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A Study Optical and Physical Properties of Soda Lime Silica Glass Doped with Cu_2O

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Abstract: Soda lime silica glass with composition of (72.5-x) SiO_2: 17.5Na_2O: 10CaO: xCu_2O (where x=0.0, 0.1, 0.2, and 0.3 wt%) have been prepared using the melt-quench technique. The effect of Cu_2O concentration on the physical and optical properties of the glasses has been studied using Archimedes's method and UV-VIS-NIR spectrometer. The results showed that the density of glass increases from 2.4860 ~ 2.6514 g/cm^3 and the refractive index of glass increases from 1.3140 ~ 1.4940 with increasing of concentrations of Cu_2O, the molar volume decreases from 24.1255 ~ 22.6526 cm^3/mol and the optical energy band of glasses decreases from 3.0490 ~ 2.9760 eV with increasing of concentrations of Cu_2O. The absorbance result shows that Cu_2O color glass with blue-green color.

Key words: Soda lime silica glass, optical properties, physical properties, Cu_2O

1. Introduction

A solid consist of atoms, ions, or molecules packed closely together and held in place by electric force. Most solid are crystalline, which mean that particles are arranged in regular, repeated pattern. Every crystal of a given kind, whether large or small, has the same geometric form. The word crystal suggests salt and sugar grain, mineral samples, and sparking gemstones. But metals and snowflakes are crystalline too, as are the fibers of asbestos and the clear, flat plates of mica. Clay is composed of tiny crystals that can trap water between them to give an easy

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shaped material. Solids whose particles are irregularly arranged with no definite pattern are called amorphous. Examples of amorphous solid are glass, pitch and various plastics.

One way to distinguish between the two kinds of solid to see what happens when the samples of each kind are heated. A crystalline solid melts at specific temperature when the thermal energy of particles is enough to break the bonds between them. An amorphous solid is really a very stiff liquid and soften gradually when heated because the random nature of the bonds between its particles [1- 6].

In principle, all crystalline solid can also exist in the amorphous or glassy state if they cooled fast enough from liquid state. The cooling rate necessary to achieve the glass state depends on the ease of crystal formation and on viscosity of the cooling liquid as its temperature is reduced. If crystal growth is slow and the liquid has a high viscosity over an appreciable temperature range, this relatively easy to form a glass. This applies to inorganic glasses and to polymers. With simpler solids, where crystallization is easy and the liquid has a narrow viscosity - temperature range, high cooling rate are necessary of order of 10^{3} - $10^{5} K.s^{-1}$This applies to pure metals, metallic alloys and solid such as silicon and germanium. The highest cooling rate 10^{7} $K.s^{-1}$may be obtained by evaporating or sputtering the substance onto a cold surface [7, 8].

One of the best methods for determination of structure of solids is X-ray diffraction [9- 14]. X-ray diffraction has, of course, long been recognized as a powerful tool in the study of crystal structure [15, 16]. As a result of X-ray diffraction studies, it is known that the atoms of a crystalline material are arranged in a symmetric manner. The techniques of X-ray diffraction indicate that most solids are crystalline and relatively few amorphous [17, 18]. Moreover, we can study crystal structure through the diffraction of neutrons, or electrons [2, 19, 20].

The main objective of this work is to investigate physical and optical properties of soda lime glass doped with Cu_2O.

2. Materials and Methods

2.1 Glass preparation

The glass samples were prepared by using conventional melt-quench technique. The nominal base composition of these samples was (72.5-x) SiO_2: 17.5Na_2O: 10CaO: xCu_2O (where x = 0.0, 0.1, 0.2, and 0.3 wt%). All chemicals were mixed and grounded for 15 minutes by using a mortar and pestle. The mixed powder was melted in a porcelain crucible placing in electric furnace for 6 hours, in air atmosphere, till temperature reached 1100 ^oC. The melted powder was annealed at 560 ^oC. Therefore, the melted powder was expected to be homogenous and bubble less. The prepared glass samples were cut and polished.

2.2 Physical properties

By applying Archimedes principle, the weight of the prepared glass samples was measured in air and in distilled water using electric balance. Density, ρ, was determined by the relation as fellow

$$\rho = \frac{\omega_a}{\omega_{a-}\,\omega_b} \times \rho_b \qquad (1)$$

where ω_a is the weight in air, ω_b the weight in water, and ρ_b the density of water. The corresponding molar volume (V_m) was calculated using the relationship

$$V_m = \frac{M_T}{\rho} \qquad (2)$$

where M_T is the total molecular weight of multi-component glass system [21].

