PROCEEDINGS

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Optical Properties of Pb:Doped Tellurite Glasses

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ABSTRACT
Tellurite glasses with molar compositions of 55TeO2–2Bi2O3–[43–x]ZnO–xPbO (in mol%) with x = 1, 2, 3, 4, 5 have been fabricated and characterized. The optical absorption spectra were recorded at room temperature using UV-VIS-NIR Spectrophotometer and FTIR while their refractive indices were determined by the Brewster angle method. It was observed that the glasses refractive index as well as their transmittance range increase with the increase of PbO content. Minimum loss of the glasses predicted from these spectroscopic data are situated between 2.31-10-3dB/m and 2.94 10-3 dB/m at wavelength around 5.5 μm.

INTRODUCTION

Compared to most of glasses (i.e., fluoride glasses, borate glasses and silicate glasses), tellurite glasses family shows higher refractive index. Phonon energy of this glasses family is relatively low. With their wide transmission ranges (approx. 0.4 – 4 μm) as well as their relative thermal stability against crystallization, tellurite glasses are of special interest for wide range of optical applications. For varied laser applications, a large number of new rare earth doped glasses have been tailored and modified. The dependence of the spectroscopic properties on composition have been reported. Further, tellurite glasses are known to have ability to dissolve high concentration of rare earth ions without any clustering. This leads to enhancing the fluorescence lifetime and quantum efficiency (Pokhrel, et al., 2012).

This paper is devoted to discussed how the optical properties of tellurite glasses change as the concentration of Pb2+ ions in glass change. Discussion will begin with this effect to glass refractive index followed by UV-edge and IR-edge shifting. More important information determining the use of the glass optical communication, i.e. the lowest minimum low loss of each glass composition is finally presented.

EXPERIMENT

Glass composition used in this experiment is (in mol%): 55TeO2-2Bi2O3-[43-x]ZnO-xPbO with x=1,2,3,4,5. All chemical used to make the glass have purity higher than 99.9%. The prepared chemicals were mixed thoroughly before being melted in platinum crucible put in an electric tube furnace. Melting was carried out at 900°C for 1 hour. To achieve homogeneity, the glass molten was stirred intermittently. The melt was then cast into preheated brass mould. The glass thus obtained were then annealed at 375°C for 6 hours before being slowly cooled to room temperature. Glass samples were then cut and polished for optical characterisation. Refractive index measurements were conducted using Brewster angle method at 560 nm. Absorption spectra measurements in the UV-VIS NIR region were carried out Perkin-Elmer UV-VIS-NIR Lambda-25 Spectrophotometer while within the range of 4500 cm-1-500 cm-1 using Shimadzu Fourier Transform Infrared (FTIR) spectrometer.

RESULTS AND DISCUSSION

Tellurite glasses fabricated in this experiment are yellowish. Visually, this color is not affected by the increase of Pb2+ ions in the glass. Glass refractive index, however, increases with increasing Pb2+ ion concentration (decreasing Zn2+ concentration). It is 1.96 for 1 mol% of Pb2+ content and goes to 2.02 for 5 mol% of Pb2+ content. This result can be explained in term of electronic ion polarizability. Lorentz-Lorentz equation relates molar refraction of a substance \( R_m \), its molar volume \( V_m \), and its refractive index \( n_0 \) as given by

\[
R_m = \left( \frac{n_0^2 - 1}{n_0^2 + 1} \right) V_m \quad (1)
\]

or

\[
n_0 = \left( 1 + R_m V_m \right) \left( 1 - R_m V_m \right) \quad (2)
\]

where

\[
R_m = 2.52 \alpha_m \quad (3)
\]

\( \alpha_m \) in this equation is molar polarizability of a substance (whole glass matrix) and it is additive quality. \( \alpha_m \) as given in equation 3 is summation of molar fractions of all ionic polarizabilities make...
up glass matrix. Ionics polarizability of Pb\textsuperscript{2+} and Zn\textsuperscript{2+} are 1.32 and 0.83, respectively. As the amount of Pb\textsuperscript{2+} ions incorporated into the glass is the same as that of Zn\textsuperscript{2+} ions reduction from the glass, molar refraction (\(R_m\)) of glass as given by equation (3) increases as the amount of Pb\textsuperscript{2+} content in glass increases. This leads to increase in glass refractive index (equation 2).

Figure 1 is typical spectrum absorption within UV-VIS-NIR range (a) and IR range (b). It is clear from this figure that the glasses start to transmit at a wavelength of 400 nm. Light with wavelength less than 400 is absorbed. Glass absorbance increases as the Pb\textsuperscript{2+} content in glass increases. Since all glasses are fabricated with nearly the same thickness, this result shows that the absorption coefficient within this range increases with the increase of Pb\textsuperscript{2+} content. Fortunately, this is not the case in IR absorption spectra. The glass absorption of IR light decreases as the Pb\textsuperscript{2+} content in glass increases.

![Image](image-url)

**Figure 1.** Spektrum absorbansi optis kaca tellurite pada daerah (a) UV-Vis dan (b) Infrared

Figure 2 is transmission range of the glass fabricated in this experiment. This figure is made by combining Figure 1 (a) and (b). It can be seen that tellurite glasses can transmit light from the wavelength between 400 nm and 6500 nm. This range is wider than that obtained in silicate glass family whose transmission range is only within range between around 300 nm and 2000 nm. Higher density and thus molar volume is the reason behind wide range of transmission. As IR-edge is determined by frequency of molecular vibration, the heavier the molecules (molecular weight) the smaller the frequency of vibration will be. The molecular weight of tellurite glasses is much more than silicate glasses. Parallel to this reason, upon the incorporation of Pb\textsuperscript{2+} ions into the glass, the IR-edge will red-shift as shown in Figure 3. The more the Pb\textsuperscript{2+} ions content is the farther the red-shifting it will be.

![Image](image-url)

**Figure 2.** Transmission range of tellurite glass for \(x=1\)

<table>
<thead>
<tr>
<th>Table 1. Optical properties of tellurite glasses</th>
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<tbody>
<tr>
<td><strong>Sample</strong></td>
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<td>TeO(_2)</td>
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<td>X=1</td>
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<td>X=3</td>
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<td>X=5</td>
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Figure 3. Shifting of (a) UV-edge and (b) IR-edge as function of Pb$^2+$

Figure 4 is theoretical minimum low loss of tellurite glass for x = 4. It can be seen that the minimum loss of glass that might be achieved is around 2.5x10$^{-3}$dB/m. This minimum loss can be achieved at the wavelength of higher than 5500 nm. Complete data for this estimation are given in Table 1. No tendency of either decreasing or increasing this value is observed. One think that sure is that in term of their optical properties, the glasses fabricated here in this experiment are of good candidate for IR-application. An application where using silicate glasses is impossible.

Figure 4. Estimation of minimum low lost of tellurite glass (x=4) using rayleigh scattering data taken from literature.

CONCLUSION

New tellurite glasses with composition of 55TeO$_2$-2Bi$_2$O$_3$-(43-x)ZnO-xPbO with x=1,2,3,4,5 have been fabricated and optically characterized. These glasses show a wide range of transmission. This width is improved as Pb content in glass increase. The minimum loss estimated from this experiment is around 2.5x10$^{-3}$dB/m at around 5500 nm. This make these glasses are good candidate for IR-application.

REFERENCES
