Low-cost fiber optic biosensors

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Contents

1 Introduction **2**
1.1 Background 2

2 Methodology **3**
2.1 Fabrication of the double gold-coated PDMS SDI sensors 3

3 Experimental results **4**
3.1 Sensor SP3-s1 4
3.2 Sensor SP4-s1 4
3.3 Conclusion 5

Chapter 1

Introduction

Optical fiber biosensors (OFB) today are broadly used in all aspects of daily life, due to a range of advantages they provide, including high sensitivity, robustness, minimal invasiveness, and versatility in applications compared to other types of biosensors[5]. Nowadays, OFBs are the crucial components of medical diagnosis and food inspection for their ease of use. However, the cost of optic fiber biosensors can still be relatively high compared to traditional biosensing methods[1]. This cost factor limits their accessibility, particularly in commercialization and mass usage.

In this chapter, we will provide an introduction to the study by first discussing the background and context, followed by the research problem, the research aim, objectives and questions, the significance and finally limitations.

1.1 Background

Parallel to this, optical sensors have emerged as the biosensing technology underlying the most effective analyzers. This is because of their excellent performance figures (in terms of detection capability, resolving specific analytes at the lowest concentration) and the ability to integrate all of the optical hardware into benchtop analyzers and, in certain cases, portable instruments[2]. OFB are designed to selectively detect biological analytes, making them a powerful alternative for diagnostic purposes. They utilize optical fibers to transmit light, which interacts with the target analytes, allowing for sensitive detection of various substances. The optical fiber consists of three main components illustrated in fig;

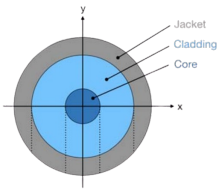


Figure 1.1: Optic fiber

The core, cladding, and a jacket. The core and cladding have a different refractive index(RI), which is key for measuring light propagation[5]. The main drawback of OFB is the high cost of optical technologies. Optical fiber interrogators have cost that ranges from a few thousand dollars up to hundreds of thousands for systems having telecom grade;

Chapter 2

Methodology

2.1 Fabrication of the double gold-coated PDMS SDI sensors

The fabrication process for the dual-SDI sensor is shown in Fig. 2.

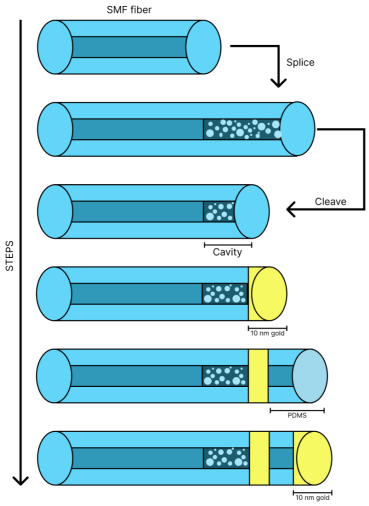


Figure 2.1: Fabrication steps

Using the SMF-SMF splicing protocol[3], the cleave SMF and splice EBF processes have been carried out utilizing a telecom-grade splicer and cleaver (Fujikura 12-S). The first SMF was spliced to an EBF, then coated with 10 nm of gold (Quorum q150 tes). A 0.1 gram of PDMS was mixed with 0.01 gram of curing acid and then deposited in 10 nm of gold. The PDMS[4] layer was drawn in the oven for 25 minutes. Lastly, the sensor was coated with 10 nm of gold (Quorum q150t es). Three sensors were fabricated using different drawing parameters to analyze the behavior of the double gold-coated PDMS SDI sensors to evaluate the optimal properties of the fiber, we fabricated three different sensors made with three different EBFs. To monitor sensitivity and return loss, all three sensors were measured in six outer mediums: Air, a 5-liter solution with 10 percent sugar, and then in every next step, 40 microliters of solution with 40 percent sugar were added.

Chapter 3

Experimental results

3.1 Sensor SP3-s1

Before applying the first coating, the SDI sensitivity showed a maximum sensitivity of 108 dB/µm. The spectra displayed a pattern similar to the Fabry-Perot scheme[**?**] with a peak at 1560 nm and another peak at 1590 nm, indicating an interval of 30 nm. Using the equation

$$L = \frac{\lambda^2}{n \cdot FSR} = \frac{(1550 \times 10^{-9})^2}{1.5 \times 30 \times 10^{-9}} \approx 53\,\mu m \tag{3.1}$$

the thickness of the coating is estimated at 50 microns. This thickness is sufficient to provide reflection, as it is more reflective than standard SDI sensors (-6 to -10 dB compared to SDI sensors, which are usually ¡ -30 dB). After the first application, the maximum sensitivity of the sensor increased to 178 dB/M2.

