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Optical properties of soda-lime-silica glasses doped with peanut shell powder

B. Aktas [a,*], M. Albaskar [a], S. Yalcin [b], K. Dogru [c]

[a] Harran University, Engineering Faculty, Department of Mechanical Engineering, 63300, Sanliurfa, Turkey

[b] Harran University, Arts and Sciences Faculty, Department of Physics, 63300, Sanliurfa, Turkey

[c] Harran University, Institute of Natural and Applied Sciences, 63300, Sanliurfa, Turkey

* Corresponding e-mail address: baktas@harran.edu.tr

ABSTRACT

Purpose: Aim of this paper is to investigate the optical properties of soda-lime-silica (SLS) glasses which doped with different quantities of peanut shell (PS) powder.

Design/methodology/approach: UV-Vis and Fourier transform infrared (FTIR) spectroscopy techniques are used to determine optical properties of glass.

Findings: It was observed that the colorless and transparent pure SLS glass turned dark green in color with the addition of the PS powder. The glasses doped with PS powder contents ≥ 1 wt.% were translucent. The maximum absorption in the UV spectrum was observed at wavelengths of 306.20, 292.40, 280.20, and 303.20 nm for SLS glasses doped with PS powder contents of 0.5, 1, 3, and 5 wt.%, respectively. The UV-Vis spectroscopy results also indicated that the amount of light transmitted by the SLS glass decreased with increasing PS powder content. The FTIR absorption spectra of the PS powder-doped SLS glasses exhibited various bands corresponding to the symmetric and asymmetric stretching of the bridging oxygen atoms between the tetrahedra.

Research limitations/implications: With the addition of the PS to the SLS glass, samples turned to dark green because of Fe_2O_3. Future researches must focus on this matter.

Originality/value: PS powders are doped to investigate optical properties of glass. Thus, glasses, which have good properties such as economically cheap, bio-friendly, are produced from food wastes.

Keywords: Soda-lime-silica glass; Peanut shell powder; Optical properties; FTIR spectra; UV-vis spectrometer

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PROPERTIES

1. Introduction

Most of the commercial glass by weight is based on the soda-lime-silica ternary system, with minor additions of other oxides to adjust the properties for specific applications. While vitreous silica has many properties that make it desirable for application as a flat, container, or lamp glass, the high melting temperature required to produce vitreous silica (> 2000°C) precludes its application for the more common consumer products, where cost is a driving force behind the choice of glass composition [1-4]. Addition of soda and lime to silica produces large numbers of non-bridging oxygen atoms, or breaks in the connectivity in the network. As discussed earlier, these non-bridging oxygen atoms cause a huge reduction in the viscosity and glass transformation temperature of the glass relative to vitreous silica. The glass transformation temperature (T_g) of commercial soda-lime-silica glasses is in the range 550 to 580°C. The thermal expansion coefficient, which also increases with increases in the fraction of non-bridging oxygen atoms in the network, is about 8 to 9 ppm K^{-1} for commercial glasses, which means that these glasses are much more susceptible to thermal shock failure than vitreous silica [5-8]. The combination of a lower T_g and a higher thermal expansion coefficient severely limits the applications of soda-lime-silica glasses for products requiring good thermal performance. The use of these glasses for incandescent lamps, for example, requires the use of very thin-walled bulbs in order to prevent thermal shock failure when a light is turned on or off. The density and refractive index of soda-lime silica glasses are greater than those of vitreous silica due to the filling of the interstices in the network by the sodium and calcium ions. As a result, the density increases to ~ 2.5 g/cm^3, while the refractive index increases to ~ 1.51 [9-11]. The small variations in these properties with typical variations in glass composition for commercial soda-lime-silica glasses are rarely of pragmatic importance [12-14]. The aim of the present study is to investigate the optical properties of the SLS glasses doped with various contents of the PS powder (0-5 wt.%).

