Characterization Studying Optical Fiber Chemical Sensor for Different Applications

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Abstract: In this work, the optical fiber chemical sensor had been introduced based on the Fabry-Perot interferometer technique. Single-mode fibers were used with different diameters (125, 60, 50) µm. Chemical etching technology is used to reduce fiber diameters. Sensor heads were immersed in chlorophyll dye with different concentrations. The submitted sensor shows good sensitivity and linearity towards the variation in the chemical dye concentration. Both the peak wavelength and peak power were changes. The higher wavelength and power sensitivities were higher for the sensors with a smaller diameter. This technique could be very useful in medicine, drug pharmaceutical and food industries applications.

Keywords: Optical Fiber Sensors, Refractive Index, Fabry–Perot Interferometer, Micro-fibers, chemical dyes.

1-Introduction

Optical fiber sensors have many advantages, such as high sensitivity, lightness of weight, small diameter, and lack of exposure to electromagnetic wave interference. They have been highly used for observation and measurement of many physical quantities, such as pressure, stress, twisting, temperature, as well as strain measurement, which is richer than in industry [1]. Chemical sensors are widely used in applications such as safety, critical care, process controls, industrial hygiene, quality controls, clinical diagnosis, emission control, home safety alerts, internal security where chemical sensors have produced social and economic benefits. Chemical sensors contain a chemical or molecular target to be measured. Biosensors are sensors that use biomolecules or structures for measurement and are of biological importance [2]. Optical fiber sensors are widely used to identify chemical and environmental materials, optical fibers serve the analytical sciences as they enable optical spectroscopy to be performed on sites that cannot be reached in traditional spectroscopy, and produce many methods of interrogation such as extra wave spectroscopy, medical and chemical molecular analysis, technology. Vitality, marine and environmental analysis, production control, vital process control [3]. Optical sensors are used to monitor the sample to be analyzed at a certain distance [4]. The chemical sensor is called Cambridge, and chemical sensors are known as miniature devices that provide information in real time and on the Internet about the presence of certain compounds or ions in complex samples. Wide, they are optical absorption and luster devices and depend on other spectrometers, as is the case in optical parameters such as reflectivity and refractive index [5]. Chemical sensors using superstructure molecule systems have attracted tremendous attention [6]. Chemical sensors such as surface sound wave sensors, conductive polymer sensors, metal oxide sensors, microcantileves have important applications in public security, environmental surveillance,
medical applications, and automotive applications. Researchers have intensified their efforts to develop all highly sensitive and selective materials and sensors, as most commercial sensors rely on pure metal oxides or anesthesia because of their compatibility with high temperature [7]. Measuring small sample sizes remotely, sensing in inaccessible locations, multiple sensing potential. FOS applications in infrared and near-range spectral biology and medicine operate from 340 nm to 2 μm [8]. In recent years, biomarkers have been developed to monitor food quality. Acidic-sensitive color sensors are often considered unsuitable for selective analysis and are sufficient to assess food quality based on pH change. Degraded proteins produce volatile alkaline nitrogen compounds (cadaverine, butricin, histamine), Carbon dioxide develops during metabolism of pathogens, so food lowers the hydrogen number, which can be detected by anthocyanin/polylysine in the cellulose matrix reversible. Chlorophyll is relevant to sensing because the structures are very sensitive to oxidizing species [9]. The quality of the fruit includes a number of sensory properties (coloration, shape, texture, taste, smell, nutritional value, mechanical properties, and chemical composition) that typically favor machine measurements over sensory techniques in research and commercial applications, many attempts have been made in the past decades to apply full fruit measurements the spectral reflection of non-destructive apple techniques [10]. the chloroplasts that contain the main part of the fruit, chlorophyll and carotenoids, are specialized in the metabolism, while the anthocyanins are responsible for the red color of apples and participate in protecting the fruit from harmful ultraviolet rays and excessive radiation of the sun. one of the most important advantages of non-destructive optical techniques is that they allow an individual to perform successive measurements of a sample, providing valuable information on the pattern and state of the pigment in plant tissue where changes in the spectral reflection of the apple fruit can be observed markedly during maturity and storage [11] Due to the importance of chemical optical fiber sensors, many articles have been published in this field.

