have to rate the pollinator management systems available in India at −273 (i.e. absolute zero, absolute zero in absolute terms). Having understood the potentiality of 'bee hive systems' and with a fine plan to improve yields of crops through this (National Commission on Agriculture, 1976) we have somewhere failed to put the plan into action, thereby leading to a colossal loss of billions of rupees of national income over several years. There need not be a more striking illustration than this, that our system is poor in investing in important fields of science, especially in agricultural research and development and worse in implementing technologies. The first constructive step could be initiated by the scientists, learned farmers and commoners by way of 'mass memorandums' to persuade the Government to look into the implementation of the recommendations of the National Commission on Agriculture, 1976 so as to sustain, if not to boost, our future economy. Meanwhile, the corporate sector could be motivated to launch plans such as 'hire a bee hive' and so on, in the lines of 'Teakquity' and tamarind tree schemes.

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NEWS

DRDO signs MOU with Bharathiar University

Under the terms of an MOU signed on 18 April 1998, DRDO and Bharathiar University (BU), Coimbatore have agreed 'to exchange scientists and faculty members for effective interaction for mutual benefits and to formulate research areas which will benefit DRDO's programmes.'

Through this MOU, DRDO and BU will collaborate on research and development projects in the following areas: Thin film technology; Bio-sensors; Infrared detectors technology; Low radiation measurement; Plasma engineering and special coatings; Microbiology and biotechnology; Bio-medical technology; Eco-toxicology; Effluent treatment; Psychological and physiological environments of the armed forces; and in any other area in which BU has, or will have, expertise.

DRDO will provide money for the programmes to BU through its various schemes of assigning projects to academia; BU will manage these funds according to its accounting procedures and regulations. The University will provide opportunities for DRDO personnel to pursue master's and doctoral degrees and attend short-term courses on its campus.

A rather large seventeen-member joint DRDO–BU Policy Committee will oversee the implementation of this 10-year MOU which is expected to lay the foundation for long-term research and strengthen the interactions between DRDO and BU, and establish this University as a centre of excellence.

RESEARCH NEWS

Optical sensors in environmental monitoring

P. K. Choudhury

Optical fibres were first developed by and for the telecommunication science community, but, today, these are widely used in multifarious disciplines. These fibres are now specially recognized as possible devices upon which to base a new generation of sensors. Fibre optic sensors have shown a major impact on the process industries. This is because optical fibres are immune to electromagnetic interference, and, also, require very little electrical power. Optical fibres have now, indeed, found their largest and highest value in the overall sensor market. Now the scientists are exploiting the use of optical fibre sensors in the emerging market of environment assessment and control, an area where a diversity of chemical measurements are required.

It is the principle of total internal reflection which is exploited for the light-wave transmission through optical fibres, and all fibre optic sensors involve the interaction of light with the measurand; the interaction being in the infrared, near infrared, visible or the ultraviolet region of the electromagnetic spectrum. Of course, there are many kinds of principles involved in the interaction of light in chemical and gas sensing contexts, e.g. luminescence, fluorescence, scatter and back-scatter, absorption, reflection, spectrometry, colourimetry, etc. The propagating light beam through an optical fibre gets affected because of these effects; the affected parameters may be phase, intensity, wavelength, polarization, and spectral distribution. So the light now suffers from change in its properties, and it is this change that is measured by electronic equipments. This is how the fibre optic sensors work. Thus, the configuration of optical fibre sensors can be achieved in numerous different formats; however, every format will essentially be equipped with a certain number of vital components, viz. the light source, the fibre(s), the light detector, and the associated signal conditioning electronics. Also, there is one more vital component, and that is the sensory element where the measurand interacts with the light, and this component may even be a part of the fibre itself or a discrete structure interrogated by the propagating light beam. Optrodes, distributed fibre optic sensors and fibre coupled sensors are the three broad structural classes among which the sensors can be divided so far as the chemical and environmental monitoring contexts of optical fibre sensors are concerned.