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2.3 Absorption measurement

The optical absorption spectra of the UV-VIS-NIR regions were recorded at room temperature by using UV-VIS-NIR spectrometer, the refractive indices and the optical band gaps have been evaluated.

3. Results

Table1. Physical and physical and optical properties of (72.5-x) SiO_2: 17.5Na_2O: 10CaO: xCu_2O glass system

Property	x = 0	x = 0.1	x = 0.2	x = 0.3
Density(ρ) (g/cm^3)	2.4860	2.6213	2.6307	2.6514
Molar Volume (V_m) (cm^3/mol)	24.1255	22.9123	22.8304	22.6526
Refractive Index (n)	1.3140	1.3220	1.3630	1.4940
Energy Band Gap (E_g) (eV)	3.0490	3.0000	2.9900	2.9760

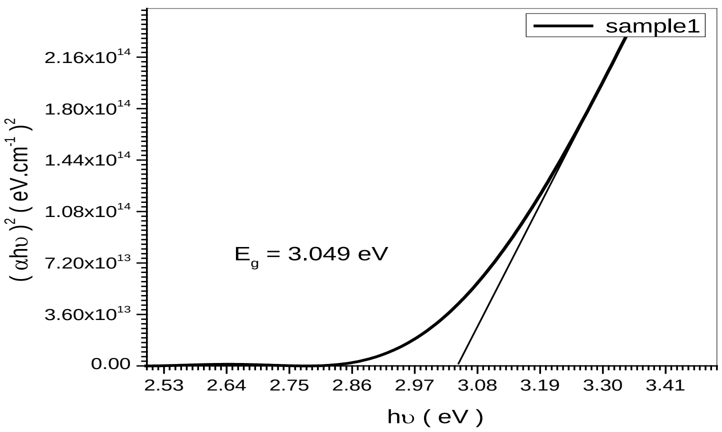

Fig.1. Energy band gap for undoped glass.

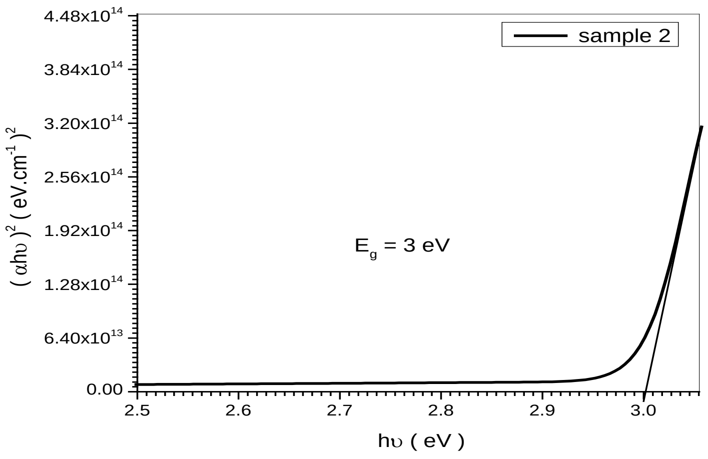

Fig.2. Energy band gap for glass doped with Cu_2O (0.1 wt%).

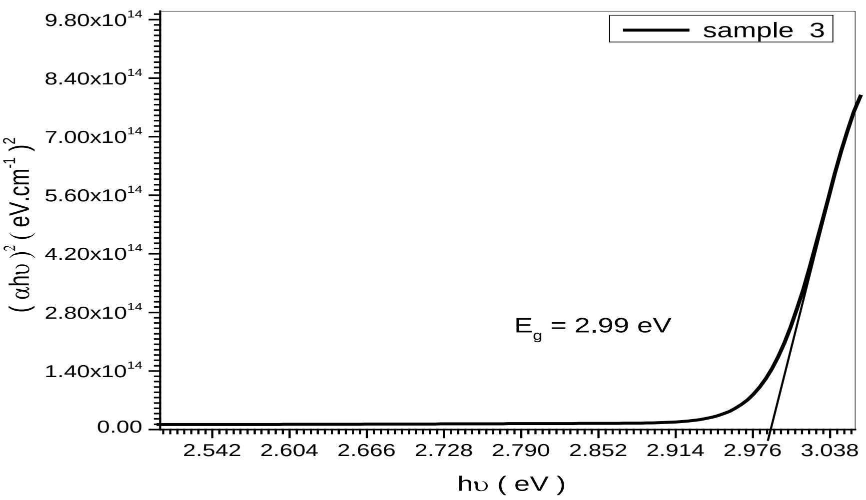

Fig.3. Energy band gap for glass doped with Cu_2O (0.2 wt%).

