International Journal of Physics, 2018, Vol. 6, No. 3, 53-56
Available online at http://pubs.sciepub.com/ijp/6/3/1

DOI:10.12691/ijp-6-3-1

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

Ali Salih Ali[1,*], Mubarak Dirar Abdalla[2], Mohammedian Adam[3]

[1]Physics Department, Faculty of Education, University of Kordofan, Elobied, Sudan
[2]Physics Department, Faculty of Science, Sudan University of Science and Technology, Khartoum, Sudan
[3]Physics Department, Faculty of Science, University of Kordofan, Elobied, Sudan
*Corresponding author: Sali61957@gmail.com

Abstract A new set of soda lime glasses doped with ZnO were prepared by melt quenching technique. The aim of this work is to investigate physical and optical properties of prepared glasses using Archimedes' method, and UV-VIS-NIR spectrometer. The data were analyzed by Origin Graph Program (version 8.6). The results shows that the density of glasses increases in rang 2.486 ~ 2.5656g/cm^3, with increasing of concentration of ZnO because of higher molecular weight of ZnO compared with SiO_2. The molar volume of glasses decreases, in range 24.1255 ~ 23.4019 cm^3/mol, with increasing of concentration of ZnO, this indicates that the structures of glasses more compacted with addition of ZnO. The refractive index and optical energy band gap of glasses change in range 1.314 ~ 1.504 and 3.049 ~ 3.253 eV respectively, because of change of non-bridging oxygen. The absorbance of UV-VIS rays shows that ZnO have a good effect on glass transparency.

Keywords: *density, glass, refractive index, transparency, absorption*

Cite This Article: Ali Salih Ali, Mubarak Dirar Abdalla, and Mohammedian Adam, "A Study Optical and Physical Properties of Soda Lime Silica Glass Doped with ZnO." *International Journal of Physics*, vol. 6, no. 3 (2018): 53-56. doi: 10.12691/ijp-6-3-1.

1. Introduction

The traditional view is that glass is a solid obtained by super-cooling a liquid and that X-ray amorphous [1]. Additionally a glass when heated, should also exhibit a thermal characteristics known as "glass transition temperature" [1,2]. Also glass is an amorphous material solid with no regularity in arrangement of it molecular constituent on a scale large than a few times the size of these groups. Furthermore, the American Society for Testing Material (ASTM) defined glass as "an inorganic product of fusion, which has been cooled to a rigid condition without crystallizing". According to this definition, a glass is a non-crystalline material, obtained by a melt-quenching process. Nowadays, non-crystalline materials, which cannot be distinguished from melt-quenching glass of the same composition, are obtainable by using various techniques such as chemical vapor deposition or sol–gel process, etc. Therefore, most glass scientists regard the term "glass" as covering all non-crystalline solids that show a glass transition regardless of their preparation method [3,4].

Although glass has been used as artistic medium and industrial material for centuries, it is currently in a state of rapid development [5]. Many of the uses of glass in modern world continue to exploit the transparency, luster, and durability properties of glass. Containers, windows, lighting, insulation, fiber, and other hand crafted art objects are typical of traditional uses of glass [6].

Impurity doping of crystalline Si is one of the most striking techniques in semiconductor technology. A rigid and perfect crystalline lattice is prerequisite for effective doping. However, it has been reported to date that introducing a small amount of impurities drastically improves also the properties of amorphous materials [7]. The main objective of this paper is to investigate physical and optical properties of soda lime glass doped with ZnO.

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: xZnO (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°C. The melted powder was annealed at 560°C. 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

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

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

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

where M_T is the total molecular weight of multi-component glass system [8,9].

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. The data were analyzed by Origin Graph Program (version 8.6).

3. Results

Table 1. Physical and physical and optical properties of (72.5-x) SiO_2: 17.5Na_2O: 10CaO: xZnO glass system

Property	x = 0	x = 0.1	x = 0.2	x = 0.3
Density(ρ) (g/cm^3)	2.4860	2.5588	2.5605	2.5656
Molar Volume (V_m) (cm^3/mol)	24.1255	23.4477	23.4321	23.4019
Refractive Index (n)	1.3140	1.504	1.400	1.398
Energy Band Gap (E_g) (eV)	3.0490	2.969	3.253	3.099

