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Refractive Index and Density Properties of Bismuth Sulfide (Bi_2S_3) Glass Nanocomposite

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Abstract

We report the synthesis of the Bi_2S_3 doped silica glass, growth of semiconductor nanocrystallites which is essentially striking temperature dependent. We also present the change in the density property and the refractive indices variations. It has been observed on thermal treatment, crystal size and distribution of semiconductor nanocrystals. This significant enhancement using these novel Bi_2S_3 quantum dot glass nanocomposites is reported in this work. Such quantum dot-glass nanocomposites will have potential applications in optical current sensors and isolators. The present paper is the investigation of quantum dot–glass nanosystems by confining nano bismuth sulfide in designated glass. The Bi_2S_3 quantum dots were grown in a special glass matrix, which involved a sequence of steps. X-Ray diffraction pattern confirms the amorphous nature of glass samples. It was found that bismuth oxide Bi_2O_3 can improve structural and optical properties of silicate glass and also showed a strong quantum confinement effect. The growth of nanocrystals is well known in glass matrix. Semiconductor micro crystallites grown in the glass matrix impart strong optical nonlinearities to the glass.

Keywords: Refractive index, density, bismuth sulfide, doping, nanocrystals, glass.

INTRODUCTION

During the past decade tremendous efforts has been dedicated to synthesize quantum confined semiconductor nanocrystals or QDs with a large surface to-volume ratio, size-dependent optical properties, arising from the spatial confinement of the electron-hole wave functions with great interest of investigations and versatile applications. Bismuth is quite unique material among the heavy metals and it can be considered as harmless, non-toxic and non-carcinogenic material. It is valuable in electronics application, ceramic production and good element for “warm” superconductors because of the high polarizability of Bi^{3+} cations. Previous research reported that silicate and borate glasses contained bismuth (III) oxide demonstrate good radiation shielding properties which can be used as radiation shielding material[1–3]. Bismuth borate glass is of great interest in optoelectronic devices due to its low melting temperature (600–800^{0}C), extensive glass formation range, high refractive index ranging from 1.9 to 2.3, high physical and chemical stability, and nonlinear optical property. Sample of glass can be differentiating by density, but the source of origin of two samples should not same. Doing comparison of density with refractive index limited discrimination may be possible. Different glass samples have different densities because they have different sources of origin. In spite of density is considered as one of the most important and characteristic properties which can be used only for confirming the structure of different types of glass. Density of solids is mostly the simplest physical property that can be measured. Some workers considered that density of the glass is additive and can thus be calculated on the basis of the glass composition[4-7] this is not always true and a number of involved formula was derived to relate the glass density to the glass composition[8-12]. Jen and Kalinowski[13] suggested a model for describing the bridging to non-bridging oxygen ratio as a function of the glass composition and the calculated values of glass density based on this model, were excellent agreement with the experimental values.

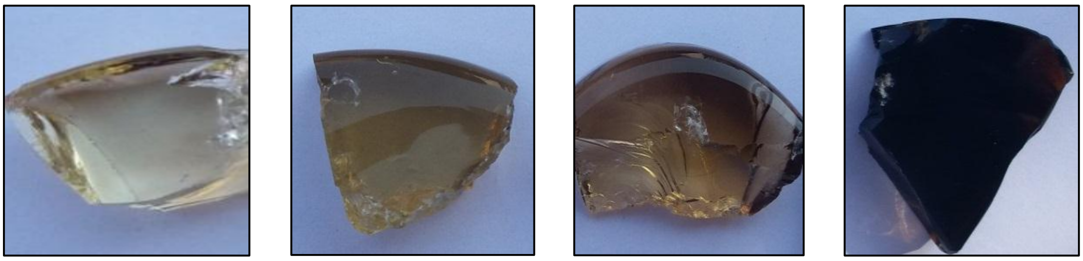
EXPERIMENTAL DETAILS

Raw Materials

The Bi_2S_3 doped glasses of various compositions were prepared by conventional melt-quench technique using analytical grade compounds SiO_2, H_3BO_3, MgO, Na_2CO_3, K_2CO_3, ZnO, TiO_2, $Bi_2S_3$and Starch as starting materials.

