An Illustration of Optic Sensors in Recent Research Domains

Dr. S. R. Boselin Prabhu[1], N. Balakumar[2], A. Johnson Antony[3]
[1]*Assistant Professor, Department of Electronics and Communication Engineering, SVS College of Engineering, Coimbatore, India.*
[2]*Assistant Professor, Department of Electrical and Electronics Engineering, Tamilnadu College of Engineering, Coimbatore, India.*
[3]*Assistant Professor, Department of Electrical and Electronics Engineering, Karpagam Institute of Technology, Coimbatore, India.*

***Abstract*— Optical fibers are used as hydrophones for seismic and sonar applications. Hydrophone systems with more than one hundred sensors per fiber cable have been developed. Hydrophone sensor systems are used by the oil industry as well as a few countries' navies. Both bottom-mounted hydrophone arrays and towed streamer systems are in use. The German company Sennheiser developed a laser microphone for use with optical fibers. The establishment of sensor systems has elated recompenses such as measurement in flammable and explosive atmospheres, resistance to electrical noises, trimness, geometrical suppleness, measurement of slight sample volumes, remote sensing in unreachable sites or harsh atmospheres and multi-sensing. Biosensors are logical devices composed of a recognition component of biological origin and a physico-chemical transducer. Immobilization plays a foremost character in developing the biosensor by incorporating both the above mentioned mechanisms. In this paper, an illustration of optic sensors in recent research domains have been studied.**

***Index Terms*— Fiber-optic sensor, chemical sensor, enzymatic sensor, complete cell biosensor, control of biologicals, tapered optical fiber, optical chemical sensor, chemical equilibrium, biosensors, physico-chemical transducer, environmental and clinical monitoring.**

I. INTRODUCTION

Optical fibers can be used as sensors to measure strain, temperature, pressure and other quantities by modifying a fiber so that the quantity to be measured modulates the intensity, phase, polarization, wavelength or transit time of light in the fiber. Sensors that vary the intensity of light are the simplest, since only a simple source and detector are required. A particularly useful feature of intrinsic fiber optic sensors is that they can, if required, provide distributed sensing over very large distances. Temperature can be measured by using a fiber that has evanescent loss that varies with temperature, or by analyzing the Rayleigh Scattering, Raman scattering or the Brillouin Scattering in the optical fiber. Electrical voltage can be sensed by nonlinear optical effects in specially-doped fiber, which alter the polarization of light as a function of voltage or electric field. Angle measurement sensors can be based on the Sagnac effect. Special fibers like long-period fiber grating (LPG) optical fibers can be used for direction recognition [1]. Photonics Research Group of Aston University in UK has some publications on vectorial bend sensor applications. Optical fibers are used as hydrophones for seismic and sonar applications. Hydrophone systems with more than one hundred sensors per fiber cable have been developed. Hydrophone sensor systems are used by the oil industry as well as a few countries' navies. Both bottom-mounted hydrophone arrays and towed streamer systems are in use. The German company Sennheiser developed a laser microphone for use with optical fibers. A fiber optic microphone and fiber-optic based headphone are useful in areas with strong electrical or magnetic fields, such as communication amongst the team of people working on a patient inside a magnetic resonance imaging (MRI) machine during MRI-guided surgery. Optical fiber sensors for temperature and pressure have been developed for downhole measurement in oil wells. The fiber optic sensor is well suited for this environment as it functions at temperatures too high for semiconductor sensors (distributed temperature sensing). Optical fibers can be made into interferometric sensors such as fiber optic gyroscopes, which are used in the Boeing 767 and in some car models (for navigation purposes). They are also used to make hydrogen sensors.

Fiber-optic sensors have been developed to measure co-located temperature and strain simultaneously with very high accuracy using fiber Bragg gratings. This is particularly useful when acquiring information from small or complex structures. Fiber Bragg grating sensors are also particularly well suited for remote monitoring, and they can be interrogated 250 km away from the monitoring station using an optical fiber cable. Brillouin scattering effects can also be used to detect strain and temperature over large distances (20–120 kilometers) [2].