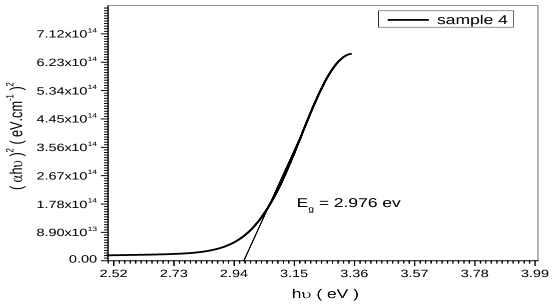

Fig.4. Energy band gap for glass doped with Cu_2O in (0.3 wt%).

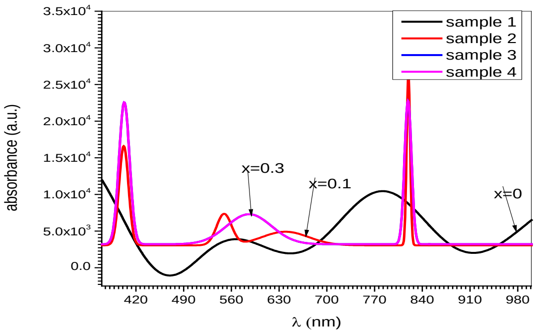

Fig.5. Absorbance of glass doped with Cu_2O in concentration (0, 0.1, 0.2, 0.3 wt%).

4. Discussion

4.1 Physical properties

Table 1 collected values of density, molar volume, refractive index of soda lime silica glass samples. The results showed that the density increased from 2.4860 to 2.6514 g/cm^3 due to increase of concentration because of higher molecular weight of Cu_2O compared with SiO_2 [22, 23]. The molar volume decreases from 24.1255 to 22.6526 cm^3 / mol due to increase of Cu_2O concentration. This result indicated that the structure of glass more compacted with addition of Cu_2O the probable explanation may be that a major part of Cu_2O enters directly into the structure without the introduction of additional non-bridging oxygen (NBOs) [22].

4.2 Optical properties

The refractive index increases with additional of Cu_2O from 1.314 to 1.494; this indicates that Cu_2O into the network which attributed to the increase in number of non-bridging oxygen. The increase of NOBs in the structure generally leads to an increase in average atomic separation. The result obtained indicates that the Cu_2O enters the glass network as a modifier by occupying the interstitial space in the network and generating the NOBs to the structure [24- 26].

The optical absorption spectra of the prepared glasses, are shown in figures 1, 2, 3, 4. It determined by plot of $(\alpha h\upsilon)^2$ versus photon energy ($h\upsilon$) for direct transitions allowed. It can be seen that there exists of a linear dependence of $(\alpha h\upsilon)^2$ in photon energy. It can be noticed that the optical energy band gap decreases with increasing of Cu_2O concentration from 3.049 to 2.976 eV; this indicates that the increase of non-bridging oxygen. This leads to increase of the degree of localizations of electrons thereby the increase of donor center in glass matrix. The increase of donor center leads to the decrease of optical band gap [23]. The absorbance of Cu_2O doped soda lime silica glasses in UV-VIS-NIR regions at room temperature are shown in figure 5. It is clearly observed that the absorption intensity of the absorption bands vary with increasing of Cu_2O concentration. All absorption band spectra are characteristics of Cu^{1+}-doped oxide glasses [24, 27]. The absorption spectra showed in figure 5 reveal law absorption of light in indigo, blue and green regions; this means the light in indigo, blue, and green regions was transmitted [24, 28]. As a result, the Cu^{1+} -doped glass is colored blue-green. However, the color of the glass samples as explained by the absorption spectra is in good agreement with color of glass samples [24].

5. Conclusions

Physical and optical properties of soda lime silica glasses doped with copper oxide (Cu_2O) have been studied. The results showed that the density and refractive index increase and the molar volume and energy band gap decrease with increasing of concentration of Cu_2O. The absorption spectra are law in indigo and blue and green regions which colored glass with blue-green.

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