Glass Preparation

The new glass composition 54SiO_2, 08Na_2O, 04MgO, 08B_2O_3, 08K_2O, 12ZnO, 06TiO_2, 01Starch, Bi_2S_3 dopant 0.5-0.8% was used for the study. The different raw materials were weighed as per the above composition and mixed in pestle mortar to obtain homogeneous charge, The amount of semiconductor dopants like Bi_2S_3 were selected depending on the type of filter and added into the composition followed by further mixing. The composition prepared was taken in recrystallized alumina crucible and melted in an electrically heated muffle furnace at 1200-1300^{0}C. The melt was soaked for the period of 3-4 hrs. After refining, the glass melt was quenched in air on hot brass plate and processed immediately for annealing. The glass was annealed in programmable furnace at its transition temperature (Tg) i.e. 470-480^{0}C and slowly cooled to room temperature to remove the residual stresses. The glass samples were heat treated at 550, 575 and 600^{0}C for time 6hrs for crystal growth. The glass obtained was polished with emery papers of different grades. The melting of optical quality glasses for optical system is quite difficult because of its high requirement of homogeneity. To achieve good homogeneity, good melting facility is essential. The melting of the semiconductor doped glasses is quite critical than the normal optical glasses. Many compositions have been melted and few of them were optimized. Among the compositions optimized, the composition containing silica content 54% has shown good homogeneity. The same composition has been selected for making glasses. The glass were prepared by following the above method and characterized by various techniques.



As prepared (Without Heat Treatment)	Heat Treated at 550^{0}C	Heat Treated at 575^{0}C	Heat Treated at 600^{0}C

Figure 1. Photographs of Bi_2S_3 Doped Glass Nanocomposite

Characterization

Prepared glasses were characterized by X-ray diffraction technique to check for possible crystallinity of glasses. Using X-ray diffractometer (model, Rigaku Miniflex II Desktop) with CuK radiation, the XRD patterns were recorded in the 2θ range 20-80 degree with scanning rate 10/mint. Refractive index is measured by using travelling microscope for all glass samples. Density was measured for all glass samples at room temperature using xylene as the immersion liquid. Density is generally measured by the fluid displacement method depending on Archimedes principle.

RESULTS AND DISCUSSION

X-ray Diffraction Study

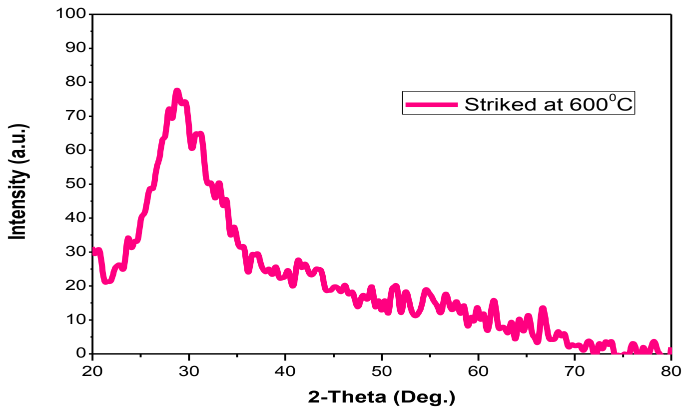


Figure 1. XRD pattern of 0.6% Bi_2S_3 glass heat treated at 600°C for 6 hrs

X-ray diffractometry of glass sample of 0.6% Bi_2S_3 glasses heat treated at 600°C for 6 hrs QDs in the matrix as shown in figure 1. X-ray diffraction patterns were obtained using Rigaku Model and Diffraction scans over a range of 2θ from 20– 80° for the Bi_2S_3 dopant glasses. In these glasses, one relatively diffuse peak was observed on a sloping background that is the portion of the broad 'halo' characteristic of diffraction of nanocrystals in glass, which implies the nanocrystalline nature of Bi_2S_3. Since silica is a major constituent in the glass, the growth of quartz is quite obvious. This is the clear indication of amorphous nature within the resolution limit of XRD instrument.

