Investigating the Rate of a Chemical Reaction by Sensing Mechanism

Biswajit Ghosh

Abstract: ***The paper investigates the rate of a chemical reaction by sensing mechanism i.e, use of a chemical sensor. The sensing element is a fiber. A chemical solution is taken. A portion of the fiber (uncladded region) is dipped in the solution for sensing the progress of the reaction. The rate of a chemical reaction can be calculated by measuring the speed at which products are formed. This can be estimated by the absorbance of lightwave as the reaction speeds up. From the curve of absorbance rate against time we can calculate the reaction rate by finding the slope.***

Keywords: sensor technology; chemical concentration; multimode fiber; slope of the curve.

I. INTRODUCTION

The significance of sensor technology is constantly growing. Sensors allow us to monitor our surroundings in ways we could barely imagine a few years ago. New sensor applications are being identified everyday which broadens the scope of the technology and expands its impact on everyday life [1][4].

Optical fibers have played an important role in the sensor technology.In sensing applications for measurement of various physical and chemical variables, including pressure, temperature, magnetic field, current rotation, acceleration, displacement, chemical concentration, pH and so forth. Such field optic sensors are finding applications in industrial process control, the electrical power industry, automobiles and the defense sector[2][3].Perhaps the least exploited feature, to date, of optical fibers is their ability to translate minute changes is their mechanical/optical properties[4] into significant changes in the path length of the guided light[5][6].There are many different types of sensors using multimode as well as single mode fibers. Sensors[7] based on single mode fibers are much more sensitive then multimode fiber sensors.

II. ROLE OF MODULATION MEDIUM AND MODULATOR

A generalized functional block diagram of an optical sensor is presented in fig.1.In this scheme the most important block happens to be the modulation medium and the modulation technique.

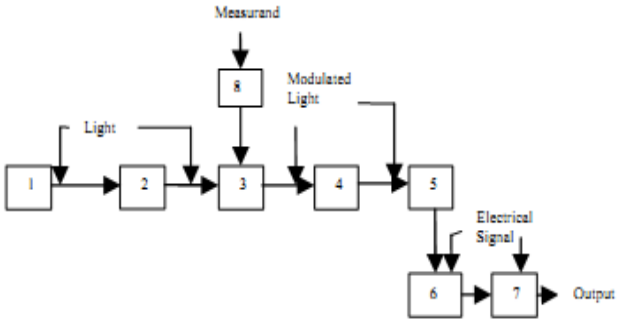

Fig.1 : Block Diagram Schematic of a Generalized Optical Sensor-1-Optical Source, 2-Waveguide, 3-Modulation Medium, 4-Waveguide, 5-PhotoDetector, 6-Signal Processor, 7-End Device, 8-Modulator.

The choice of the modulation medium makes an optical sensor[8] invasive or non invasive. When the medium is air, it is non invasive technique, but when it is an optical fibre[9], it is likely to be an invasive technique. Modulators for optical sensors have wide scopes in design and configuration. The properties of optical signal that can be modulated irrespective of the medium ar(a)Intensity,(b)Phase,(c)Frequency,(d)Wavelength or colour,(e)Polarization,(f)Scattering,(g) Evanescent electric field.

III. CHEMICAL SENSORS

A chemical sensor [13] is a device that transforms chemical information, ranging from the concentration of a specific sample component to total composition analysis, into an analytically useful signal. The chemical information [14], mentioned above, may originate from a chemical reaction of the analyte or from a physical property of the system investigated. The recent availability of high quality ,inexpensive optical fibers[9][15] provides an exciting new direction for chemical sensor designs, because optical transduction allows a wide variety of chemical detection schemes that previously were not possible for sensor development.