2. Materials and procedure

In this study, the SLS powders were used as the matrix material and the PS powders were used as the additives. The soda lime silica and peanut shell powders were prepared by grinding the SLS glasses (Trakya Glass Industry Co.) and the PS wastes, respectively. The chemical compositions of the powders used in the study were determined using inductively coupled plasma mass spectrometry (ICP-MS) and are shown in Table 1.

Different amounts of the PS powders (0.5, 1, 3, and 5 wt.%) were mechanically mixed with the SLS powders. Mechanical mixing was performed in an attritor type mixer at 200 rpm for 1 h. The powders were then pressed at 250 MPa in a single-axis die with a radius of 32 mm which produced pellets of 32 mm diameter and 6 mm thickness. The glass samples were prepared by melting the undoped and the PS-doped SLS powders in a graphite mold at 1300°C for 2 h to ensure homogeneity. The molten glass was then quenched in the mold. After quenching, the samples were formed in a square shaped graphite mold at 1100°C. The formed samples were annealed at 500°C for 3 h and then slowly cooled to room temperature inside the furnace. For the microstructural investigations, the surfaces of the samples were successively ground using 120, 240, 400, 600, 800, and 1200 grit SiC papers, and finally polished using 6, 3, and 1 μm diamond suspensions. The surfaces of the polished samples were etched by HF acid for 1 min and then analyzed using an optical microscope. The density of the sample was measured by Archimedes' principle using distilled water. Electronic absorption spectra were obtained using a Perkin Elmer Lambda 25 UV-Vis spectrophotometer in the wavelength range of 200-400 nm at room temperature. Fourier transform infrared (FTIR) spectroscopy data of the glass samples were acquired using a Perkin Elmer spectrometer with an instrument resolution of (1 cm^{-1}), in the wave number region from 500 to 4000 cm^{-1}.

3. Results and discussion

Figure 1 shows the microstructures of the undoped and the PS powder-doped SLS glasses. After chemical etching for 1 min (HF acid), many superficial cracks appeared extending in depth. These cracks were not visible before the chemical treatment and are believed to have developed due to the chemical attack on the apparent randomly oriented micro-cracks. The dissolution of the crests near the surface grooves led to the clustering of the holes, which appear as large and nearly homogeneous craters.

The effect of different amounts of the PS powder on the densities of the SLS glasses is indicated in Figure 2. There was a slight decrease in the density of the SLS glass with the addition of the PS powder. The results of the ICP analysis showed that the PS powders contained high amounts of sodium oxide (Na_2O; Table 1). Therefore, the density of the SLS glasses decreased due to the presence of the low-density sodium oxide (2.27 g/cm^3).

Table 1.
Chemical composition of the powders used in the study

Powder	wt.%								
	SiO_2	Al_2O_3	CaO	K_2O	Fe_2O_3	MgO	MnO_2	Na_2O	TiO_2
SLS	71.5	1.5	9.5	-	0.024	2	-	15.5	0.08
PS	0.789	4.812	29.732	13.268	3.966	9.148	1.655	36.633	-

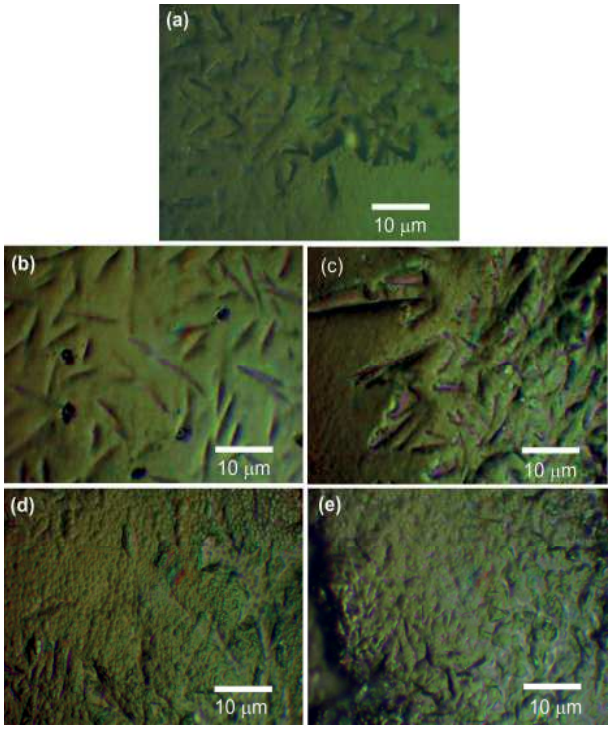

Fig. 1. The optical micrographs of the SLS glasses doped with (a) 0, (b) 0.5, (c) 1, (d) 3, and (e) 5 wt.% PS powder