IN(2013)Yulian Liu et al Study of fruit coloration and biosynthesis of anthocyanins, evolution of apple color (L * and a / b) and accumulation of anthocyanins and activity of the enzymes phenylalanine ammonia-lyase (PAL), dihyroflavonol-4-reductase (DFR), UDP-Glucose: flavonoid-3-O-galactosyl transferase (UFGT) and chalcone isomerase (CHI), In red apple sacks are packed Golden Delicious and Granny Smith varieties and Pink Lady and 'Starkrimon' red apples. The young fruits were placed in bags 40-45 days after flowering, Starkrimon, Golden Delicious were detected and exposed to 120 DAF, Granny smith, pinklady were exposed to 160DAF. The results showed that cyanidin 3-galactoside (Cy3-gal) The anthocyanins were the most abundant of both. The red and non-red varieties had a higher anthocyanin level in Granny smith than in Golden Delicious. The researchers concluded that the red color was easier to develop in Granny Smith than the yellow Golden Delicious after removing the cyst. The cy3-gal The accumulation of non-red varieties tested was not significantly associated with PAL, CHI, and DFR activity, but was significantly associated with UFGT activity, as during non-red apple redness, UFGT may be the most important factor in anthocyanins [12].

IN (2016) MD Arafat Hosssain et al, a fiber-optic-based smartphone spectrometer incorporating an endoscopic fiber package is demonstrated. The internal range allows the smartphone camera’s LED to be transmitted from light to sample, eliminating complications from various backlighting. Reflected spectra were collected from a surface or scattered interface on the camera using a diffraction reflector grooved CMOS. The spectral accuracy was low 2.0 nanometers wide of the range 250 nanometers obtained using a crack width, lit. 0.7 mm. The machine has enormous potential in a number of industrial applications, as well as analysis of agricultural products. Apple spectroscopy shows a direct measurement of chlorophyll dyes, anthocyanins, carotenoids, all of which decrease as storage time increases [13].

IN(2019) Asnake Lealem Berhanu et al The study of Schiff's bases as a photochemical sensor, Schiff's bases and mineral complexes have become well known as catalysts in various processes and biological properties such as anti-fungi, antiviral bacteria and malaria. Since its discovery in 1864 by Hogo Schiff, multi-use tools have been used in many applications, such as fluorescent operating sensors to identify analyses as diverse as metal components. A method for identifying toxic ions and their types in
environmental media has been introduced, and a wide range of Schiff rules used in metal caterpillar and anionic sensing applications have been studied in different types of environmental and biological media. One Schiff base can be used as a sensor for more than one ion at the same time and under the same state, where color can appear from the uncomplicated form to the complex form photo dynamically with a given ion. Schiff's rules change color from yellow to purple with fluoride ions, the complex ability of Schiff's rules makes them suitable for detecting different targets in nature, very specific. The detection of toxic chemicals from the environment using the Schiff base as optical sensors is a difficult problem and can be done by creating probe electronics using chemical sensors and integrated signals with the Internet to map different environmental samples, which helps detect pollution. The researchers concluded that Schiff's rules could be used in a variety of fields including optics, sensors and in many other applications such as antibiotics, antibacterial, anticancer, antioxidants and catalysts. Since the easy composition of Schiff’s rules makes them important for versatile applications in various uses. Domains [14].

In (2020) Emanuela Drago et al. Studying food packaging to develop active products and smart packaging techniques that provide high-quality food products with more safety, active packaging includes integrating the active ingredient into the packaging to maintain product quality and prolong the shelf life. To provide information about product quality during transport and storage, smart systems are used to monitor the status of packaged foods. It produces a multi-purpose food packaging system [15].

IN (2020) Yashar Esfahani the design of fiber-optic biometric sensors, which have high sensitivity to the nanomaterials of the surrounding medium, are flexible and compressed to detect biological species as cells and proteins because of their small size, low cost, accuracy, remote controllability and distributed sensing, optical fiber biosensors are promising alternatives to traditional methods of detection of biomolecules, which lead to great advances in monitoring food processes, clinical diagnosis, drug discovery, and environmental monitoring. Researchers have studied the design concepts of biosensor design for optical fibers, including geometric shapes based on traditional fibers. Designs such as side polished and tapered fibers, uncoated fibers, engineering based on specialized optical fibers such as oblique fibers, crystal fibers It can be used by engineers in the field of optical fiber technology, scientists in the fields of bio sensitivity, biomedicine, and it can also replace traditional biosensors in environmental monitoring, ocean monitoring, chemistry, drug discovery, oil industry [16].

In this work, the optical fiber chemical sensor designed and submitted based on the Fabry-Perot interferometer technique using a single-mode optical fiber with different diameters.