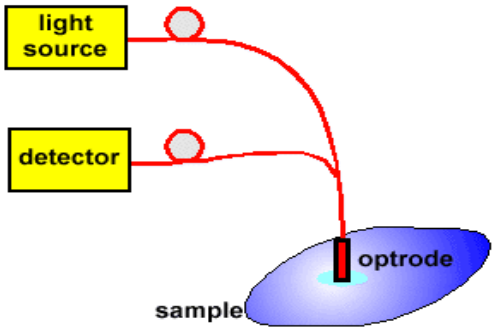

Fig.2: Schematic experimental set-up of FOCS

Manuscript received October, 2013.
Biswajit Ghosh, Asst Professor in ECE, Sribhumipally, S.P.More,Suri Birbhum,WB, India

IV. RATE OF CHEMICAL ABSORBANCE

The reaction taken was that between potassium iodide (KI) and copper sulphate ($CuS0_4$, $5H_2O$). Equimolar solutions of potassium iodide & copper sulphate were taken in a cell (cylindrical glass tube of 5 cm diameter & 6 cm in length).When KI is added to copper sulphate,cupric iodide is precipited quantatively and for each atom of copper present there is liberation of one atom of iodine.The reaction involved is as follows:-

$[CuSO_4,5H_2O] + 4KI = Cu_2I_2 + 2K_2SO4 + I_2\uparrow + 10H_2O$

The evolution of iodine from this standard reaction was monitored using the sensor mechanism.To enhance the EW absorption, 1% starch solution was added in the reaction cell.

A multimode plastic clad silica fiber was taken with core diameter of 250/380 µm with its cladding removed from a region 4 cm in length. The uncladded region of the fiber which functions as the sensor element was immersed in the chemical solution [10][11]. Fig.3 shows the sensing arrangement. A 1mW compound semiconductor laser (GaAs-GaP) with stabilized output was used as the source, and the transmitted power through the fiber was detected using a suitable detector. An Avalanche photo detector[6] [12] along with a digital millimeter was adequate for monitoring slow reactions.

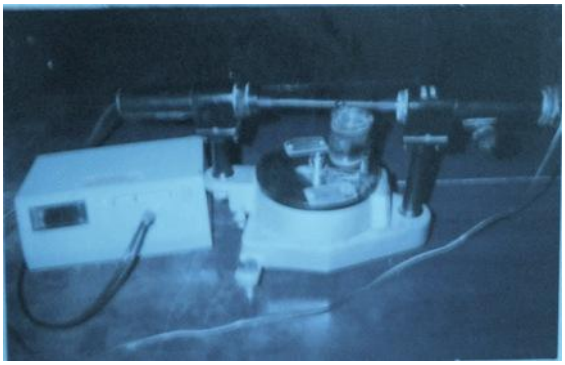

Fig.3: Sensing arrangement to monitor the time dependent chemical reaction

Let P be the laser power transmitted in absence of the chemical solution and L is the length of the uncladded region of the fibre,

Then

$$P' = P \exp[-K(t)L]$$

Or,

$$K(t) = (2.303/L)\log_{10}[P/P']$$

$$= (2.303/L)\log_{10}[V/V'] \quad \text{.....(i)}$$

Where K(t)is the absorbance rate,V is the input voltage, V ' is the recorded or output voltage.

V. ESTIMATING THE REACTION RATE

Here the absorbing species that evolves during the reaction is iodine. To enhance the absorption at 7100 A (GaAs-GaP laser wavelength), starch solution was added to the medium and this resulted in an intense blue colour of the medium. As the reaction proceeds, blue colour deepens (in proportion to the iodine concentration) and hence the light intensity (milli volts) at the output end decreases at the same rate. We can actually watch this process happen in time by measuring the amount of light absorbed by the iodine, called the absorbance. The absorbance is proportional to the concentration of the reactants in the solution, so observing the absorbance as a function of time is essentially the same as observing the concentration as a function of time. By measuring the absorbance rate from the formula given in equation (i) we can plot a graph between absorbance vs time as shown in fig.4.

