ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Optical Sensing of Ammonia Gas for Detection of Human Infections.

Shilpa Kulkarni[1]*, and Sujata Patrikar[2].

[1] Department of Applied Physics, Shri Ramdeobaba College of Engineering and Management, Katol Road, Nagpur (M.S.), India.
[2]Department of Applied Physics, Visvesvaraya National Institute of Technology, Nagpur, (M.S.), India .

ABSTRACT

Ammonia gas is released in excess in human body under certain diseased conditions. In this work, highly sensitive, quantitative, optical ammonia gas sensor is presented, which can detect less than 10ppm of the gas.

Keywords: Ammonia, gas, human infections

Corresponding author

ISSN: 0975-8585

INTRODUCTION

Ammonia gas sensing has now a days gained much attention due to its use in detecting human infections such as urinary track infections, pulmonary infections, etc [1]. The diseased person releases more amount of ammonia, (breaking of protein molecule) which remains unused and carried by the blood. It is circulated in all the parts of body including brain. Under extreme conditions it badly affects functions of brain leading to loss of memory and finally, death. Thus, reliable and quantitative detection of ammonia is a useful tool in preventing the occurrence of extreme diseased conditions. Detection of the extracellular ammonia at sites of pulmonary infection at an initial stage and its continuous monitoring by optical technique can save a patient's life.

In the present work, it is shown that, using mesoporous silica coated single mode silica nanowire quantification of respiratory ammonia can be done which will be useful in early detection of the respiratory infections. Mesoporous silica is found to be a good adsorbent for ammonia gas. Its 60-80nm smooth thin films having refractive indices around 1.39.1.43 and having highly ordered porous structures and controllable morphologies have been obtained on cylindrical surfaces such as carbon nanotubes and fibres [2]-[4]. Ammonia gas gets chemisorbed as well as physisorbed on the mesoporous silica [5]-[6]. Room temperature adsorption of ammonia on its surface has been reported[7]. Ammonia gas gets selectively adsorbed on its surface and the adsorption is reversible.

In the present work, miniature ammonia gas sensor is proposed. The sensor is constructed by using Mach-Zehnder interferometer (MZI) employing mesoporous silica coated silica nanowire. The coating adsorbs ammonia gas, which changes its refractive index. MZI is simulated for finding the level of ammonia gas detection. MZI is simulated for various diameters, in which phase difference, sensitivity, detection limit, minimum required sensing lengths, suitable diameters etc. are found.

THE SENSOR

Present sensor employees usual Mach-Zehnder interferometer (MZI) having single mode silica nanowire in its two arms. Both the nanowires are coated with mesoporous silica so as to maintain same initial phase condition before exposure in both the arms. A small region of the sensing arm is left uncovered for its exposure to ammonia gas. The refractive index profile in both the arms before exposure is: central silica core has refractive index of 1.4468, 50nm thick mesoporous silica film having a refractive index of 1.40 at a wavelength of 1.55μm, and air as infinite medium outside. After exposure, the refractive index of mesoporous silica increases due to ammonia gas adsorption.

SIMULATIONS

Let the refractive index of mesoporous silica after exposure changes to 1.41, which corresponds to 10% of filling of pores of adsorbed ammonia gas. Before and after exposure, the sensing region exhibits three layers tightly guiding waveguide structure having successively decreasing refractive index profile. The field equations having the Bessel functions as 'J' in the core region, a combination of 'I' and 'K', in layer region and 'K' in the cladding region are written. Considering the Ez, Hz and E_θ, H_θ field continuities at each boundary, 8 x 8 matrix is built. The determinant of the matrix equals to zero is solved for finding propagation constant (β).

RESULTS AND DISCUSSION

The phase difference ($\Delta\Phi$) in the two arms of MZI, which is equal to $\Delta\beta \times L$, where $\Delta\beta$ is the difference in propagation constants in its two arms after exposure, is calculated and plotted as shown in Fig. 1.