A fiber-optic AC/DC voltage sensor in the middle and high voltage range (100–2000 V) can be created by inducing measurable amounts of Kerr nonlinearity in single mode optical fiber by exposing a calculated length of fiber to the external electric field. The measurement technique is based on polarimetric detection and high accuracy is achieved in a hostile industrial environment. High frequency (5 MHz–1 GHz) electromagnetic fields can be detected by induced nonlinear effects in fiber with a suitable structure. The fiber used is designed such that the Faraday and Kerr effects cause considerable phase change in the presence of the external field [3-12]. With appropriate sensor design, this type of fiber can be used to measure different electrical and magnetic quantities and different internal parameters of fiber material. Electrical power can be measured in a fiber by using a structured bulk fiber ampere sensor coupled with proper signal processing in a polarimetric detection scheme. Experiments have been carried out in support of the technique.

Fiber-optic sensors are used in electrical switchgear to transmit light from an electrical arc flash to a digital protective relay to enable fast tripping of a breaker to reduce the energy in the arc blast. Fiber Bragg grating based fiber optic sensors significantly enhance performance, efficiency and safety in several industries. With FBG integrated technology, sensors can provide detailed analysis and comprehensive reports on insights with very high resolution. These type of sensors are used extensively in several industries like telecommunication, automotive, aerospace, energy, etc. Fiber Bragg gratings are sensitive to the static pressure, mechanical tension and compression and fiber temperature changes. The efficiency of fiber Bragg grating based fiber optic sensors can be provided by means of central wavelength adjustment of light emitting source in accordance with the current Bragg gratings reflection spectra. The establishment of optical fiber (OF) in the sensor system has transported a number of recompenses such as diminishment of the device, geometrical suppleness, extent of small sample volumes, remote sensing in normally unreachable sites or punitive environments, multi-sensing option, unceasing quantifiable or qualitative capacity and the confrontation of an OF to electrical noises. Chemical and thermal stability of quartz glass, which is the material of predominant OF for the spectral range from ultraviolet to mid-infrared, are equivalent only with platinum.

The significant ethics of fiber optic sensor (FOS) operation were engaged and the modern expansions in optical fiber devices and their solicitations to sensor technology in numerous areas are industry, transportation, communication, safety and defense as well as in daily life. Chemists used to engage sensors with electrodes as pH, Clark and ion-selective electrode.

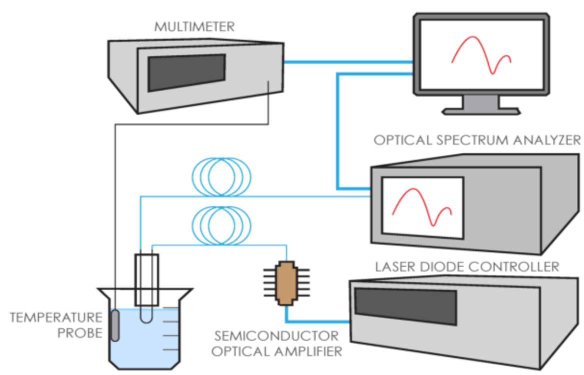

Figure 1: Biosensing with U-shaped fiber

Amid fiber optical chemical sensors, which are fewer commercially obtainable, only sensors of oxygen converted to be more used. An operative way of acquisition of the biological selectivity is a combination of cell cultures, tissue slices, organs and occasionally of whole living creatures with the transducer. Optical sensors can be based on plentiful optical principles (absorbance, reflectance, luminescence and fluorescence), covering unrelated regions of the spectra (UV, Visible, IR and NIR) and allowing the dimension not only of the strength of light, but also of other supplementary properties such as lifetime, refractive index, scattering, diffraction and polarization [13-19].

Optical chemical sensors have plentiful compensations over traditional electricity-based sensors like electivity, protection to electromagnetic interference and comfort while working with flammable and explosive compounds. They are also subtle, non-destructive and have numerous capabilities. Though, besides a number of paybacks, optical sensors also exhibit disadvantages: ambient light can obstruct with their operation, the long-term steadiness is restricted due to indicator leaching or photo-bleaching, there may be an insufficient dynamic range, selectivity may be underprivileged and a mass transfer of the analyte from the sample into the indicator phase is indispensable in order to obtain an analytical signal. Fiber-optic chemical sensors (FOCSs) describe a subclass of chemical sensors in which an optical fiber is typically employed to transmit the electromagnetic radiation to and from a sensing area that is in straight contact with the sample [20-27]. The spectroscopically detectable optical stuff can be restrained through the fiber optic arrangement which authorizes remote sensing.