Optrodes are, as the name implies, effectively optical fibre-based analogues of electrodes, and these offer a point measuring capability. Typically, an optrode comprises an optical fibre the tip of which reacts with the measurand, and, in this way the coated tip of the fibre responds to the measurand. In the case of distributed fibre optic sensors all or a part of the fibre's length is sensitized that reacts with the measurand, and, therefore, these offer a spatially distributed measuring capability. In fibre-coupled sensors, these fibres act as passive waveguides that take light to and from the point of measurement. These fibre-coupled sensors offer the best ability to make quasi-remote measurements, particularly in inaccessible or hostile environments[1].

It has now become a global issue how technology can cost effectively solve our rapidly growing problems in the environmental context, and maintain and improve the quality of life of the nation. The environmental sensor industry is keenly aware of the importance of this major subject, and reports, what catches one's eye, the optimistic business income projections that evolve and resolve around several environmental regulation agencies. These sensors mostly exploit various optical techniques such as multiwavelength infrared absorption, ultraviolet and infrared absorption, chemiluminescence, etc. The two remote sensing optical devices, extensively used for environmental monitoring, are spectroradiometers and lidars. Spectroradiometers analyse the spectrum of the radiation absorbed, scattered or emitted, and then quantify average contaminants. Passive sensors absorb used special light sources to emit radiation that interacts with the pollutants. Lidars are used to measure chemical species, opacity and aerosol mass loading. In all kinds of fibre optic sensing devices, optical fibres serve as a passive pipe of light in spectroscopic analysis, or can be coated with a substance to produce an electrochemical response. Photoluminescence is an extremely sensitive and promising optical sensor technique based on the fact that many organic compounds re-emit radiation when excited by an electromagnetic radiation. Because of its high sensitivity, photoluminescence offers the potential or remote fibre fluorometric analysis for monitoring groundwater contamination. Electrochemical sensors produce an electric signal in response to a chemical reaction. Bio-sensors, that fall into the category of electrochemical sensors, are a very interesting area of ongoing investigation[2–4]. These sensors, in fact, represent the merging of biochemistry with microelectronic or optoelectronic technologies, and have attracted much attention from the research community as well as the commercial sector. Such sensors play important role in some other applications such as food analysis, defence, process control, medical diagnostics, environmental monitoring, etc. Mechanical sensors are mass-sensitive, and these include piezoelectric bulk devices involving piezoelectric transduction, i.e. the conversion of mechanical stress into electrical signal and vice-versa. Piezoelectric crystals are generally coated with a film of sensitive chemical that interacts with the target contaminant. The change due to interaction induces a stress on the piezoelectric crystal, producing thereby an electrical signal. Smart skin technology includes one of the most commercially available environmental sensors used for leak detection of underground storage tanks. Such sensors monitor and thereby solve the problems related to the leakage of various toxic substances from the underground tanks. It is rather important to remember, while sorting out the various flavours of environmental sensors, that it will become increasingly difficult to classify a sensor by one single technology. This is because the trend is now towards hybrid devices meaning thereby the entire system as a combination of various technologies.

In the present world of technological improvements, one of the hottest applications of fibre optic sensors is in the area of environmental gas monitoring[1–5]. Recent advancements in industrial technology have essentially initiated the scientific community for the research and development in the area of environmental safety monitoring by inventing a variety of gas sensors. Gaseous species detected by these gas sensors include toxic gases and air pollutants[6–7] which are hazardous for human beings, and exist in the air at ppm level. Classical techniques like gas chromatography and infrared absorption are available but these methods sometimes present difficulties in the associated detection measurements. A novel range of gas sensing devices incorporate solid-state gas sensors including self-diagnostic types, insulated gate silicon FET-based gas sensors, etc.

There is an almost unlimited scope for the use of fibre optic chemical sensors in monitoring various chemical processes taking place in the environment. The simple method for detection of gases is achieved by the measurements of change in electrical parameters like capacitance or resistance induced by the absorption of gas molecules on the surface of an organic polymer like polyaniline mixed with polypyrrole, and it has been found that polypyrrole can act as an efficient ammonia gas sensor. The role of several interesting fibre-based gas sensing techniques is primarily aimed at health and safety monitoring purposes that include the detection of gases like methane and other hydrocarbons which are now deemed to be environmentally threatening. For instance, sensors that offer multi-point measuring capability, used for the detection of methane, are distributed fibre optic sensors that exploit the interaction of the evanescent wave associated with the light in a distributed fibre and with a methane sensitive coating. Experimental results indicate that such sensors exhibit sensitivities approximately 100 ppm. Infrared methanometer is another highly sensitive and selective methane sensor that uses a Fabry–Perot etalon filter, and exploits infrared absorption correlation spectroscopy. Another class of methane sensor uses a thallium-doped fibre laser that operates at a wavelength of 1.648 μm. This is certainly a novel kind of fibre optic sensor used for gas detection in the environmental context. Efficacy of such sensors lies in that these can be used for detecting several gases in the wavelength range 1.65–2.05 μm.

