International Journal of Nanotechnology and Applications
ISSN 0973-631X Volume 11, Number 1 (2017), pp. 29-34

http://www.ripublication.com

Optimization of Sensing Length of Modified Cladding Optical Fiber Sensor for Toxic gas sensing Application

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Abstract

In this paper, work carried out on the development of the fiber optic chemical sensor is presented. The sensor is based on the change of optical power or optical intensity modulation induced within modified multimode optical fibers. The sensor design is based on modified cladding technique; the conducting polymer film of the polyaniline doped with (Acrylic acid) AA, and Hydrochloric acid HCl sensitive to ammonia gas with optimized synthesis parameters was coated on a small section of the uncladed fiber. The sensing properties of the optical fiber sensor for ammonia vapors at room temperature have been studied. These experimental results have demonstrated that a sensing length optimization is important parameter in the design of optical fiber sensor

Keywords: Fiber-optic chemical sensor, modified cladding, sensor technology, sensing length

INTRODUCTION

Optical fiber sensors are being used to sense the chemical species. The optical fiber sensors have found many application in chemical [1-5], biochemical and biomedical [6-8], and environmental sensing[9-10].There are several advantages of optical fiber sensor in chemical sensing such as suitability for in-situ measurement, free from electro-magnetic interference and potential for distributed sensing. Optical fiber evanescent wave chemical sensor uses a light modulation, i.e. one of the light parameter changes according to the analytes presence. Organic conducting polymer such as polypyrrole, polyaniline, polythiophene shows a reversible change in their

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resistance when exposed to certain vapors [11-12]. The change in conductivity will change permittivity, which leads to change in the refractive index. Coating based sensor is the largest class of the intrinsic fiber optic evanescent wave chemical sensor .The analytes reacts with the coating to change the optical properties i.e. refractive index, absorbance, and fluorescence which is coupled to the core to change the transmission properties through the optical fiber. The active coating plays important role in the sensor designing. An intrinsic fiber-optic evanescent wave chemical sensor can be developed by replacing a certain portion of the original cladding with chemically sensitive material specifically polyaniline [13].

THEORY

The configuration of the fiber-optic sensor is created on the fiber itself, as shown in Fig.1, using the cladding modification methodology. In a small section of an optical fiber, the original passive cladding is replaced by a sensitive cladding.The sensing mechanism is based on the interaction between the light transmitted in the optical fiber with an external chemical perturbation in the modified cladding region. This interaction results in the intensity modulation. The interaction between the evanescent field in the cladding and external perturbation results in the attenuation of the guided light in the fiber core through absorption and fluorescent.If the modified cladding has a higher refractive index than the core, a portion of guided modes transfer to the radiation modes. The percentage of the light reflected back into the core depends on the refractive indices of core and modified cladding as well as the light incident angle. The light propagated inside the modified cladding is partially absorbed and the rest refracts back into the core. When the light passes through the absorbing cladding, the light energy is attenuated which depends upon the absorption coefficient of the cladding material. The total energy loss after the light passing through the modified area depends on the light absorption by the modified cladding and the number of interactions between core and cladding.

Fig.1. also shows that the guided ray does not interact with the core/modified cladding interface.

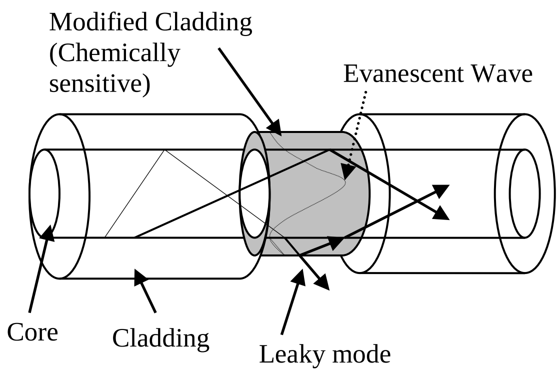

Fig.1 Configuration of fiber optic sensor and geometric optics ray through the sensing region.