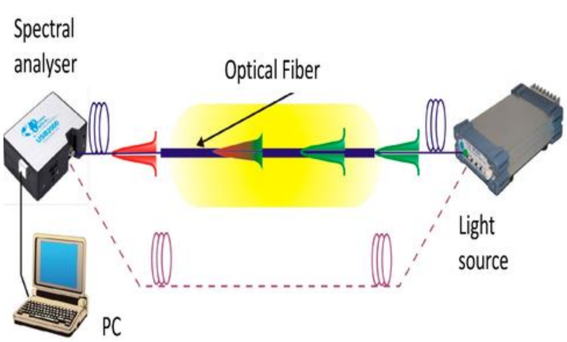

Figure 2: IPE Sensor of oxygen and glucose

Multiple laboratory tests are used for the diagnosis and management of patients with diabetes. The blood glucose concentration is the major diagnostic criterion for diabetes with HbA1c level and is a useful tool for patient monitoring. Self-monitoring of blood glucose (SMBG) has been established as a valuable tool for the management of diabetes. The goal of SMBG is to help the patient achieve and maintain normal blood glucose concentrations in order to delay or even prevent the progression of microvascular (retinopathy, nephropathy and neuropathy) and macrovascular complications (stroke and coronary artery disease). The findings of the Diabetes Control and Complications Trial (DCCT) and the United Kingdom Prospective Diabetes Study (UKPDS) clearly showed that intensive control of elevated levels of blood glucose in patients with diabetes, decreases the frequency of complications such as nephropathy, neuropathy, and retinopathy, and may reduce the occurrence and severity of large blood vessel disease.

In addition, it can also be useful for detecting hypoglycemia and providing real-time information for adjusting medications, dietary regimens, and physical activity in order to achieve glycemic goals. Regular and frequent measurement of blood glucose may provide data for optimizing and/or changing patient treatment strategies. In addition to advantages in terms of stinginess, ease of miniaturization, gaining safe, small, lightweight, compressed and inexpensive sensing systems, a wide inconsistency of sensor designs are possible. The most common taxonomy of FOCs distinguishes between the intrinsic and extrinsic types of sensors. 1) In the intrinsic type of FOCs, the sensing approach is based on the variation in light transmission features due to the modification happening in a fiber property (e.g., refractive index or length) upon the communication with the analyte or the system being intended. The optical fibre itself has sensory features.

This type of sensor is frequently applied to measure corporeal or physicochemical constraints such as the pressure, temperature or enthalpy of reactions. 2) In the extrinsic type of FOCs, the optical fiber acts as a transmission media by means of managing the radiation from the source to sample or from the sample to the end detection system. Extrinsic sensors can be segmented into a) distal and b) lateral types. The most communal are distal-type sensors, in which the indicator is stopped at the distal end (tip) of the optical fibre. Else, in a lateral sensor, the sensing chemistry can be immobilized along a section of the core of the optical fibre to make a momentary field sensor [28-30].

Nevertheless, the most frequently applied methods in optical sensing are those grounded on light absorption or light emission. Related to absorption-based methods, the molecular emission (i.e., fluorescence, phosphorescence, and generally speaking, luminescence) is primarily important because of its abundant sensitivity and decent specificity. The sensitivity of luminescence approaches is about 1000 times superior to that of most spectrophotometric methods. In addition, inferior limits of detection for the anticipated analytes can be accomplished. Calculating the emission intensity is also the most predominant because the instrumentation needed is very modest and low-priced. Nevertheless, measuring the light emission intensity has some inadequacies compared to emission lifetime measurements, in which the model is stressed only by a pulse of EM moderately than via unceasing illumination which is the case with intensity-based approaches.

