Antimony-modified soda-lime-silica glass: towards low-cost radiation-resistant materials

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Citation:

Sb₂O₃-modified float glass: a potential low-cost high-energy radiation-resistant material for future applications

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S – 1: Evaluation of absorption coefficient from absorbance

Beer-Lambart's law states that if the I_0 is the intensity of EM wave incident on the particle and I is the intensity of the wave passing through the sample then,

$$I = I_0 \exp(-\alpha l) \qquad \text{(Eqn. 1)}$$

where α is the absorption coefficient of the material and l represents the thickness of the sample. Here we are typically considering scattering is negligible that could be considered nearly zero. Now, the absorbance of the material is considered as A that can be expressed as,

$$A = \log_{10} (I_0/I) \text{ or, } (I_0/I) = 10^A \qquad \text{(Eqn. 2)}$$

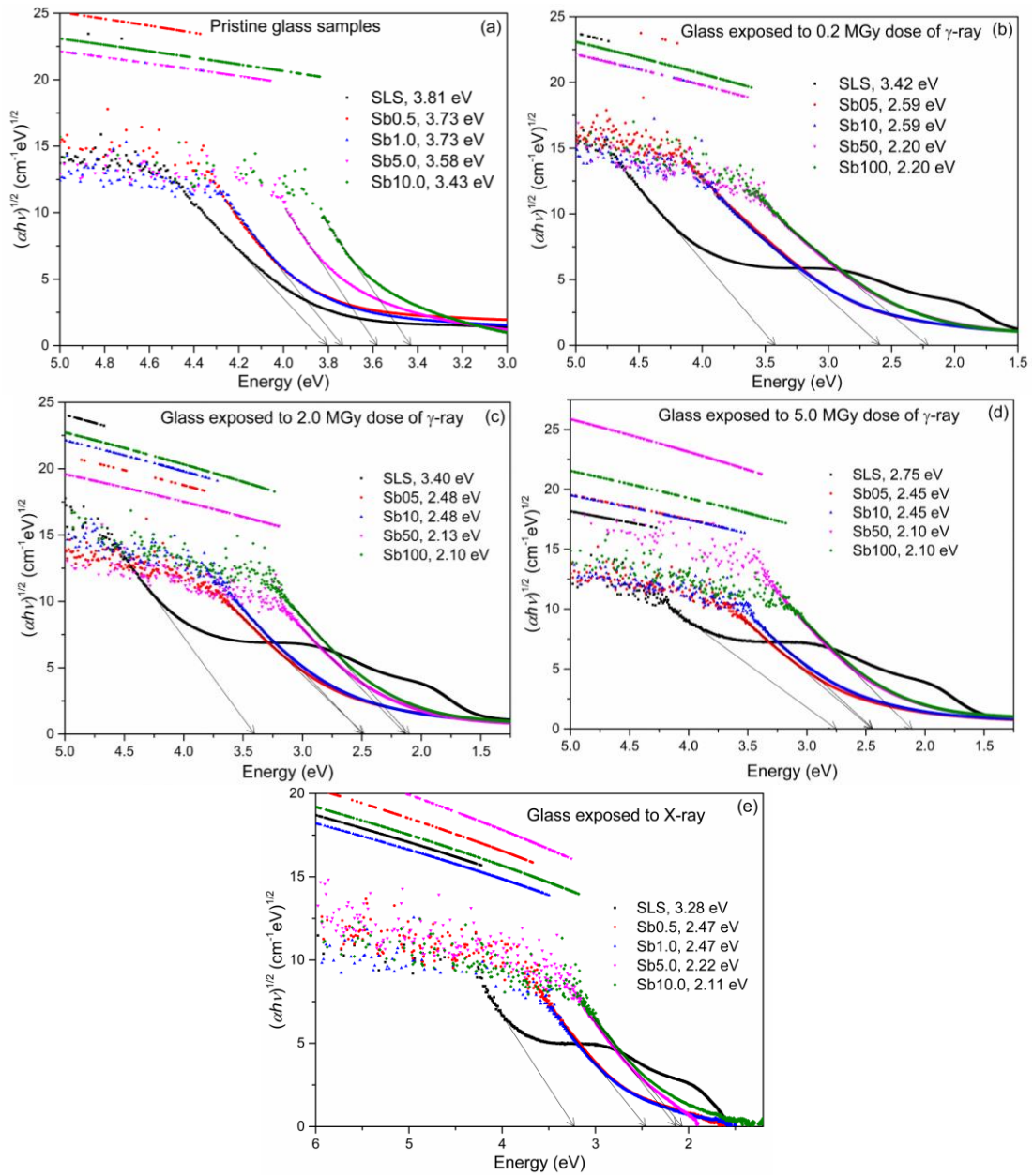If we substitute the eqn. 2 in the eqn. 1 then the relation typically becomes,