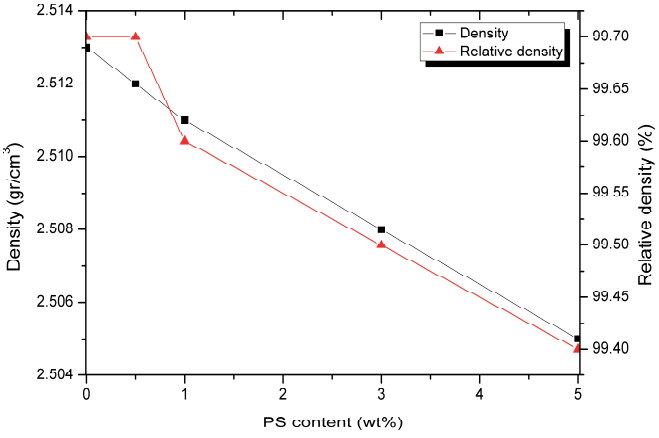

Fig. 2. Variations in the densities of the undoped and the PS powder doped SLS glasses

The appearance of the pure SLS glass and the PS powder-doped glasses taken post-annealing are shown in Figure 3. The pure SLS glass was colorless and transparent, whereas, with the addition of the PS powder, the color of the glass turned dark green. When the PS powder content was ≥ 1 wt.%, the glass became translucent; this resulted from the presence of Fe_2O_3 in the peanut shell powder.

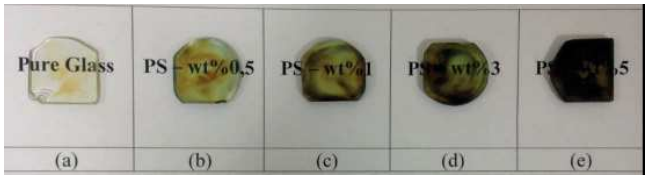

Fig. 3. Photographs of the SLS glasses doped with (a) 0, (b) 0.5, (c) 1, (d) 3 and (e) 5 wt.% PS powder

The UV-Visible absorption spectra of the SLS glasses with PS powder contents of 0.5, 1, 3, and 5 wt.% are shown in Figure 4. The SLS glass prepared with the PS powder content of 0.5 wt.% showed peaks centred at 285 and 306 nm in the spectrum. At 1 wt.% PS powder, the spectrum revealed two sharp and strong peaks at 271 and 292 nm. The spectrum of the glass containing 3 wt.% PS powder revealed strong ultraviolet bands at about 270 nm with a neck at 280 nm. Addition of 5 wt.% PS powder to the glass showed the presence of three UV absorption band at 254, 282 and 303 nm. The comparison of the spectra in Figure 4 indicates that the amount of transmitted light decreased with increasing PS powder content in the SLS glass. This is attributed to the increase in the colour centre of the PS powder doped SLS glass which increases the absorption of the UV light.

Figure 5 shows the FTIR spectra of the PS powder-doped SLS glasses. The spectrum of each PS powder-doped glass followed the same pattern as the spectrum obtained from the undoped glass. There were very slight variations in the spectral curve profiles of the different samples (Fig. 5). The band centered at 1455.64 cm^{-1} in the FTIR spectra was related to the carbonate groups and the bands observed at 2916.48 and 2847.47 cm^{-1} were respectively attributed to the asymmetric and symmetric

stretching modes of the interstitial H_2O molecules. The bands observed around 770-820 cm^{-1} are attributed to the Si-O-Si symmetric stretching of the bridging oxygen atoms within the silicate tetrahedra. The bands centered around 970 and 1050 cm^{-1} are related to the Si-O-Si asymmetric stretching of the bridging oxygen atoms within the silicate tetrahedra [15]. A weak indication of the non-bridging Si-O stretching band is also visible at 950 cm^{-1}.

