LOW TEMPERATURE ULTRASONIC ATTENUATION IN TELLURITE GLASSES

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Abstract

The new semiconducting non-crystalline solid “tellurite glasses” of the form 0.7 TeO\textsubscript{2} -(0.3-x) V\textsubscript{2}O\textsubscript{5} - xCeO\textsubscript{2} have been prepared in bulk form with different compositions. Longitudinal ultrasonic attenuation in these glasses has been measured at frequencies 2,4,6 and 8 MHz and in the temperature range 100-300°K. The results showed the presence of a very well defined peak which shifts to higher temperature with increasing frequency, suggesting a kind of relaxation process. The acoustic activation energy has been found to be strongly depend upon the value of the oxygen density in the glass. The ultrasonic loss is thought to arise from the thermally activated transitions of the bridging oxygen atoms from one minima in the two-well potentials. The number of cation-anion-cation units in unit volume has been calculated. So, the macroscopic activation energy could be correlated to the barrier height of the two-well potentials.

1- Introduction:

Considerable international progress has been made during 1990’s both in the discovery of new tellurite glasses, and in knowledge of the optical & physical properties, structural & bonding nature of these glasses (1-25). The main justification for research in this field is the possibility of extending the infrared transparency domain towards long wavelengths and consequently achieving of mid IR ultratransparently. Tellurite glasses with high refractive indices are promising materials for photonic switches (4,5). TeO\textsubscript{2} -V\textsubscript{2}O\textsubscript{5} - M glasses have the property of switching phenomena (3) where M= CeO\textsubscript{2}, La\textsubscript{2}O\textsubscript{3}, Y\textsubscript{2}O\textsubscript{3}.

2- Experimental Work:

Mixtures of reagent grade TeO\textsubscript{2}, V\textsubscript{2}O\textsubscript{5}, CeO\textsubscript{2} were placed in an alumina crucible. The glass was prepared by putting the batch in an electric furnace at temperature in the range of 700-800°C. To improve homogeneity the high viscosity melt was stirred a few times. The melt was then cast into a heated steel mold followed by annealing at 250°C for 1 h. The ultrasonic attenuation of each sample was measured for the longitudinal waves at the frequencies 2,4,6 and 8 MHz in the temperature range 120-300 K. A cryostat arrangement with liquid air was used to cool the sample. The sample with the bonded transducer was mounted on a sample holder and placed inside a chamber. The temperature was checked by a thermocouple placed in direct contact with the
sample. The pulse echo technique was the method used for the measurements as described before.(22).

Fig. 1 : Absorption Coefficient $\alpha$ for TeO$_2$-V$_2$O$_5$-CeO$_2$ glasses in the temperature range 140 - 300 K.
3- Results and Discussion:

The attenuation coefficient of each sample is given by: \( \alpha = (20 \log h_1/h_2)/2x \), where x is the length of sample and h1, h2 are the heights of the first and second echoes respectively. The ultrasonic absorption \( \alpha \) vs. temperature for all samples are shown in Fig. 1. The peak occurs at temperature ranging 180-238 K depending upon the sample composition and frequency. For each sample the attenuation, especially at the peak temperature, increases with the frequency. The peak temperature shifts to higher values for higher frequencies. Table 1 summarizes the values of the attenuation at the peak temperature for all samples. Plots of log frequency (f) against inverse peak temperature (1/\( T_p \)) yield straight line as shown in Fig. 2. It is clear from fig. 2. that the present glass fit an equation of the form \( \omega \tau_0 \exp(E/kT)=1 \). From the slope and intersect of these lines the activation energy E and attempt frequency \( \tau_0 \) have been calculated in Table 1.

The present analysis of ultrasonic attenuation at low temperatures of these glasses is based on the fact that in all noncrystalline solids (Glass) there is a distribution of the thermally averaged cation-anion-cation spacings about the equilibrium values. It has been reported(26) that there would exist two-well systems with a distribution of barrier heights (activation energies) for both longitudinal and transverse vibrations of the anions (oxygen in the present glass) as shown in Fig. 3.

The relaxation process can be described to a particle moving in a double-well potential and the sound wave disturbs the equilibrium and produce a relative energy shift between the minimum if the two wells by an amount \( \Delta E \). According to the Debye relation (27,28), the absorption coefficient is given by

\[
\alpha = n A \left\{ \tau^2(V) \right\} / \left(1 + \tau^2(V)\right)
\]  

(1)
where $n$ is the number of relaxing particles per unit volume which (calculated from the chemical formula for each glass) which increased from $6.21$ to $6.41 \times 10^{28}$ m$^3$ for the change of CeO$_2$ from 0.03 to 0.10 mol %. $A$ is the relaxation strength is given by:

$$A = 2\alpha_{\text{max}} V L /\pi f_0,$$

$VL$ is the sound velocity (29). The relaxation strength has been increased due to increase in the frequency for each sample. While the attempt frequency has been decreased from 2.66 to 0.2 Sec.$^{-1}$ for higher CeO$_2$ in the glass. So, the higher number of vibrating anions is the present glass is responsible for the attenuation. The decrease in the experimental values of activation energies from 0.095 to 0.049 eV for higher CeO$_2$ could be attributed to the decrease in the value of the average force constant in the glass due to the presence of CeO$_2$ from 234 to 216 N/m.

### 4- Conclusions:

The maximum absorption of ultrasonic waves that propagated in a noncrystalline solid (tellurite glasses) at low temperatures has been analyzed quantitatively according to the increase

<table>
<thead>
<tr>
<th>Comp. $f$ (MHz)</th>
<th>$\alpha$ (dB/m)</th>
<th>$A^{+} \times 10^{-6}$</th>
<th>$T_p$ (K)</th>
<th>$f_0$ (sec$^{-1}$)</th>
<th>$E$ (eV)</th>
<th>$\frac{F}{N/m}$</th>
<th>$n \times 10^{28}$ m$^{-3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03</td>
<td>2</td>
<td>2.05</td>
<td>37</td>
<td>180</td>
<td>2.66</td>
<td>0.095</td>
<td>234</td>
</tr>
<tr>
<td>0.05</td>
<td>2</td>
<td>2.08</td>
<td>3.76</td>
<td>188</td>
<td>1.05</td>
<td>0.092</td>
<td>229</td>
</tr>
<tr>
<td>0.07</td>
<td>2</td>
<td>2.00</td>
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<td>0.66</td>
<td>0.056</td>
<td>224</td>
</tr>
<tr>
<td>0.10</td>
<td>2</td>
<td>2.00</td>
<td>2.05</td>
<td>203</td>
<td>0.20</td>
<td>0.049</td>
<td>216</td>
</tr>
</tbody>
</table>

**Fig. 3 : Schematic two-dimensional representation of longitudinal and transverse vibrations of the amorphous solids.**
in the number of oxygens. The values of the acoustic activation energy (activation energy of anion atoms in the two-well system) depends upon the value of the cation-anion force.

References

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