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Infrared Chalcogenide Optical Fibers: The Unique Sensors

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ABSTRACT
Chalcogenide glasses have suitable properties for the elaboration of special fibers for use in optical sensors. Infrared chalcogenide single-index fibers with fiber evanescent wave spectroscopy have various applications. Single-mode chalcogenide optical fibers can detect molecules like water, carbon dioxide, ozone and can detect life on earth-like planets.This paper represents various aspects of chalcogenide optical fibers for infrared sensing.
***KEYWORDS**: Chalcogenide glasses, Single-index fibers, Fiber evanescent wave spectroscopy, Single-mode chalcogenide optical fibers*

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INTRODUCTION
Chalcogenide glasses have a broad infrared window from 2 to 25 micrometre depending on their composition and response to the vibrational domain of most of the biological and chemical molecules due to their suitable thermo-mechanical properties. Fibers can be fabricated at low temperatures. Fiber evanescent wave spectroscopy (FEWS) based sensors also known as optical sensors point toward Chalcogenide glasses.Special spectroscopy as known as fiber evanescent wave spectroscopy is based on the elaboration of low loss infrared optical fibers. Standing waves arise inside the waveguide due to interference between the incident and reflected wave perpendicular to the waveguide-sample interface. Due to this process, an evanescent field is created inside the sample and the evanescent wave attenuates exponentially as it enters the sample. A phenomenon in which the sample absorbs the wave partially at a specific wavelength (the reflectivity is less than 1) is known as attenuated total reflection (ATR). Evanescent wave spectroscopy is based on the principle of attenuated total reflection. This method can be applied for real-time, remote and in-situ analysis. This method is simple and needs a standard spectrometer and MCT detector. The light from the source is focused at the input of optical fiber and detected by the MCT detector at fiber output. The signals collected for samples are analysed by putting the sample and fiber in contact.

FABRICATION OF THE FIBER SENSOR
The sensor needs suitable glass composition and elaboration of the fibers.

Composition of glasses
A large transmission window in the infrared, thermo-mechanical properties for the elaboration of the optical fibers, high glass transition temperature and good chemical stability are necessary requirements for the glasses used for fibers for the application in mid-infrared spectroscopy. Te-based glasses show the lowest absorption in the infrared in comparison to the glasses of sulphur and selenium. TAS glasses($Te_2As_3Se_5$) are the best

composition for easy shaping into fiber due to their strong covalent bonds and their unqiue thermo-mechanical properties. These glasses are very stable. Se and Te chains rigidify the structure of glass by the introduction of trivalent arsenic atoms that reticulate the chains.Transparency of this glass can be improved by chemical purification by reducing the presence of impurities such as oxygen, hydrogen, carbon, and silicon. To achieve the highest sensitivity for a sensor needs broad and optimised transparency.

Elaboration of the fiber

FEWS experiments need infrared TAS fibers which are single–index fibers. Single index fibers are obtained from a single glass rod. Glass rod is heated at 300°C to allow drawing. The fiber diameter during the fibering process is controlled by modifying the experiment conditions.

SENSOR CHARACTERIZATION AND OPTIMIZATION

Properties of fiber glass

Single index optical fiber with a sensor has two functions i.e., transporting the infrared signal from the source to the detector and detecting a sample by simple contact.

The attenuation of TAS optical fiber is low enough to permit applications in the wavelength range extending from 2 to 12 micrometres. Infrared spectroscopy with the attenuated total reflection is applied to planar sensors in which ZnSe is placed directly positioned in the sample compartment of a spectrometer [1].

Depth of penetration

The penetration of the evanescent wave increases linearly with the wavelength. The evanescent mode shows lower intensities at the shorter wavelength in comparison with those of the transmission mode. Chalcogenide glasses have a high refractive index which increases the penetration depth and the number of bound propagation modes in the fiber hence increasing the sensitivity of the sensor.

Diameter of fiber

The sensitivity of the sensor is decreased when the Fiber diameter is increased. The diameter of the fiber can be reduced by two routes. First by increasing the drum speed during the fiber process and the second one by a chemical etching process.

The concentration of analyte substance

Chalcogenide glasses show a linear relationship between the absorption by evanescent field and the concentration of various analytes in the solution interface.

Length of the fiber in contact with the analyte

The sensitivity of the probe is directly proportional to the length of the immersed fiber.

Hydrophobicity

The effect of hydrophobicity could only be demonstrated for solvents by showing an absorbing peak at a short wavelength [2].

APPLICATIONS OF THE SENSOR

Remote

FEWS technique follows up remote analysis manufacturing processes and assists to improve the quality of products by a better knowledge of their compositions by studying absorption peaks during the process. This technique gives information by following in situ the kinetics of a chemical reaction during the process. Monitoring of Chemical reaction in a microwave oven during the irradiation of microwave can be done with the help of the FEWS technique.

A study on the monitoring of polymerisation of resins is done by this technique by using Sb-Se-Ga-Ge fibers [3].

Environmental

The fiber used in this application permits in-situ and real-time analysis without sampling and the addition of a reagent. This technique allows selective detection of different polluting molecules as every molecule have their optical signature and detects pollutants in water.
A single index As_2Se_3fiber used with FEWS experiments is used to detect and analyse CO2 and monitor carbon dioxide in the atmosphere [4]. This system can be used to detect carbon dioxide at natural sites.

Biomedical

Due to length and flexibility, to permit the remote collection of IR signals, fibers can be used directly for patients by guiding the probe light onto the area of interest. In the biomedical analysis using Chalcogenide fibers the biocompatibility of the fibers with the biological molecule is very important. Analysis of tissues and serum can be performed with the help of this technique using Chalcogenide optical fibers. Monitoring of bacterial biofilms can be performed by in situ and real-time analysis. FEWS is sensitive enough to detect minute biochemical alterations.

Food

FEWS can be used to detect various food-borne pathogens [5] and can be extended to various applications in the health-related sectors.

Space

New materials containing a high amount of Te can be used to detect carbon dioxide at 15micrometres [6].

CONCLUSION

The Chalcogenide glass optical fibers can be used as sensors in many fields of applications. TAS optical fibers are one of the best fibers used for FEWS experiments. With the help of this technique, chalcogenide optical fibers can detect signs of life on earth-like planets. For the best biomedical applications of these fibers need improvements in instrumentation as well as analysis techniques. The miniaturisation of the equipment is also very important.

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