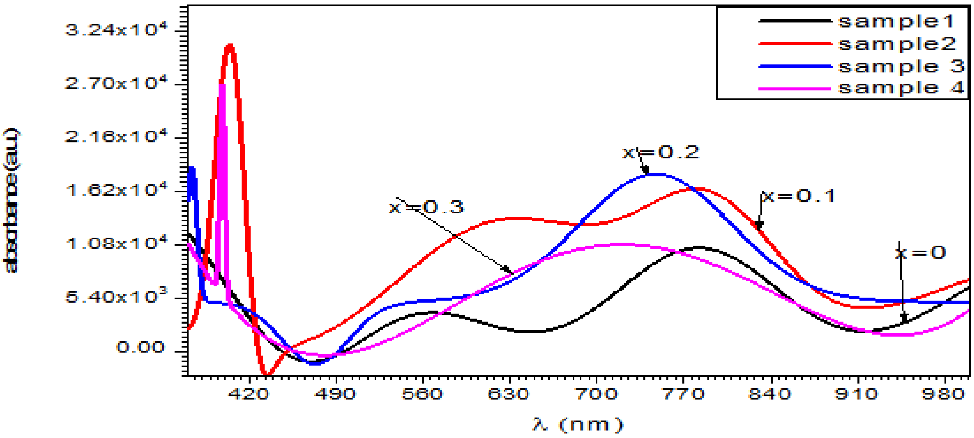

Figure 1. Absorbance of soda-lime-silica glass sample doped with $xZnO$ (where x=0, 0.1, 0.2, 0.3) in wt%

