Proc. of Int. Conf. on Current Trends in Eng., Science and Technology, ICCTEST

Study Of Chalcogenides For Sensor Applications

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***Abstract*— In this paper, we review the study, optical characteristics of chalcogenide thin films and its sensor applications. Chalcogenide Glasses (ChGs) are most widely used candidate for sensing with wide infrared transparency as well as almost limitless capability for composition alloying and property tailoring. Radiation sensors, Surface Plasma Resonance (SPR) based sensors, Respiratory sensors, Bio-molecule sensors and filter less color image sensor are discussed.**

***Index Terms*— Chalcogenide glass, Surface plasma Resonance, photo detector, Attenuated Total Reflection.**

I. INTRODUCTION

In current years, ChGs are most attractive candidate material for various applications from thermal imaging to hyperspectral imaging. ChGs are Amorphous semiconductors and are made from chalcogen elements like Sulphur(S), Selenium(Se) and Tellurium (Te). chalcogenide glass can be made more stable by adding up of other elements such as Germanium(Ge), Antimony(Sb) and Arsenic(As) etc. Sulphide are usually transparent in high wavelength range where as tellurides and selenides are opaque. Specifically for sulphides-near 12µm, selenides-15 µm and tellurides-20 µm respectively. ChGs compositions like arsenic trisulfide (As2S3) and Selenide glass (As2Se3) are used for xerography application [1, 2].

An important characteristic of ChGs is having broad spectral range, from the near-infrared well into the Long Wavelength IR spectrum. . ChGs are most widely preferred than silica or oxide for imaging in the IR regime because of their high transmission, low dispersion, and low refractive-index change with temperature. the wide range of compositions are available and associated with the properties like a refractive index, dispersion, glass transition temperature etc to be tailored to meet a particular need[2] . So spectral range corresponds to the region of strong basic vibrational modes of organic and biologically relevant molecules are broad between 2 and 16 microns; therefore, the ChGs are likely to revolutionize in various domain of broad infrared sensing. Broad IR sensing is used for biological sensors, measurement of temperature, radiation sensor, detection of CO2, identification of presence of micro-organisms and pollution monitoring and so on. The remaining paper gives the outline of the various applications of these promising material.

A. Radiation sensor

The main function of radiation sensors is to identify and measure radiation. Radiation sensors find applications in different fields such as, to identify the contamination level, radioactive material identification, personal dosimeters in medical diagnostics and therapy. It is essential to design this sensor that are highly sensitive with good degree of resolution and that are low-cost [3].

Grenze ID: 02.ICCTEST.2017.1.175

These sensors are used to sense the radiation itself based on ionization. Ionizing radiation is able to create charges in the material. The radiation energy is adequate to ionize the molecules and pierce through the material. The α , β, γ are the examples of high frequency radiation, range is above UV light . The photon energy is depends on frequency of radiation, frequency increases with increase in photon energy. This leads to the exclusion of electrons from the atoms. Ionizing, scintillation and semiconductor based radiation sensors are the three basic types. Out of which, semiconductor based sensors are preferred. It converts the incident radiation directly into light. The radiation makes this charge to move across the band gap of the semiconductor. Higher ionizing radiation can be achieved by using materials with higher band gap and thickness. These sensors have very good energy resolution but are very expensive than other types available in the market. Due to amplification circuit complexity in both ionization chamber and scintillation sensors, Semiconductor radiation sensors are preferred. Also an added feature of semiconductor sensors are at low levels of radiation, the current produced becomes analogous to the background/dark current. Keeping these aspects a sensor should be developed. Important parameter of any sensor includes sensitivity, precision and range [3].

The Study has proved that ChGs are best material of candidate for an application of radiation sensor. These are amorphous semiconductors reveal a property of radiation induced phenomenon. ChGs can be utilized for radiation sensing due to flexibility and freedom associated with their atomic structure. Electronically these glasses are a type of semiconductors with an abundance of states within the band gap due to lone-pair electrons localized at chalcogen atoms. The composition used is Ge20Se80 films with silver (Ag) films on top. This composition was chosen as Ag diffuses quickly with rich material of Se. The resistivity of the ChG can be varied by the inclusion of Ag into chalcogenide films. This incorporation has been noticed with UV light (photo-diffusion). The reason for choosing silver as a top layer is due to its high mobility in ChG,, diffusion takes place at normal room temperature and enhanced by using photo-diffusion. This study clears that variation in resistance of the silver film on top of the chalcogenide film with γ and UV radiation. The resistance variation upon irradiation can be put to use in a detector/ sensor [2,3].

