Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Fiber Optic Humidity Sensor Using a Novel Polymer Complex

Bindu Krishnan[1*], Ramiz Ahmad[2]

[1]Department of Physics, Sree Kerala Varma College, Thrissur, Kerala, India.680011
[2]Department of Physics and Astronomy, University of Delaware Newark, DE-19716,
IIST, Thiruvananthapuram, Kerala, India (Address at the time of work)

ABSTRACT

A simple fiber optic humidity sensor is fabricated based on novel polyelectrolyte complex film of the polymers, Chitosan and Carboxy Methyl Cellulose. A small portion of the cladding of the optical fiber is removed and is coated with the hydrogel polymer film. Coating is done using layer by layer technique. This portion is inserted into the region where the humidity has to be monitored. The sensor makes use of the intensity variation of guided light through the plastic optical fiber due to scattering and the phenomenon refractive index variation of the coated hydrogel film. The output power variation is found to be linear, and without hysteresis.

KEYWORDS: Humidity sensor, Evanescent wave, Optical fiber, Hydrogel, polymer composite

*Corresponding author:

Bindu Krishnan

Department of Physics,

Sree Kerala Varma College, Thrissur, Kerala, India. PIN 680011

email :bindukris@gmail.com Ph.9447483535

1. INTRODUCTION

Fiber optic humidity sensors have certain advantages over other types of humidity sensors like its immunity to electromagnetic interference, lightness, smallness, high sensitivity, and ease in implementing multiplexed or distributed systems. Many methods are used in fiber optic humidity sensors which include direct spectroscopy, evanescent wave method and fiber grating method to mention a few. In the evanescent wave technique, sensors have been made using changes that are susceptible to changes in humidity of surroundings such as the scattering, the absorption as well as the refractive index in the modified cladding material.[1] The technique of using hydrogels for altering the evanescent wave and hence the intensity of the guided light is a relatively simple and common technique.[2,3] Here instead of using a single hydrogel, we report the use of a polyelectrolyte complex made of two natural polymers, cationic Chitosan (CS) and anionic Carboxy Methyl Cellulose (CMC).The coulomb interaction between the oppositely charged polymer molecules is more effective than the usual chemical activation during chemisorption process. Hence the multilayer film using layer by layer (LBL) self-assembly technique gives thin films of better adhesion and stability.[4] Chitosan is an abundant but underused biopolymer. Chitosan hydrogel shows properties like reversible water absorbing capacity and excellent swelling effect, good film forming ability, biodegradability and transparency. Silica core fibers are often used in fiber optic humidity sensors. We have used plastic fiber, which is relatively more cost-effective.

2. EXPERIMENTAL SECTION

We used commercial plastic fiber to develop the sensor (HOLMARC). About 4 cm of the cladding was removed and was coated with the poly electrolytes by LBL technique. The CS used was 2% solution in acetic acid and CMC was prepared by dissolving 1g of commercially available Na-CMC (Merck). The stripped fiber was dipped into the two solutions alternatively 5 times. The rate of ascent and descent into the solution was controlled using a dip coating machine (HOLMARC, model no. HO-TH-01). After the dipping, the set-up was left undisturbed to dry for a day. A semiconductor diode laser having a power output of 5mW at 630 nm was used as power source and a photodiode (Phy-We) was used as a detector. The sensing portion of the fiber was inserted in a standard climatic chamber (Model Challenger 340, ACS), where RH was varied from 20 to 90 %.The temperature was kept constant at 25^{o}C.

3. RESULTS AND DISCUSSION

An evanescent field is created whenever light undergoes total internal reflection at the boundary between two dielectric media, exhibiting exponentially decaying amplitude given by the expression:

$E(x, t) = E_0 \exp(-z/d_p)$

The depth of penetration d_p will depend on the refractive indices of the core and cladding. In EW sensors, we make use of the interaction of the evanescent wave in the modified cladding region with the surroundings. In the present sensor, the intensity of the leaky modes changes with water absorption in the hydrogel.

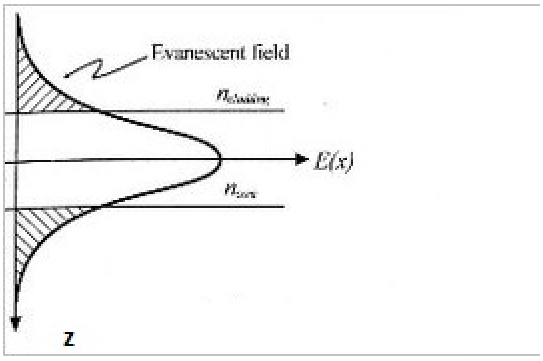

Figure.1 . Evanescent field formation in the cladding region.

Two essential characteristics of any sensor are linearity of the output and lack of hysteresis while increasing and decreasing the sensing variable, in the present case, humidity. Figure 2 shows the variation of fiber output with humidity change. One can see that the output optical power varies almost linearly for the range of 20 to 80 % RH, and shows good reversibility.