The exactness and correctness of luminescence intensity-based schemes are suggestively affected by fluctuations in the light-source's intensity, detector warmth, inner filter special properties, indicator absorption (bleaching and leaching), sample turbidity and sensing layer wideness. Conversely, some of these difficulties can be reduced or even overcome by measuring luminescence lifetimes instead of intensities. But again, lifetime measurements also have some shortcomings, which are the instrumentation difficulty and high costs, along with an insufficient number of indicator dyes available that display noteworthy analyte-dependent changes in the lifetime.

Figure 3: e-Health Sensor Platform

Alternative way to diminish the difficulties related with intensity as well as with lifetime detection ethics is the use of ratiometric measurements. This technique employs dual-emission or dual-excitation indicators or combinations of two luminophores, displaying detached spectral areas with varied behavior. For illustration, the ratio of two fluorescent peaks is used in its place of the total intensity of one peak. The sensors therefore typically contain a reference dye; the benefit of this method is that factors such as excitation source fluctuations and sensor concentration will not interrupt the ratio between the Fiber optics serve analytical sciences in abundant ways. First, they enable optical spectroscopy to be attained on sites inaccessible to conventional spectroscopy over enormous distances or even on several spots beside the fiber. Second, fiber optics in being waveguides, enable less communal methods of interrogation, in specific evanescent wave spectroscopy.

Fibers are obtainable now with transmissions over a wide spectral range. Major Fields of applications are in medical and chemical analysis, molecular biotechnology, maritime and environmental examination, industrial production observing and bioprocess control and the automotive industry. Active current areas of research include progressive methods of examination such as time-resolved or spatially determined spectroscopy, evanescent wave and laser-assisted spectroscopy, surface plasmon resonance and multidimensional data acquisition. In current years, fiber bundles also have been employed for tenacities of imaging, for biosensor arrays or as arrays of nonspecific sensors whose distinct signals may be processed via artificial neural networks.

II. DIFFERENT TYPES OF BIOSENSORS

Biosensors can be categorized according to bio-recognition system. The biological elements used in biosensor technology are the enzymes, antibody or antigens and nucleic acids or harmonizing sequences.

2.1. Calorimetric Biosensors:

Many enzyme catalyzed reactions are exothermic. Calorimetric biosensors measure the temperature change of the solution containing the analyte following enzyme action and interpret it in terms of the analyte concentration in the solution. The analyte solution is passed through a small packed bed column containing immobilized enzyme; the temperature of the solution is determined just before entry of the solution into the column and just as it is leaving the column using separate thermistors. This is the most generally applicable type of biosensor, and it can be used for turbid and strongly coloured solutions. The greatest disadvantage is to maintain the temperature of the sample stream, say ± 0.01° C, temperature. The sensitivity and the range of such biosensors is quite low for most applications. The sensitivity can be increased by using two or more enzymes of the pathway in the biosensor to link several reactions to increase the heat output. Alternatively, multifunctional enzymes may be used. An example is the use of glucose oxidase for determination of glucose.

2.2. Potentiometric Biosensors:

These biosensors use ion-selective electrodes to convert the biological reaction into electronic signal. The electrodes employed are most commonly pH meter glass electrodes (for cations), glass pH electrodes coated with a gas selective membrane (for CO_2, NH, or H_2S) or solid state electrodes. Many reactions generate or use H+ which is detected and measured by the biosensor; in such cases very weak buffered solutions are used. Gas sensing electrodes detect and measure the amount of gas produced. This reaction can be measured by a pH sensitive, ammonium ion sensitive, NH_3 sensitive or CO_2 sensitive electrode. Biosensors can now be prepared by placing enzyme coated membranes on the ion-selective gates of ion-selective filed effect transistors; these biosensors are extremely small.

2.3. Acoustic Wave Biosensors:

These are also called piezoelectric devices. Their surface is usually coated with antibodies which bind to the complementary antigen present in the sample solution. This leads to increased mass which reduces their vibrational frequency; this change is used to determine the amount of antigen present in the sample solution.