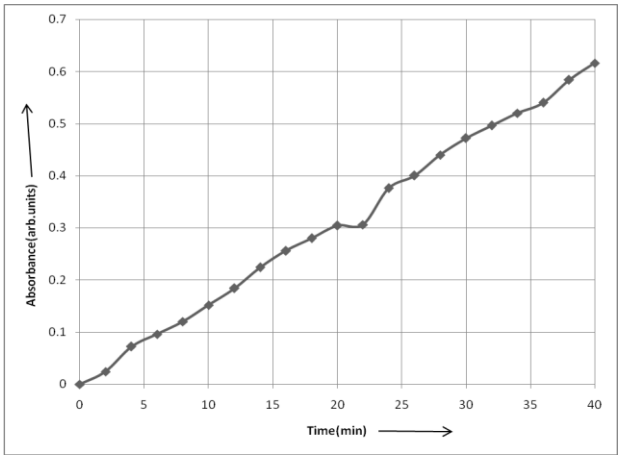

Fig.4: Rate of absorbance using the FOS setup

VI. RESULTS AND CONCLUSIONS

Fig .4 shows the time variation of absorbance describing the evolution of iodine in the experiment. From this curve we can safely say that the decrease in light intensity at the output is due to the increase in the light wave absorption with time. The rate at which the decomposition reaction is occurring is clearly related to the rate of change of the concentration, which is proportional to the slope of the graph. The slope is found out to be s =0.012 arb.unit/min which is equal to the reaction rate. The values of wave absorbance are also dependent on the length of the uncladded region of the fiber.

The investigative approach to record the decrease in light intensity is an effective way to determine the chemical reaction progress and thereby its speed.

REFERENCES

[1] Keiser Gerd, "Optical Fiber Communications",Mc Graw Hill International Editions, 2000.

[2] Hocker G.B.," Fiber-optic sensing of pressure and temperature",Applied Optics, Vol. 18, Issue9,pp.1445-1448 (1979).

[3] Yao.S.K,Asawa.C.K., "Fibre optical intensity sensors",IEEE J.Selected Areas in Communication,SAC-1/3,pp-562-573,1983.

[4] Pal Bishnu P., "Fundamentals of Fibre Optics inTele-communication & Sensor Systems", New Age Int. Limited,Delhi,2001.

[5] Ghatak.Ajoy, Thyagarajan.K,,"Introduction to Fibre Optics",Cambridge University Press, 1999.

[6] Senior.John M., "Optical Fibre Communications", Prentice Hall of India Private Ltd, 2nd Edition, 2004.

[7] Culshaw. Brian,Kersey.Alan, "Fiber-Optic Sensing: A Historical Perspective", Invited Paper, Journal of Lightwave Technology, Vol. 26, No. 9, May 1, 2008.

[8] Beck, W.J. ,Urbanczyk, W.; Barwicz, Andrzej, "Performance analysis of fiber-optic transducer for measuring low pressures", Instrumentation and measurement Technology Conference,1995,IMTC/95,Proceedings,Integrating Intelligent Instrumentation and Control,IEEE,24-26 ,April 1995.

[9] Wendeker, Kaminsk.M ," Development of a fiber-optic sensor for the measurement of dynamic cylinder pressure in spark ignition engine"Sensors, 2005 IEEE ,Dept. of Internal Combustion Engines, Lublin Tech. Univ. ,Oct. 30 2005-Nov. 3 ,2005.

[10] Yang, Cui-rong , Hangzhou Dianzi Univ.,Hangzhou Pang, Quan; Fan, Ying-le; Xu,Ping ,"Fibre-optic Chemical Sensor Based on Characteristic Spectrum Recognition and its Application", Control

and Automation, 2007. ICCA 2007. IEEE International Conference, May 30 2007,June 1 2007,**Page(s):**802–805.

[11] Klainer, Stanley M., "The Use of Fiber Optic Chemical Sensors for Monitoring Specific Parameters and Species in Aqueous Systems", OCEANS '86,23-25,Sept.1986,**Page(s):** 828–833.

[12] Ming Max,Liu Kang, "Principles and Applications of Optical Communications",TMH.

[13] R.W. Cattrall, " Chemical Sensors", Oxford Univ.Press, Oxford, 1997.

[14] J. Janata,"Principles of Chemical Sensors", Kluwer Academic Publishing Plenum, Dordrecht, 1989.

[15] Mark A.Arnold, " Fiber optic chemical sensors",Anal Chem, Nov.1992,64(21),pp1015A–1025A.