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OPTICAL FIBER SENSOR WITH AG-NPS CLADDING FOR TEMPERATURE SENSING

S. M. Kadhim*[1], K. A. Sukkar[2] & N. H. Jabbar[1]
[1]Laser and Optoelectronics Engineering Department, University of Technology,
[2]Chemical Engineering Department, University of Technology, Baghdad, Iraq
Baghdad, Iraq

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ABSTRACT

The modified temperature sensing system by using single mode fiber optics that coated with nanoparticle material (Ag). The presences of nanoparticles in the fiber optics sensor have given a high surface area in the cladding region. This area has showed an extension in the path of light movement, leading to a high response for temperature sensing.

I. INTRODUCTION

Temperature sensors are fundamental and useful devices in various areas of the lives. They have been originally utilized for measuring and monitoring the temperature which driven by several condition of the environment. Temperature sensor hasmany applications in different fields such as the beverage and food industry, medicine/biomedicine. Horticulture and agriculture, industrial processing, and research and development [1].
Temperature sensors have been also utilized in the petro-chemical industry, the auto-motive industry, geothermal wells, metal industry, petroleum industry, the consumer-electronics industry, and application in hard environmental [2].

Lately, the optical fiber temperature sensor are the excellent candidates and that because of their low weight, small size, versatility of the geometrical, electron isolation, remote-sensing capabilities, and immunity of electromagnetic interference [3, 4]. Optical fiber sensor has been designed for collecting the data through an optical fiber; the variation in a specific physical property which must be sensed for the surrounding medium will cause variation in the characteristics of the light that transmitted over the fiber optic [5].

II. THEORY

In the last years, the optical fiber evanescent-wave sensors have been developed and received great attention. These sensors have been based on the principle attenuated-total internal reflection (ATR) spectroscopy technique [6], where this technique uses the absorption of evanescent-wave penetrated into cladding section where the absorbing medium is placed. Therefore, the cladding has been removed from a specific part of the fiber and replaced by an absorbing or sensitive material, thus the light in the core section is able to expose to it directly [7, 8].

The material of the sensitive region changes the absorbance in presence of analyte or a specific parameter, therefore; the change of the guided light is observed. The mechanisms of absorption have been explained by the Lambert-Beer Law, where the absorbance of the light through a sensitive region, material or analyte can be expressed by [9, 10]:

$$A = -\log_{10}\frac{I}{I_o} = \alpha L = \varepsilon C L \qquad (1)$$

where, I_o light intensity before and I the light intensity after passing the sensitive region,$\alpha$is the absorption coefficient which can be denoted as the product of the molar absorptivityε, L is the length of interaction within the absorbing region, and C is the targetconcentration [9, 10]

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Also, the transmission of the light through a sensitive region, such as analyte or a material called (transmittance), represents the relation between the intensity of light before (I_o) and that after (I) passing through this sensitive region, can be expressed by [9, 10]:

$$T=\frac{I}{I_o} = 10^{-\alpha L} = 10^{\varepsilon CL} \quad (2)$$

The construct of the standard single modeoptic-fiber evanescent field sensor is shown in Figure (1). One portion of the optical fiber cladding is removed and replaced by an absorbing material and the core will exposed directly to the analyte. Therefore; a part of the evanescent field is absorbed and interact with the analyte. This is the basic principle of the optical fibers evanescent wave sensors [11, 12].

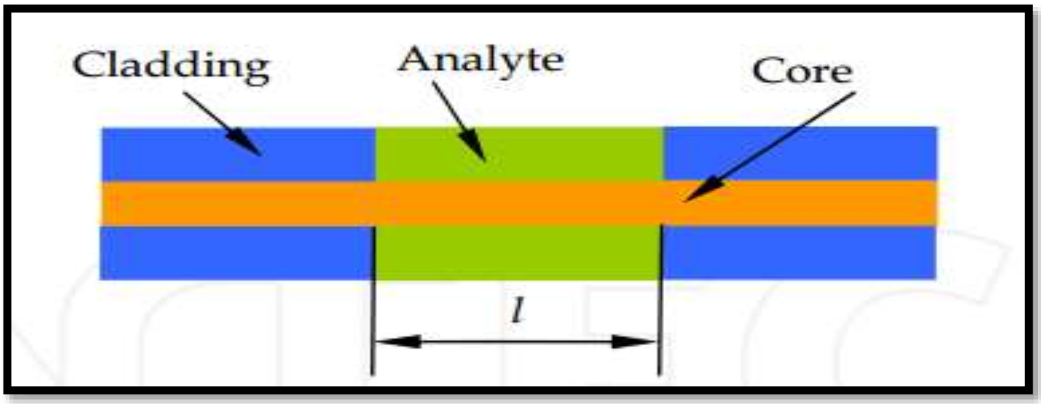

Figure (1): Schematic diagram of the evanescent field optical fiber sensors [12]