EXPERIMENTAL

In-situ deposition of polyaniline on the optical fiber sensor

The in-situ deposition of the chemically active polyaniline on the fiber modified section is achieved by suspending the uncladed region of the optical fiber in the reaction container, consisting of monomer, oxidant and the dopant acid, with optimized parameters.

Characterization of the optical fiber sensing element

The sensing element was exposed to ammonia gas for different concentration (20-200 ppm). The output intensity was recorded by (Optical Fiber test bench, Ruby Optosystems, Pune, India) and indigenously developed optical fiber gas sensing chamber.
The effect of sensing element lengths for different concentration of ammonia gas was investigated by employing indigenously developed optical fiber gas sensor characterization unit and Optical Fiber test bench, Ruby Optosystems, Pune, India.

Determination of sensing properties of optical fiber sensor

An experimental set-up implemented in order to characterize the optical fiber sensor is shown in Fig.2. It was built by integrating the optical fiber sensing part with a light source, a photo detector and other electronic devices. A part of the testing fiber coated with PANI layer was placed in special gas chamber of the indigenously developed optical fiber sensing system, making possible to bring the sensing region of the fiber into the contact with vapors. The sensing elements prepared were cleaved at both ends to have mirror flat edges.

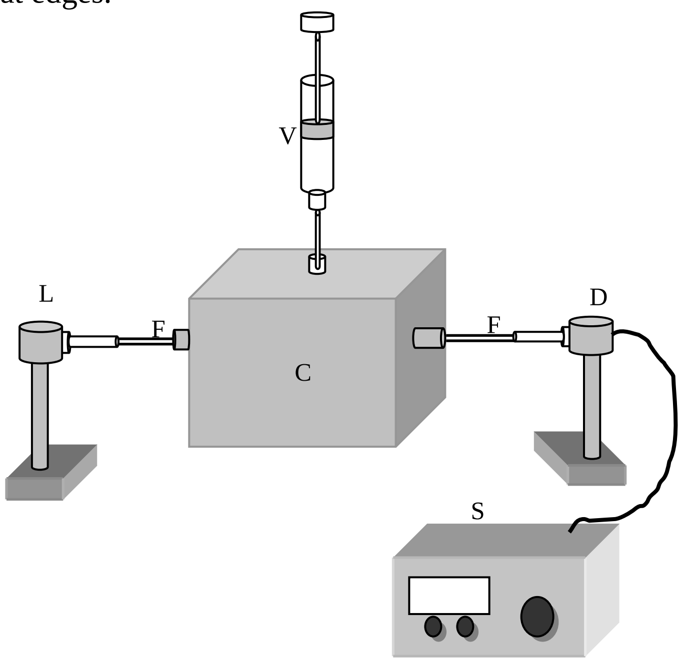

Fig.2. Schematic diagram of the experimental set up L: Light emitting diode, F: optical fiber, C: airtight chamber, V: ammonia vapor,D: photodetector, S: signal processor.

The cleaved sensor element is then integrated with a LED (wavelength 633 nm) light source and a silicon photo-detector (Optical Fiber test bench, Ruby Optosystems, Pune, India). The light source was focused onto the one end of the modified optical fiber sensor. At the other end, a photo detector was positioned to receive the optical signal, converted into electrical signal form. The change in output power is measured when the sensor is exposed to different concentrations of ammonia vapors (20-200 ppm) at room temperature.

Effect of the sensing length of the sensor

The different sensing elements i.e. 1 cm to 4 cm were prepared and coated with polyaniline film doped with HCl and AA with the optimized parameters. Figure 3 shows the sensor response for four sensing elements. I observed best response for 2 cm sensing element, when it was exposed to 50 ppm of ammonia vapor.