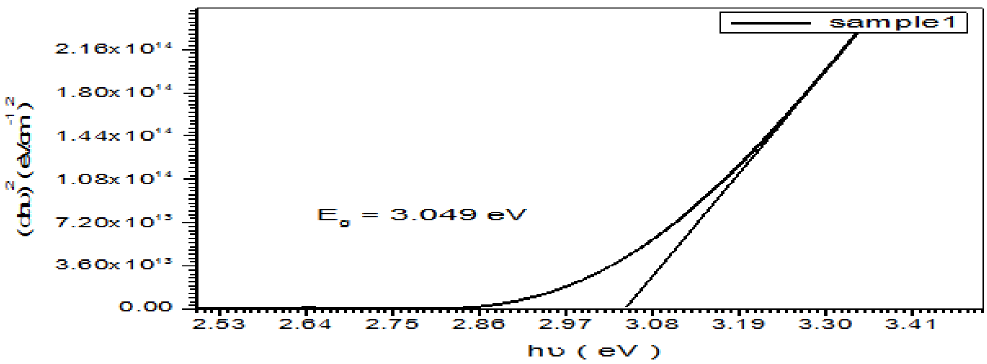

Figure 2. Energy band gap of glass doped concentration 0.0%

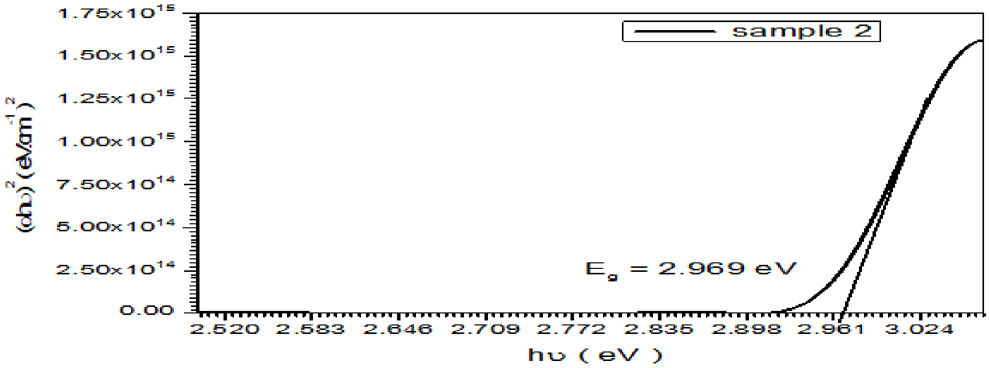

Figure 3. Energy band gap of glass doped with ZnO in concentration 0.1%

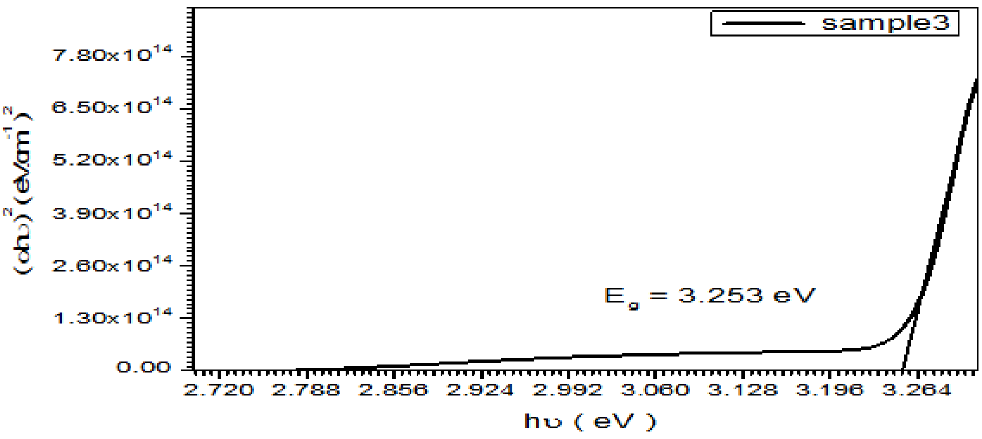

Figure 4. Energy band gap of glass doped with ZnO in concentration 0.2%

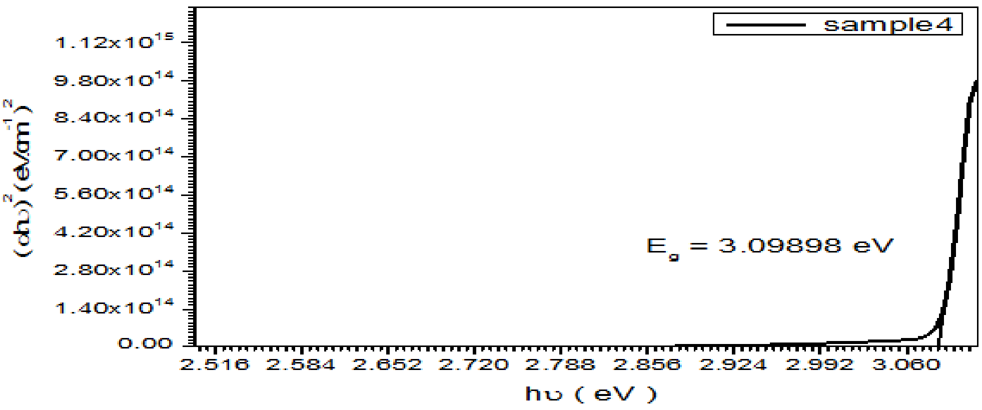

Figure 5. Energy band gap of glass doped with ZnO in concentration 0.3%

4. Discussion

4.1. Physical Properties

The values of room temperature density and molar volume of soda-lime-silica glass are summarized in Table 1 show the density of glass increase with increasing of ZnO concentration because of higher molecular weight of ZnO compared with SiO_2 as discussed in many reports [10,11].

The molar volume decreases with increasing of ZnO concentration; this result indicated that the structure of glass more compacted, with addition of. The probable explanation may be that a major part of ZnO enters directly into the structure without the introduction of additional non-bridging oxygen as explained by K. Boonnin et al. [10].

4.2. Optical Properties

Table 1 showed that the refractive indices of present systems of glass vary with additional of ZnO. This may indicate that the ZnO into the network which attributed to the increase in the number of non-bridging oxygen (NBOs). The increase of NOBs in the structure generally leads to an increase in average atomic separation. The result obtained indicates that the zinc oxide enters the glass network as a modifier by occupying the interstitial space in the network and generating the NBOs to the structure as discussed in many reports [9,12,13].

The energies band gap were determined by plot of $(\alpha h\upsilon)^2$ versus photon energy (hυ) in Figure 2 ~ Figure 5 for direct transitions allowed. It can be seen that there exists a linear dependence of $(\alpha h\upsilon)^2$ in the photon energy. This suggests that at higher energy the transitions occurring in the present glass samples are of direct type. The obtained values of optical energies bad gap are listed in Table 1. It can be noticed that the optical band gap varies with change of doped concentration of ZnO as discussed by Parnuwat [11].

It can be noticed that the optical band gap varies with increasing of ZnO concentration from 2.969 to 3.253 eV; this result may indicate that the concentration 0.2% has lower non-bridging oxygen. This leads to decrease of the degree of localizations of electrons thereby the decrease of donor center in glass matrix. The decrease of presence of donor center leads to the increase of band gap as reported by Parnuwat [11].