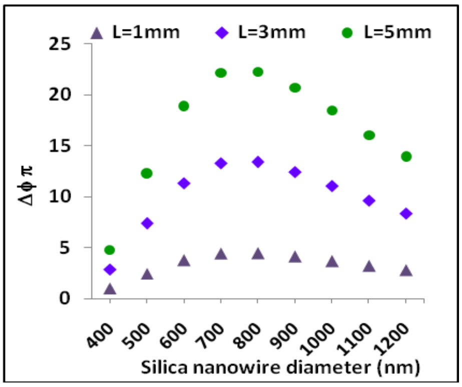

Figure 1: Phase difference in the two arms of Mach-Zehnder interferometer

It is observed from Fig. 1 that with small sensing lengths, appreciable phase difference between the two arms of MZI is obtained, which is high as compared to the detection limit of MZI, which is $2\times10^{-3}\pi$ [8].

Phase sensitivity (S_{phase}) is calculated by expression (1) and plotted as shown in Fig.2.

$$S_{phase} = \frac{1}{L}\frac{d(\Delta\phi)}{dn_c} \qquad ...(1)$$

In expression (1), $d(\Delta\Phi)$ is the small variation in phase difference arising due to the small variation in refractive index (dn_c) which is considered to be from 1.40 to 1.401, i.e. 0.001.

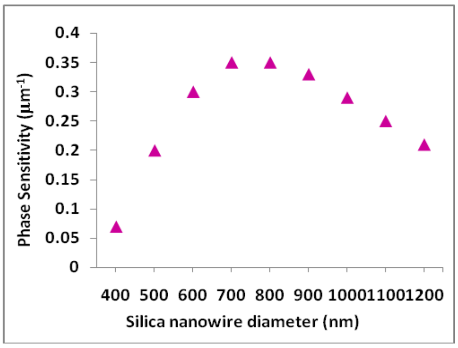

Figure 2: Phase sensitivity

It is observed from Fig.2 that the sensitivity values for various nanowire diameters fall in the range of $0.07\mu m^{-1}$ to $0.35\mu m^{-1}$. The sensitivity is found to be high and almost independent of diameter for 600nm-1000nm diameters. It is also found that the sensing length of 18μm is sufficient to produce phase difference equal to the detection limit of MZI. Also, the measurable refractive index over a sensing length of 1mm is found to be of the order of 10^{-5}. With a gas pressure of about 3600ppm, there is 10% of gas adsorption in a coating material, which corresponds to the refractive index variation of about 0.017 of the coating [8]. If this data is compared with the present case, then with the measurable refractive index of 10^{-5} as per the present case, less than 10ppm of gas pressure will be is measurable using this sensor. Thus, over a sensing length of few micrometers, it is possible to detect less than 10ppm of ammonia gas pressure, which corresponds to release of ammonia in the respiratory diseases. Thus present sensor shows endoscopic application due to miniature size and is capable of early detection of the harmful diseases.

CONCLUSION

Present sensor is the miniature ammonia gas sensor, useful for endoscopic applications. It can detect ammonia gas concentration, as low as less than 10ppm. Middle range of diameters is suitable for constructing the sensor since sensitivity is almost independent of these diameters.

REFERENCES

[1] HZ Wise, CY Hung, E Whiston. Microb Pathog 2013:19-28.
[2] S Korposh, SW Lee, SW James, RP Tatam. Meas Sci Technol 2011;22:075208.
[3] M Zhang, X Zhang, X He,L Chen , Y Zhang. Mater Lett 2010;64:1383 –1386.
[4] Z Sun, H Zhang, Y Zhao, C Huang, R Tao , Z Liu, Z Wu. Langmuir 2011;27:6244-51.
[5] DWL Griffiths, HE Hallam and WJ Thomas. Trans Faraday Soc 1968;64:3361-3369.
[6] JB Peri. J Phys Chem 1996;70(9):2937–2945.
[7] BA Morrow, IA Cody, Lydia SM Lee. J Phys Chem 1976;80(25):2761–2767.
[8] Nebiyu A Yebo, Petra Lommens, Zeger Hens, and Roel Baets. Optics Express 2010;18(11):11859-11866.