III. EXPERIMENT WORK

The experiment work configuration consist of a single mode optical fiber (SMF-28) with (9/125) core to cladding diameter, and (1 m) of length. The core and cladding refractive index are (n_1 = 1.45, n_2 = 1.44) respectively. The middle of the optical fiber with (3 cm) is exposed to etching process to obtain the sensitive region with the core only. Then the NPs-coated process is done by impregnation that section in the NPs-material (Ag). This section (3 cm) NPs-coated of the fiber called the sensing region, which expose to the temperature.
The experiment set-up of SMF temperature sensor is shown in figure (2), where the light source with (200-1100) nm wavelength range (Deuterium, UV-VIS-NIR light source, DH200) is connected to one end of the optical fiber and the other end connected to the optical spectral analyzer (OSA). The sensing region of the optical fiber is immersed in water path (Thermostat Water Path HH-1, KW-1000DC), where expose to different temperature range (26 to 60) ^{0}C by step of 5 ^{0}C.

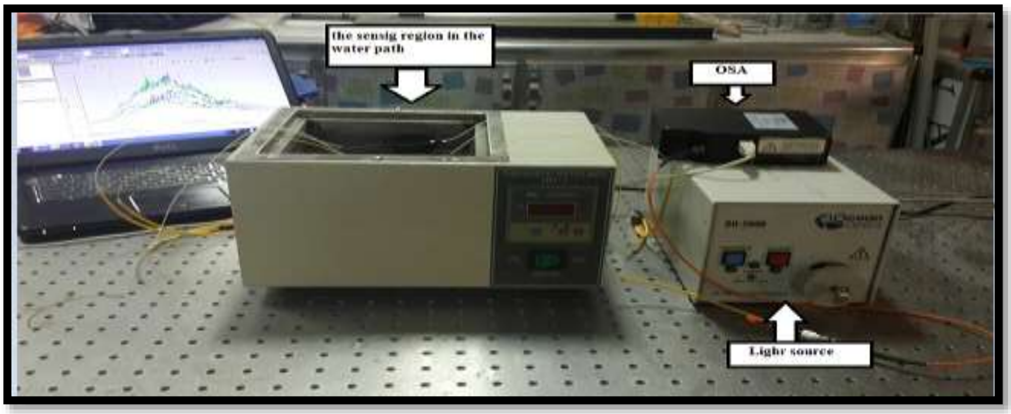

Figure (3): The experiment set-up of SMF temperature sensing

IV. RESULT

The results are achieved with temperature range of (26-60)℃. Figure (4) shows the spectra at end of optical fiber sensorthat obtained at different temperature values. It can be observed that the output intensity decreases as the surrounding temperature increases, due to the thermal effect on the refractive index of the NPs material and a large fraction of the intensity is propagated out-side the fiber core

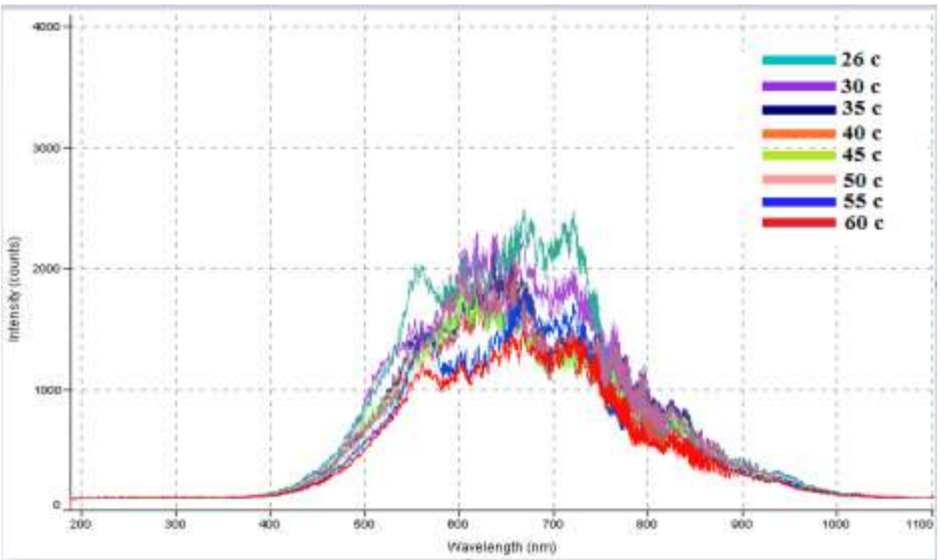

Figure (4):Intensity spectra of SMF sensor that coated with Ag nanoparticles at various temperatures