B. Surface Plasma Resonance (SPR) based sensors

Chalcogenides are the most guaranteed materials for sensing applications, due to its properties of IR transmission and high refractive index[1]. Surface Plasma Resonance is a technique for determining the small variations in sensing samples refractive index in metal-sample interface. An application of SPR phenomenon as sensing tool for detection of gas and bio sensing. The type of ChG used is 2S2G, Ge20Ga5Sb10S65. High R.I and large transparency region from 600nm in visible and up to 11µm in Mid-IR. Effects of SPR sensing near IR wavelength region can be known by comparing resonance curves and admittance loci plots [4].

C. Respiratory sensors

Respiratory sensor are made for detecting carbon dioxide in exhalation of a patient using the factor -IR absorption of carbon gases, would be highly suitable for monitoring the respiration of a patient during the process of Magnetic Resonance Imaging (MRI). Continuous monitoring is essential for high risk condition of patients. Due to high electromagnetic field interference it is difficult to measure biomedical factors such as respiration signals in MRI environment. Electromagnetic Interference can be overcome by using fiber optical sensor made up of dielectric material like glass or plastic. Basically, the optical fiber sensors are small in size, low cost nonexistence of electrical interference, reference electrode are not necessary and are also suitable for remote sensing applications[5].

Chalcogenide material of composition As2S3 is used, with the core(As2S3) diameter is 0.50 mm, and thickness of the cladding(As-S) is 0.015 mm. The refractive index of the core is 2.4, and the numerical aperture (NA) is 0.35. Ambient temperature range for operation is from 7 to 127°C were reported[5]. The fundamental absorption line of carbon dioxide (CO2) is 4.26 µm in the infrared wavelength range [5]. Finally, it concludes that sensor design is of low cost and compatible with mid-IR component and it can easily insertable in the environment of electromagnetic field [5].

D. Filterless color image sensor

Chalcogenide are form of amorphous semiconductors that exhibit good photoconductive properties and has been used in a various devices such as photocopiers, medical imaging systems and high-definition television broadcasting cameras. It comprises of a light-sensitive cell having a lower electrode and an upper electrode. A chalcogenide is placed in between the lower and the upper electrode. It also contains an image sensing circuit for the measurement of wavelength or intensity of incident light depends on an electric characteristic value generated from the photo-sensitive cell. The principle is based on the direction of band bending. Direction of band bending has to be identical between the upper electrode and the chalcogenide material to the lower electrode and the chalcogenide material [6]. Selection of suitable material for an image sensor is a combination of at least one element from chalcogenide group such as S, Se, Te[1] and other element chosen from the group consisting of Gallium (Ga), Indium (In), Copper (Cu), Cadmium (Cd),Tin (Sn) and Zinc (Zn) or also elements chosen from the group made up of Silicon (Si), Antimony (Sb), Germanium (Ge), Arsenic (As) and Phosphorus (P) [1][2]. In order to implement this sensor, the following constraints has to be meet by the material: the band gap (Eg) should be equal to or smaller than the energy region of visible rays (1.8-3.1 eV)[6] and the enormous light absorption coefficient.

The chalcogenide material are good choice over silicon material for the following reasons. Firstly, Chalcogenide has larger efficiency in transforming photoelectric phenomenon, and second, the chalcogenide may also form a junction only when contacting with metal and whose features are same as that of PN junction. These PN features may be realized only by metal contact, a complex process for making a PN junction at silicon may be expelled, which reduces the cost of production. Since the chalcogenide material are having a larger band gap than that of silicon (1.1 eV)[6]. In general, band gap is located at a region where visible ray spectrum is biggest, which gives a great photoelectric effect [6].

E. Biomolecule sensor

IR spectroscopy method is used to identify the presence of microorganism and their strain, the fingerprint region between 3-20μm are permitted to detect the vibrational signature of microorganisms[7] and harmful species.IR spectroscopy has its limitation in sensitivity than in analytical techniques. This can be a disadvantage when analyzing a sample in-situ where the analyte might not be in sufficiently high concentration. Filtration and culture growth are then required to enhance the sample up to the detection limit. The Composition used for this sensor is Germanium-Arsenic-Tellurium glass (attenuated total reflectance element), which serves as both an optical sensing zone and an electrode for driving the bio-molecules within the evanescent wave of the sensor[7]. An electric field is applied between the optical element and electrode in order to induce the movement of bio-molecules surface charges. biomolecules and microorganisms like proteins, spores of bacteria and viruses bring a net surface charge. This approach enriches bio-molecules and provides selectivity and sensitivity for detection of bio-molecules. This is possible by make use of of a opto-electrophoretic sensor, designed with telluride glass with high electrical conductivity, transparency and good resistance towards crystallization [1][2][7].

II. CONCLUSION

Chalcogenide glass is non crystalline Semiconducting materials and is best choice for the applications of an infrared photonics due to their wide transparency window. Fabrication of ChGs are easy to fabricate in bulk as well as thin film and flexibility in compositional allows tuning of optical properties such as refractive index making them ideal for infrared photonics. Thus, Chalcogenides are the most promising materials for implementing different sensor applications and will be of wide spread use in a decade or two.

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