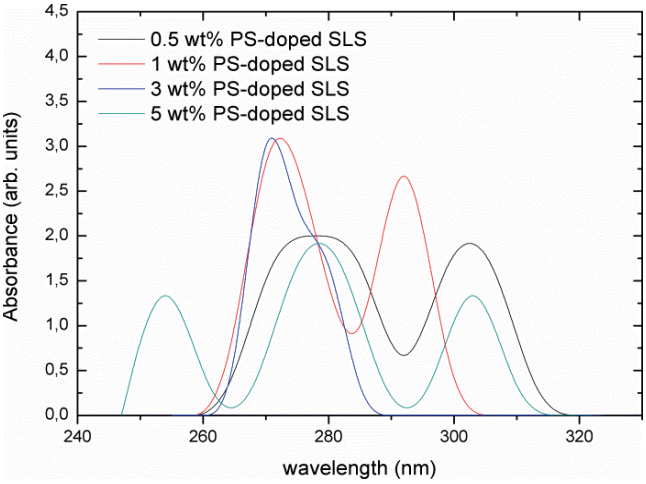

Fig. 4. The absorption spectra of the PS powder-doped SLS glass samples

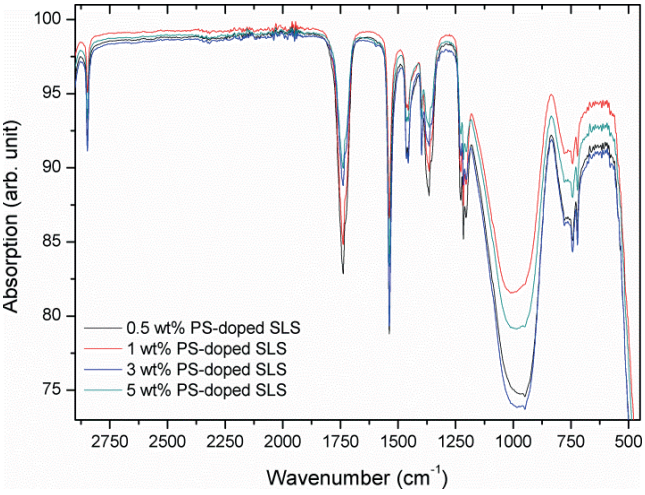

Fig. 5. The FTIR spectra of the PS powder-doped SLS glass samples

Wang et al reported that the FTIR absorption spectra consists of three main absorption bands at: 470 cm^{-1} assigned to Si-O-Si bending vibration, 780 cm^{-1} assigned to Si-O-Si symmetric stretching and 1050 cm^{-1} assigned to Si-O-Si asymmetric stretching [16]. Khalil et al. reported that the FTIR spectrum in the range 400-1400 cm^{-1} comprises absorption due to the vibrations of the main groups in the silicate network with different bonding arrangements and the spectrum extending from 1400 to 4000 cm^{-1} consists of vibrations due to water, hydroxyl, Si-OH or similar groups [17]. The FTIR spectroscopic studies of alkali silicate glasses have revealed that the structures of these glasses were generally independent of the content of the alkali oxide, and the constitution retained the tetravalent nature of the main silicon ion.

4. Conclusions

PS powder-doped SLS glasses have been prepared by the melt-quench technique. The density of the glasses decreased with increasing PS powder content. The pure SLS glass was colourless and transparent, whereas it became dark green after adding the PS powder. The maximum absorption in the UV spectrum was observed at wavelengths of 306.20, 292.40, 280.20, and 303.20 nm for the SLS glasses doped with PS powder contents of 0.5, 1, 3, and 5 wt.%, respectively. The FTIR spectra of the PS powder-doped SLS glass showed a band centered at 1455.64 cm^{-1}, which is attributed to the stretching of the carbonate groups.

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