CHAPTER 3

Polymers for Optical Fiber Sensors

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3.1 Introduction

The design and realization of chemical sensors which are more and more reliable and capable of continuous monitoring constitute a continuous challenge in the scientific world. Measurement of bioanalytes in the medical field, control of many industrial processes, and control of air and water quality in environmental areas require the development of innovative sensors.

In many cases the drawing of the sample and the determination of its components in the lab with traditional instrumentation are not considered satisfactory, and continuous and in situ measurements are preferred. This approach has many advantages since:

- It avoids errors arising from a change in the drawn samples during transportation from the field to the laboratory
- It allows for a complete view of the trend of the process, and avoids errors in evaluation or failure in detection which may exist in the case of measurements that are limited in time
- It provides a real time response which, if necessary, makes possible an immediate remediation procedure

Within this framework, optical fiber sensors can play a fundamental role since, in addition to the above-mentioned benefits, they are characterized by advantages which other technologies are unable to offer [1–3]. For example:

- The absence of electromagnetic interference in the sensing process and the absence of electric contacts in the probe, which make them particularly suitable in the biomedical sector for invasive applications and in environmental or industrial sectors for the measurements in potentially hazardous or explosive environments
- A high degree of miniaturization and considerable geometrical versatility, which very often provide unique performances in biomedical invasive applications, since the probe can easily enter the human body without representing a risk or pain for the patient
- The possibility of combining the sensing process with an optical fiber network which is able to interrogate simultaneously many sensors for different parameters with the same optoelectronic unit

After an explanation of the principles at the basis of an optical fiber chemical sensor, the different types of polymers utilized and the different roles which these can play in the probe are described.
3.2 The Optical Fiber Sensor

An optical fiber sensor consists of three main parts:
- An optoelectronic system containing the hardware and software for interrogation of the probe and processing of signals
- An optical link which carries the optical signal from the instrumentation to the probe, and vice versa
- The probe, called optode or optrode, in which modulation of the optical signal takes place

3.2.1 The Optoelectronic System

The optoelectronic system is an extremely important part of an optical fiber sensor, even if, in chemical sensors, the main problem is concerned with the design and construction of the probe. On the other hand, an appropriate optoelectronic system must be developed in order to achieve a complete and satisfactory detecting system. In fact, many scientists often refer to optical fiber chemical sensors, even if only laboratory systems have been realized by using instrumentation which cannot be proposed for the development of a competitive and industrialized apparatus.

Therefore, before taking into consideration the problems related to construction of the probe, the main optoelectronic characteristics of the complete optical fiber sensor system must be considered.

Lamps, lasers, light emitting diodes (LEDs), and laser diodes can be used as sources. In the case of lamps or lasers, the use of optical (lenses, for example) or mechanical (for example, micropositioners) volume components, not always characterized by an easy and compact assembling, is necessary in order to guarantee the best coupling with optical fibers. Moreover, these sources must often be coupled with a light modulation system (usually mechanical choppers). In the case of lamps, optical filtering is necessary in order to select the right wavelength for the analysis of the chemical species being tested. This makes preferable the use of LEDs or diode lasers, because of their easy coupling to optical fibers by means of commercially-available components and because of their capacity to be modulated electronically, thus avoiding the use of any mechanical coding of the optical signal.

The detecting system consists of a photodetector (photomultiplier, photodiode, etc.) coupled to appropriate electronics for the signal processing. With fluorophores, the use of optical filters connected to the photodetector is necessary in order to obtain good discrimination between excitation and emission radiation.

At this point, it is important to emphasize that market considerations make sensors which utilize simple and low-cost optoelectronics components more competitive. On this basis, LEDs, as sources, and integrated circuits coupled to simple photodiodes, are the best solution. On the other hand, this solution cannot always be followed, since LEDs available on the market cover only the visible band and some regions of the near infrared, and not all the regions of interest for the detection of chemical species.