Refractive Index and Density Measurements

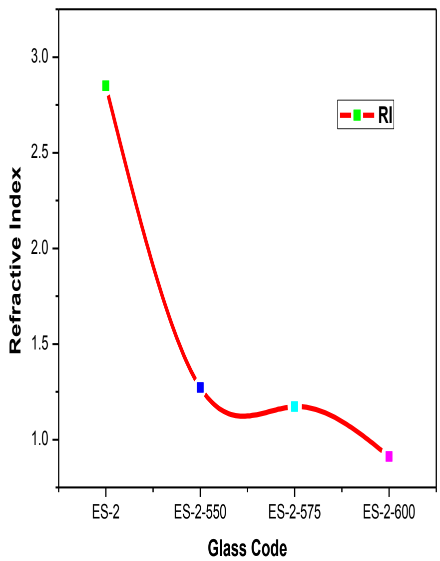


Figure 2. Refractive Index of 0.6% Bi_2S_3 Doped Glass Nanocomposite

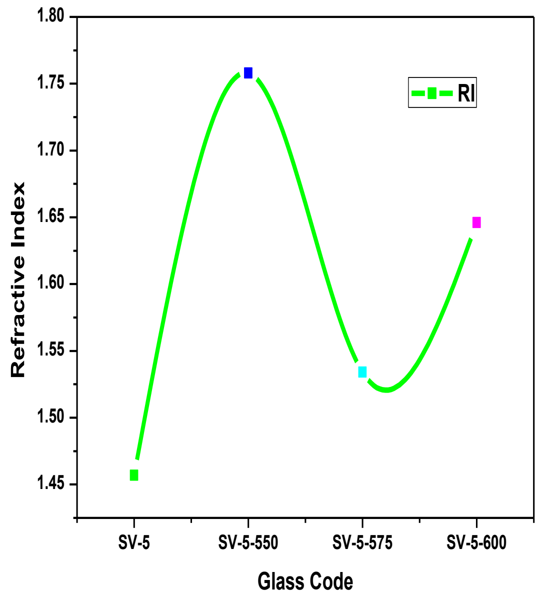


Figure 3. Refractive Index of 0.7% Bi_2S_3 Doped Glass Nanocomposite

Table 1: Density and Refractive index of 0.6% Bi_2S_3 Glass Nanocomposite

Sr. No	Sample Code	Composition X mole %	Thickness of Sample (cm)	Density (g/cc)	Refractive Index (cm)
1	ES-2	0.6	1.091	1.788	2.850
2	ES-2-550^{0}C	0.6	1.350	1.928	1.272
3	ES-2-575^{0}C	0.6	1.172	2.089	1.173
4	ES-2-600^{0}C	0.6	1.024	2.554	0.912

Table 2: Density and Refractive index of 0.7% Bi_2S_3 Glass Nanocomposite

Sr. No	Sample Code	Composition X mole %	Thickness of Sample (cm)	Density (g/cc)	Refractive Index (cm)
1	SV-5	0.7	1.253	1.544	1.457
2	SV-5-550^{0}C	0.7	1.492	2.331	1.758
3	SV-5-575^{0}C	0.7	1.147	1.985	1.534
4	SV-5-600^{0}C	0.7	1.318	2.293	1.646

Refractive index of the all glass samples heat treated at 550, 575 and 600^{0}C at for time 6hrs respectively is obtained by the using travelling microscope method. Here in the table (1 and 2) and graph (2 and 3) shows that the increase in striking temperature the refractive index of the 0.6% Bi_2S_3 decreases from 2.850 to 0.912 cm and 0.7%

Bi_2S_3 doped glasses indices increases from 1.457 to 1.646cm from all the observation shows that increase in Bi_2S_3 dopant the refractive index also increases. Refractive index is an important property for optical uses of glass. In the other hand density of glass is one of the simplest physical properties that can be measured. It can be defined as the degree of compactness of a substance/glass structure. Density of 0.6% Bi_2S_3 varies from 1.788 to 2.554g/cc and 0.7% Bi_2S_3 doped glasses also increases from 1.544 to 2.293g/cc. The increase in density observed is attributed to increase in the rigidity of glass. This is may be due to compactness of glass network formation. Density measurements showed that the density of the composite systems increases by doping and also increases with increasing the size of Bi_2S_3 nanoparticles. Fluegelet.al.,[14] reported that the density values increases from 2·354 g/cc and 2·415 g/cc are obtained at 1200°C and 1000°C this value is good agreement with our values. The data obtained for density and refractive index for 0.6% Bi_2S_3 and 0.7% Bi_2S_3 doped glasses are shown in table 1 and 2. The density was measured by Archimedes method. Density for both glass systems are increased as Bi_2O_3 contents increase.

CONCLUSIONS

In conclusion, Bi_2S_3 quantum dots were grown in a special type of 54% SiO_2 containing multi component glass systems. A uniform distribution of quantum dots and wires in the glass matrix was observed. Structural and optical properties of two different glass systems have been studied. The highest density in bismuth glass nanocomposite is 2.554g/cc for 0.6% Bi_2S_3 dopant glass at heat treated 600^0C. The density of glass system is dependent on the composition which is the higher the compactness of the structure, the higher the density. Higher refractive index of the preferred glass sample is obtained 0.6% Bi_2S_3 2.850cm at unstriked glass sample which is due to present of non-bridging oxygen in glass matrix. Hence, it was found that bismuth oxide Bi_2O_3 can improve structural and optical properties of silicate glass and also showed a strong quantum confinement effect.

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