresist before the expiry date and “old” the one after the expiry date.

![Figure 3](image1.png)

**Figure 3.** SPR transmission spectra of the SPR–POF sensor with SU-8 3005 photoresist layer under the gold film.

![Figure 4](image2.png)

**Figure 4.** SPR transmission spectra of the SPR–POF sensor with the “new” and “old” S1813 photoresist layer under the gold film.

The measurements were performed by using different water-glycerin solutions, with refractive index ranging from 1.332 to 1.392 as displayed in the label of Figure 4.

Figure 5 compares the effects of the SU–8 3005 and “new” or “old” S1813 photoresist in terms of Sensitivity (S) versus refractive index. The Sensitivity was calculated by the ratio between the resonance wavelength shift (δλ) and the refractive index variation (Δn), where the resonance wavelength shift (δλ) was calculated with respect to water solution (1.332 RIU).
4. Conclusions

The proposed analysis shows that the choice of photoresist buffer layer is strictly related to the refractive index range of interest. In particular, at higher refractive index, in the 1.370–1.393 range, the best sensitivity of the D–shaped POF optical sensors is achieved by the configuration based on a “new” S1813 photoresist buffer layer, as required for molecularly imprinted polymers (MIPs) cases. On the contrary, in the bio-receptors cases, where refractive indices minor than 1.370, the best configuration between those analyzed is based on an SU-8 photoresist buffer layer.

Author Contributions: N.C.: investigation, conceptualization, methodology, validation, formal analysis, writing, review, administration of the scientific project. P.Z.: analysis, writing, review. F.A.: investigation, methodology, validation, formal analysis. L.Z.: conceptualization, review and editing, project administration.

Conflicts of Interest: The authors declare no conflicts of interest.

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