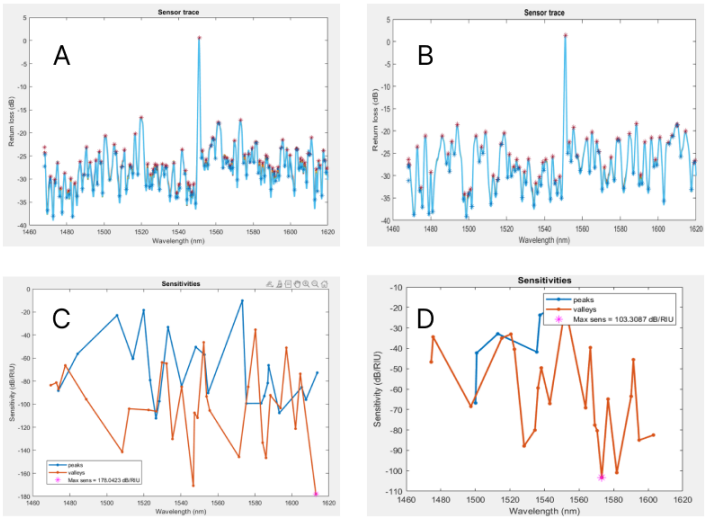


Figure 3.1: *Sensor SP3-s1*
A-Return Loss before first coating; B-Return Loss after 1st coating; C-Sensitivity before first coating; D-Sensitivity after 1st coating:

3.2 Sensor SP4-s1

Before the first coating was applied, the maximum sensitivity of the sensor was 110 dB/M2. A pattern similar to the Fabry-Perot pattern indicates that the coating with a thickness of about 50 microns works well, making the sensor more reflective and improving its characteristics. Figure 2 shows the zero sensitivity of the RBB, which is not affected by RI. We need to check if the spectrum is shifting or if the intensity is changing to confirm its repeatability and stability. If Figure 1 already shows the spectra for different RI values, that's great, but we still need to make sure they are consistent. The PDMS coating creates

resonance at a wavelength of 1570-1575 nm, demonstrating maximum sensitivity, which has a positive effect on the operation of the sensor. The sensors seem to work better after 1-2 coats, showing improved spectral characteristics and sensitivity.

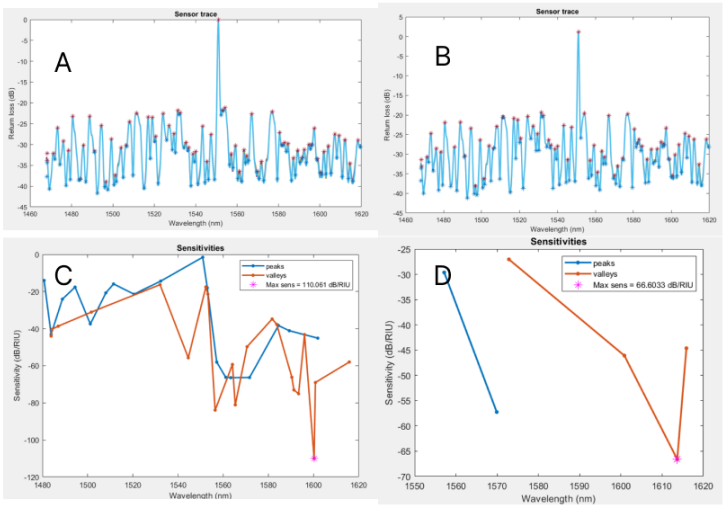


Figure 3.2: *Sensor SP4-s1*
A-Return Loss before first coating; B-Return Loss after 1st coating; C-Sensitivity before first coating; D-Sensitivity after 1st coating:

3.3 Conclusion

The experimental results show that PDMS SDI sensors with double gold coating, especially SMF sensors, have significantly better sensitivity after coating. The resonance and pattern similar to the Fabry-Perot pattern suggest that the coating thickness is just right, which makes the sensors more reflective. We still need to check if the spectrum shifts and repeatability are stable to make sure the sensors are reliable.

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