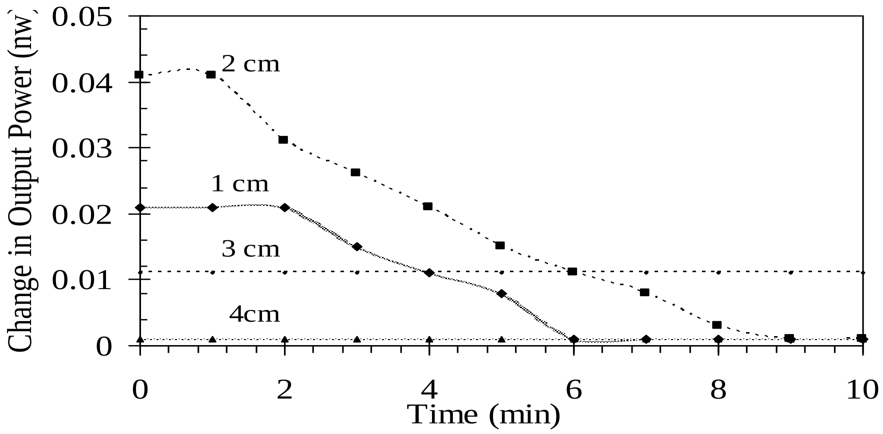

Fig 3. Sensor response for different sensing length
A: 4 cm; B: 3 cm; C: 1 cm; D: 2cm.

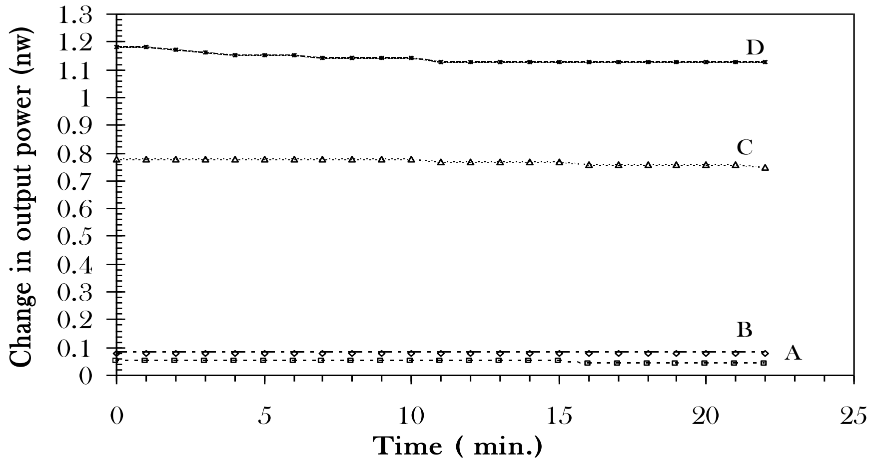

Fig 4. Sensor response for different source power.
A: 1µw; B: 2µw; C: 3µw; D: 3.5µw.

The decrease in output power (intensity) with increasing sensing length is attributed to the increase in the number of leaky modes. The increase in the sensor response is due to the increase in sensor length from 1 cm to 2 cm, but for 3 cm and 4 cm sensor response is less i.e. the change in power (intensity) is less, which may be due to the more sensing length which incorporates more leaky modes and hence less light can interact with the film and therefore the sensor response is less.
Figure 4 shows the sensor response obtained for 1µw, 2 µw, 3 µw, 3.5 µw source power for 2 cm sensor and 50 ppm of ammonia gas .The change in output power was maximum for 3.5 µw source power. This may be due to the more source power has the more evanescent power available at the sensor, which incorporates more interaction with the film.

CONCLUSION

I have designed and developed an optical fiber based chemical sensor for ammonia gas sensing. The sensor is based on modified cladding approach. i.e. ammonia sensitive layer was deposited on the core of the sensor. A simple approach was used to design the sensor. The sensing properties of the optical fiber sensor for ammonia vapors at room temperature have been studied. These experimental results have demonstrated that a sensing length optimization is important parameter in the design of optical fiber sensor.

ACKNOWLEDGMENT

Author is thankful to the UGC New Delhi, India,University of Pune, University of Mumbai for the financial assistance and Optoelectronics and Sensor Research Laboratory, Department of Physics Dr.Babasaheb Ambedkar Marathwada University Aurangabad for Instrumental facility support.

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