2.4. Amperometric Biosensors:

These electrodes function by the production of a current when potential is applied between two electrodes, the magnitude of current being proportional to the substrate concentration. The simplest amperometric biosensors use the Clark oxygen electrode which determines the reduction of O_2 present in the sample (analyte) solution. These are the first generation biosensors. These biosensors are used to measure redox reactions, a typical example being the determination of glucose using glucose oxidase. A major problem of such biosensors is their dependence on the dissolved O_2 concentration in the analyte solution. This may be overcome by using mediators; these molecules transfer the electrons generated by the reaction directly to the electrode rather than reducing the O_2 dissolved in analyte solution. These are also called second generation biosensors. The present day electrodes, however, remove the electrons directly from the reduced enzymes without the help of mediators, and are coated with electrically conducting organic salts.

2.5. Optical Biosensors:

These biosensors measure both catalytic and affinity reactions. They measure a change in fluorescence or in absorbance caused by the products generated by catalytic reactions. Alternatively, they measure the changes induced in the intrinsic optical properties of the biosensor surface due to loading on it of dielectric molecules like protein (in case of affinity reactions). A most promising biosensor involving luminescence uses firefly enzyme luciferase for detection of bacteria in food or clinical samples. The bacteria are specifically lysed to release ATP, which is used by luciferase in the presence of O_2 to produce light which is measured by the biosensor.

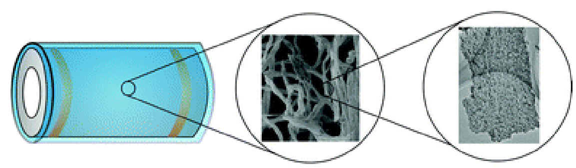

Figure 4: Microstructure fibers sensitive to gaseous oxygen

In addition, microorganisms, animal or plant whole cells and tissue slices, can also be shared in the bio-sensing system. Reliant on the method of signal transduction, biosensors can also be divided into dissimilar groups: electrochemical (amperometric, potentiometric or conductometric), optical, thermometric and piezoelectric. Biosensors offer numerous profits over conservative analytical techniques. The judgement of the biological sensing element offers an instance for the development of tremendously specific devices for real-time analysis in complex mixtures, without the need for comprehensive sample pre-treatment or great sample volumes. The determination of a biosensor will be contingent on the biochemical specificity of the biologically active material. Biosensors also promise highly sensitive, rapid, reproducible and simple-to operate investigative tools. Biomolecules have destitute stability in solutions hence it is important to stabilize them by immobilization. Thus immobilization plays an imperative role in developing stable bio-component for incorporation with transducers. Among the numerous biosensors for methyl parathion recognition, principal schemes are normally grounded on acetylcholinesterase (AChE) and organophosphorus hydrolase (OPH) enzymes.

AChE biosensor is based on enzyme inhibition mechanism, hence it requires longer incubation time and also has underprivileged specificity because of interference from carbamate insecticide and metals. OPH catalyzes hydrolysis of methyl parathion pesticide into obvious product p-nitrophenol (PNP) and yields dual protons as a result of the cleavage of the P-O bond. Products that are chromophoric or electroactive can be perceived by colorimetric and electrochemical approaches, and are burdened to advance biosensors for discovery of methyl parathion pesticide. The analyte can be determined, as the rate of product development is unswervingly proportional to the concentration of the analyte. As the OPH is a periplasmic enzyme, complete cells can be immobilized straight on the matrix and integrated with transducers for biosensor development.

III. CONCLUSION

A biosensor is an analytical device which employs biological material to specifically interact with an analyte. Producing some detectable physical changes which is measured and converted into an electrical signal by a transducer. The electrical signal is finally amplified, interpreted and displayed as analyte concentration in the solution/preparation. Biosensors are rational devices composed of a recognition component of biological origin and a physico-chemical transducer. Immobilization shows a leading character in developing the biosensor by integrating both the above mentioned mechanisms. In this paper, an analytical review of fiber-optic sensors and biosensors for the development of biosensors for environmental and clinical monitoring have been revised. Reliant on the method of signal transduction, biosensors can also be distributed into dissimilar groups: electrochemical, optical, thermometric and piezoelectric. Biosensors offer many profits over conventional analytical techniques. Biosensors are rational devices composed of a recognition component of biological origin and a physico-chemical transducer. Immobilization plays a foremost role in developing the biosensor by integrating both the above stated mechanisms.

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