In Figure (5) and figure (6), the response of the transmittance or (relative intensity) and the absorbance to various temperatures are exhibited based on Eq.(1) and (2). It can observed that a decline in transmittance with the rise of temperature. That due to high amount of light is leaked at the interface between the core and the surrounding NPs material in sensing region of the fiber via evanescent-waves.On the other hand observe the absorbance is directly proportional with the temperature.

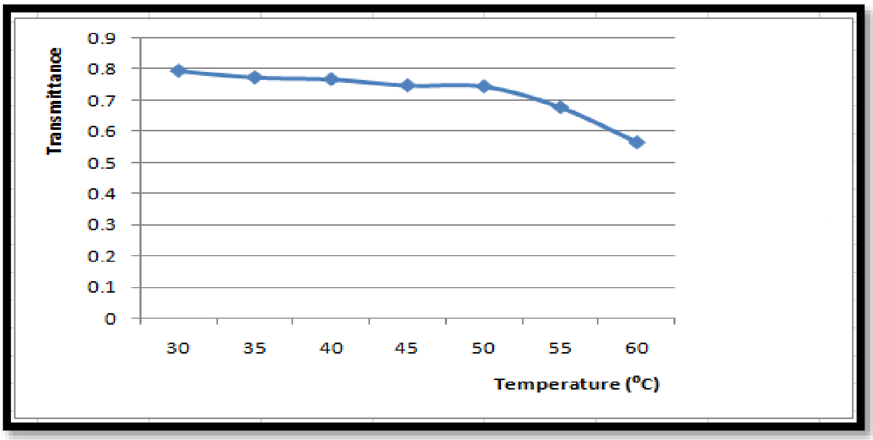

Figure (5): The relationship between transmittance and temperature of Ag NPs-coated optical fiber sensor

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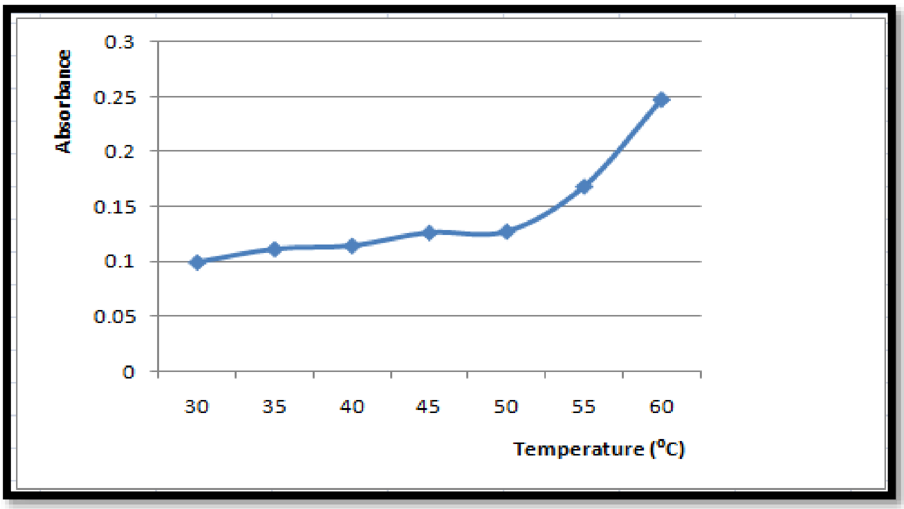

Figure (6): The relationship between absorbance and temperature of Ag NPs-coated optical fiber sensor

V. CONCLUSION

The results have showed a positive interaction between the Ag nanoparticle that coated on cladding with the propagation light, leading to enhance the optical fiber properties and then the characteristics of the sensing process. The fiber achieves a high sensitivity to temperature changes. Hence, the optical transmitted intensity decrease respectively,the changes of optical transmitted intensity of fiber optic with NPs-coated follow the changes in surrounding temperature, thus the optical fiber with NPs-coated can be used as a fiber-optic temperature sensors.

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