2. Experimental Work

In this work, commercially available single-mode fibers (SMF) had been used for manufacturing the sensor head. The chemical etching method was used to reduce the diameter of the SMF. In the inscription process, the fibers diameter changes at room temperature using a distilled HF solution, where the sensor's experimental arrangement consists of a single-mode SMF optical glass with a diameter of 125 micrometers, the chemical etching achieved using 40% concentration HF diluted with distilled water (DW) with percentage (1 HF:2 DW) for 60 minutes and 95 minutes to obtain an area of high sensitivity to the surrounding concentrations. This part of the fiber is called (sensor head). The diameter of the fibers were measured using optical microscope (Nikon Eclipse ME600) The diameters after the chemical etching were 60 µm for etching time 60 minutes and 40 µm for etching time 95 minutes. Figure 1 shows the microscopic images of sensors heads.
The signal is transmitted from a single-mode fiber pigtailed Laser diode source (Thorlabs) of center wavelength 1550 nm, and power 1.5 mw. This source was connected to the input arm of 1x2 optical coupler with splitting ration (50%:50%). one of the outputs arms connected to the sensor head. Three sensor heads with different diameters were investigated; (125, 60, and 40) µm. The above sensor heads were immersed into chlorophyll dyes liquid with different concentrations. The reflected spectrum of the end tip of the sensor head travelling through the second arm of the optical coupler, which is connected, to the Optical Spectrum Analyzer (OSA). THORLABS (OSA 203) with a wavelength range of 1000 to 2600 nm, and resolution 0.1 nm was used to record and analyzing the reflected spectra for each case. Figure 2 shows the photographic image and the schematic diagram of the submitted work.
3. Results and Discussions

The influence of variation the sensor head diameter on the responsivity of chemical sensor immersed into chlorophyll dyes was studied and analysed. The sensor diameters were (125, 60, and 40) µm. These sensors heads were immersed into chlorophyll dyes with different concentrations to study the effect of solution concentration on sensor characteristics. Figure 3 shows the reflected spectra from sensor heads with diameters (125, 60,40) µm immersed into chlorophyll dyes of concentrations (a) very high concentration, (b) diluted dye with percentage (2 chlorophylls: 2 alcohol), (c) diluted dye with percentage (2 chlorophyll: 4 alcohol), (d) diluted dye with percentage (2 chlorophyll: 6 alcohol), and (e) diluted dye with percentage (2 chlorophyll: 8 alcohol) respectively.
Figure 3. The reflected spectra from sensor head with diameter diameters (125, 60, 40) µm immersed into chlorophyll dyes of concentrations (a) very high concentration, diluted dye with percentages (b) (2 chlorophylls: 2 alcohol), (c) (2 chlorophyll: 4 alcohol), (d) (2 chlorophyll: 6 alcohol), and (e) 2 chlorophyll: 8 alcohol).

From figure 3 it could be noticed that the intensity of reflected spectra was decreased due to decrease of sensor diameter. Also, there is a slightly wavelength shifting towards the blue region due to sensor diameter increasing. The power and wavelength sensitivity calculated from the slope of the linear relationship as it clears in figure 4.
Figure 4. The power and wavelength sensitivity for sensor head with diameter diameters (125, 60, 40) µm immersed into chlorophyll dyes of concentrations (a) very high concentration, diluted dye with percentages (b) (2 chlorophylls: 2 alcohol), (c) (2 chlorophyll: 4 alcohol), (d) (2 chlorophyll: 6 alcohol), and (e) 2 chlorophyll: 8 alcohol).

The above results summarized in table 1.

Table 1. The wavelength and power sensitivity for submitted sensors

| Concentration of chlorophyll dye | Wavelength sensitivity (pm/µm) | Intensity sensitivity (nW/µm) |
|---------------------------------|-------------------------------|-----------------------------|
| full concentration             | (-) 9                         | 2.5                         |
| 2:2                             | (-) 3                         | 2.2                         |
| 2:4                             | (-) 2                         | 2                           |
| 2:6                             | (-) 1.7                       | 1.7                         |
| 2:8                             | (-) 1                         | 1                           |
From the above table and figures, we note that the wavelength and intensity are affected by the immersion of the sensor head with different concentrations of chlorophyll. As the wavelength decreases (its blue shift) as the fiber diameter increases as for the intensity, it increases with the increase of the fiber diameter, because the attenuation is less. The sensitivity in general decreases as the chlorophyll concentration decreases. The decreasing of fiber diameter leads to increase the evanescent field and thus more light modes will interact with the chlorophyll dye and thus increase the sensitivity of the sensor.

4. Conclusion

An optical fiber chemical sensor based on the Fabry-Perot interferometer technology is presented in this work. Various fiber sensor diameters have been tested to improve system performance. The sensor head was immersed in a chlorophyll dye with different concentration. The performance of all sensors is linear and sensitive. This type of technology can be very successful in chemical or biological environments or applications

5. References:

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