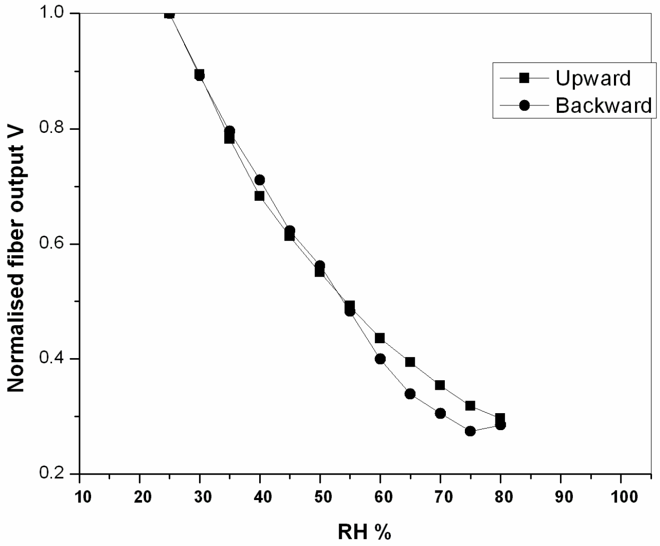

Figure. 2. Variation of normalized fiber output with change in relative humidity

To measure response time of sensor, it should be exposed to fast humidity changes. Human breath has enough water content to do this testing. Hence the sensor was exposed to mouthfuls of rapid exhalation. It was found that after each exposure, the sensor reached a fast equilibrium with atmospheric moisture in less than 1 min. (Figure 3).

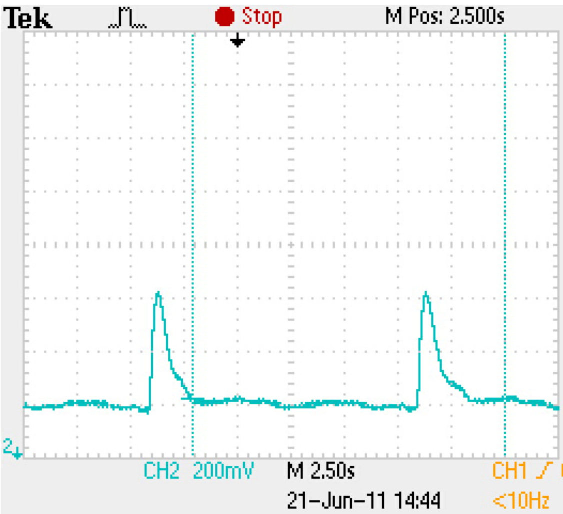

Figure. 3. Response time of the sensor to human breathing

The core refractive index of the PMMA fiber we have used is 1.47. Chitosan films in dry state are reported to have refractive index 1.52-1.59 in the dry state while CMC usually has 1.51-1.58. Hence the modified cladding converts the light in the sensing region into leaky modes to begin with. In the case of films made from a single hydrogel material like chitosan, it is reported that with the increase in RH, the refractive index (n) of the film becomes smaller and the thickness (L) becomes larger.[5] For the light propagation, it is effective optical path length, given by L*n, which is important. The net variation in this quantity will affect the light propagation and hence the light output when such a film is used as cladding in optical fiber. The action of water absorption in the layer by layer assembly of chitosan and CMC will be more complex and will be the synergetic effect of refractive index variation and change in the optical path length due to swelling. The net effect is found to be increased light coupled into the cladding mode as the humidity increases up to 80%. This results in decrease in the light output in the fiber, the decrease being almost linear and without hysteresis.

5. CONCLUSION

A low cost, low complexity fiber optic humidity sensor is fabricated using a plastic fiber. The sensor is based on evanescent wave absorption spectroscopy and utilizes a film of two hydrogels, Chitosan and CMC, coated on the unclad sensing region of the fiber. The sensor is found to be sensitive to RH ranging from 20 to ~80 %, exhibiting good linearity, fast response time and extremely good degree of reversibility.

6. ACKNOWLEDGEMENTS

Authors sincerely thank Dr Rajendran, QRMG, VSSC, Thiruvanthapuram for lending the climatic chamber facility and Director, IIST for all the support given where the authors were affiliated to, during the time of this work.

REFERENCES

1. T.L. Yeo, T. Sun, K.T.V. Grattan. Fiber-optic sensor technologies for humidity and moisture measurent. Sensors and Actuators A. 2008; 144:280-295.
2. F. J. Arregui, Zuri Ciaurriz, Maria Oneca, et al. An experimental study about hydrogels for the fabrication of optical fiber humidity sensors. Sensors and Actuators B. 2003; 96:165-172.
3. Jinesh Mathew, K.J. Thomas, V.P.N. Nampoori, et al. A comparative study of fiber optic humidity sensors based on Chitosan and Agarose. Sensors and Transducer Journal. 2007; 84:1633-1640.

4. R.K.Iler. Multilayers of Colloidal Particles. Journal of Colloid Interface Science.1996; 6: 569-594.
5. Christopher A. Murray and John R. Dutcher. Effect of Changes in Relative Humidity and Temperature on Ultrathin Chitosan Films. Biomacromolecules.2006; 7: 3460-3465.