The absorbance of ZnO doped soda-lime-silica glasses in UV-VIS-NIR region at room temperature are shown in Figure 1. It is clearly observed that the absorption intensity of the absorption bands vary with increasing of ZnO concentration. All absorption band spectra are characteristics of Zn^{2+}-doped oxide glasses as discussed in many reports [9,14]. The absorption spectra in visible and NIR regions (400-1000nm) showed in Figure 1 reveal law absorption of light in the indigo, blue, green, yellow regions (433-560 nm) and high absorption in the orange, red and NIR regions (625-850 nm). On the other hand, it means that the light in the blue, indigo, green and yellow regions was transmitted. However, a glass sample with 0.1% concentration of ZnO, it is seen in Figure 1 that some more light in the red and NIR regions was absorbed as indicated by the absorption edge was slightly shifted to a higher wave length as discussed in many reports [9,15].

5. Conclusion

According to these obtained results, this work can recommend that: Doping ZnO in soda-lime-silica glasses increase density, decrease molar volume, vary refractive index, energy band and affect slightly absorbance of UV-VIS spectra; it may use as a modifier for transparency.

References

[1] K. J. Rao, Structure Chemistry of Glasses, Elsevier Science &Technology Book 2002.

[2] M. B. Tang, W. H. Wang, L. Xia, and J. T. Zhao. Constant-Volume Heat Capacity at Glass Transition, Journal of Alloys and Compounds 577 (2013) 299-302.

[3] J. E. Shelby, Introduction to Glass Science and Technology, The Royal Society of Chemistry 2005.

[4] Emad El-Meliegy and Richard Van Noort, Glasses and Ceramics for Medical Application, Springer, New York 2012.

[5] L. D. Pye, H. J. Stevens, and W. C. Lacourse, Introduction to Glass Science, Plenum Press, New York 1972.

[6] Arun K. Varshneya, Fundamental of Inorganic Glasses, Acadimic Press, Inc., London 1994.

[7] Fuji Funabiki, Tashio Kamiya and Hideo Hosono, Doping Effects in of Japan 120 (2012) 447-457.

[8] J. Kaewkhao, W. Siriprom, S. Insiripong, T. Ratana, C. Kedkaew and P. Limsuwan, Structure and Magetic Properties of Glass Doped with Iron Oxide, Journal of Physics: Conference Series 266 (2011) 1742-6596.

[9] Weeranut Kaewwiset, Kheamrutai Thamaphat, Jakrapong Kaewkhao and Pichet Limsuwan, ER^{3+}- Doped Soda-Lime-Silicate Glass Artificial Pink Gemstone, American Journal of Applied Science 9 (2012) 1769-1775.

[10] K. Boonin, P. Chimalawong, N. Srisittipokakul, J. Kaewkhao, Optical Properties of Sm3+− Doped Soda-Lime-Siligate glass system, Proceeding-science and Engineering (2013) 519-523.

[11] Parnuwat Chimalawong, Jakrapong Kaewkhao and Pichet Limsuwan, Spectroscopic Studies of Nd^{3+} Doped Soda−Lime-Silicate Glasses, Journal of Material Science and Engineering 6 (2012) 363-367.

[12] Abdel-Baki, M., F. A. Abdel-Wahab, A. Radi and F. El-Diasty, Factors Affecting Optical Dispersion in Borate Glass System, J. Phys. Chem. Solid, 68 (2007) 1457-1470.

[13] Sindhu, S., S. Sanghi, A. garwal, V. P. Seth and N. Kishore et al., Effect of Bi2O3 Content on the Optical Band Gap, Density and Electrical Conductivity of MO.Bi2O3.B2O3 (M=Ba,Sr) Glasses, Mater. Chem. Phys. 90 (2005) 83-89.

[14] Y. K. Sharma, S. S. L. Surana, R. K. Singh and R. P. Dubedi, Spectral Studies of Erbium Doped Soda Lime Silicate Glasses Invisible and Near Infra Red Regions, Optical Mater. 29 (2007) 598-604.

[15] Nattapon Srisittipokakun, Chittra Kedkaew, Jakrapong Kaewkhao, Treedej Kittiauchawal, Kheamrutai Thamaphat and Pichet Limsuwan, Electronic Spin Resonance (ESR) and Optical Absorption Spectra of a Manganese Doped Soda-Lime-Silicate Glasses System, Kasetsart J. Nat. Sci. 43 (2009) 360-364.