A wide variety of sensors have been

developed using novel membrane technology for applications in multifarious disciplinary areas which include environmental monitoring and analysis. However, in the area of chemical sensing devices, an extensive use has been made of thick-film technology, although it has yet to offer much as a tool in the development of sensors[8,9]. This is because of the fact that a significant amount of fundamental research and development still remains before such devices can be made widely available for their commercial exploitation. However, recent researches on thick film sensor arrays describe the method for the discrimination of chemical species in both gaseous as well as dissolved forms. In order to improve several factors such as noise immunity, environmental cross-sensitivity, long-term accuracy, etc., the arrays of sensing elements are now in use to detect several parameters that affect these factors. A certain guarantee for the future success of such kind of sensors comes from the ability of fabrication of robust, cheap and repeatable sensors which are compatible with the interface electronics.

Integrated optical acoustically tunable filters are expected to play vital roles in future generations of acousto-optic gas sensors, and in spectroscopic applications. Such devices are developed with their operation at a wavelength of 0.8 μm. Optochemical microsensors are the other kind of sensors that also have been developed and appear to be well suited for environmental monitoring applications. Such sensing devices are used for the detection of nitrate, ammonium, and heavy metals. Besides these, much technical information is now available on electrochemical measuring techniques and fabrication technologies that is equally relevant, or other classes of sensors such as planar gas sensors, chemical sensors and silicon sensors.

Efforts have been made by investigators to sense the reducing gases like hydrogen, carbon monoxide, methane, etc., and for such sensing, semiconducting oxides of zinc and tin with a small percentage of promoter like Pt, Sb, Al, Ni, Al_2O_3, MoO_3, etc. are widely used. These semiconductor gas sensors can sense the reducing gases by yielding a deviation in the electrical conductance. A thin metal catalytic film is used to enhance the selectivity of zinc-oxide-on-silicon gas sensors. The principle of specific infrared absorption by the rotational–vibrational transition of gas molecules has been successfully employed for the development and fabrication of infrared gas sensors that can be used for ambient air monitoring, meteorological measurements, etc. The sensitivity for detection of such infrared gas sensors depends upon the proper choice of the spectral range, and having optical path in a closed or open configuration, the length of which may vary from a few centimeters to several meters. The gases examined so far include CO_2, CO, CH_4, and water vapour.

With regard to the open configuration system of infrared sensing devices, some compact multiple reflection arrangements are usually made to enhance the detection that limits up to the values in the parts per million range. Some additional gas filters can also be applied to improve the selectivity of the sensor. The detector signal is processed by lock-in techniques synchronously with the modulation.

Nowadays systems, that comprise an air pollutant metering system, a sample container, and a gas removal system are available in order to test up to four gases in the chamber simultaneously at a time. In such modules, programmable control systems are provided to keep various parameters like pollutant concentrations, temperature, relative humidity, etc. constant even for a period of one year or more. This module also contains a heat exchanger and an air jacket heating system to maintain uniform temperature distribution in the sample container, and thereby, the problem due to condensation is eliminated.

Academic research in the field of fibre optic sensors reflects their prospects in environmental sector[1]. In fact, most of the commercially available sensor devices are fibre-coupled instruments for monitoring liquid chemical species in which fibres themselves play a passive role by taking light to and from remote measuring locations. The examples of such sensing devices are fibre-coupled spectrometer, optrodes, etc. Companies in the sensor market which aim to promote the understanding and exploitation of fibre optic sensor technology have shown their impact which is evident from their rapid growth in numbers during the recent years, and it is sure that fibre optic sensors will definitely exert a major impact on future generations of environmental products.

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