$$\alpha l = \log_n (10^A) \text{ or, } \alpha = [(\log_n 10) \times A] / l \text{ or, } \alpha = (2.303 \times A)/l \text{ since } \log_n 10 \sim 2.303.$$

Therefore, the absorption coefficient can be written as,

$$\alpha(\varepsilon) \approx \frac{2.303 \times A}{l} \qquad \text{(Eqn. 3)}$$

Here the absorbance A is directly measured using the spectrophotometer.

**S – 2: Tauc plots: UV band-edge evaluation**

S – I: Tauc plots of $(\alpha h\nu)^{1/2}$ versus energy ($h\nu$) to study the effect of various irradiation on the UV cut-off energy of Sb_2O_3-modified soda-lime-silica glass system.

The absorption coefficient spectra have utilized to estimate the UV band-edge of the glass samples. The UV band-edge of the present series of glass under various irradiation doses has estimated using following relation,[1]:

$$\alpha(hv) = C\frac{(hv - E_g)^n}{hv} \tag{S.1}$$

where $\alpha(hv)$ presents the absorption coefficient as a function energy (i.e., hv), E_g represents UV band-edge energy of the system, C is the constant of the equation, n represents the exponent of the equation. The value of exponent n is '½' for direct and '2' for indirect bandgap. The oxide glass is insulator as a result, the bandgap is indirect. Therefore, $(\alpha hv)^{1/2}$ against (hv) have plotted for the present series of samples to evaluate the UV band-edge and depicted in S – I.
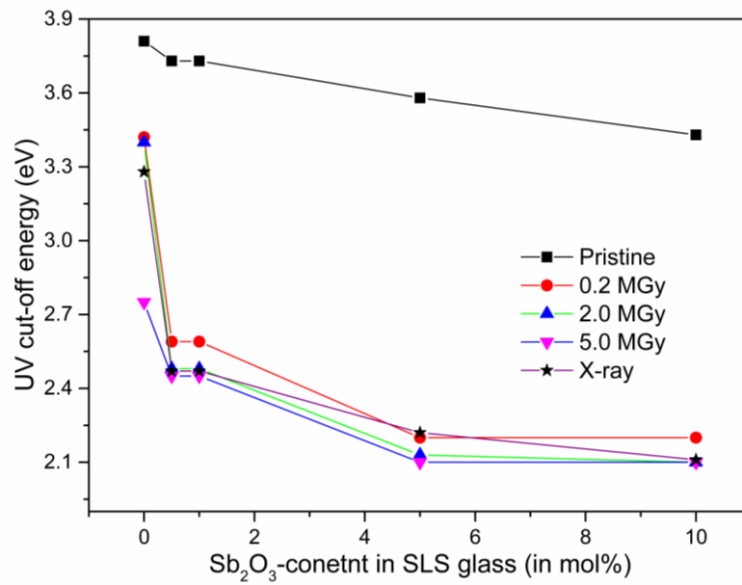

S - II: The influence of various doses of γ-rays and X-rays on the UV cut-off energy on the studied glass system.

The influence of various doses of γ-ray and X-ray on the UV cut-off energy as a function of Sb_2O_3-content in the SLS network is depicted in the figure S- II. Considerable decrease of cut-off energy with the increase of γ-ray dose is revealed.

S – 3: EPR absorption hyperfine spectra

The EPR absorption hyperfine spectra have calculated by integrating the measured EPR signal and shown in the S– III. The EPR absorption signal has confirmed the formation of Sb^{4+}-ion related hyperfine splitting for the γ-ray irradiated and Sb_2O_3-modified glass samples.
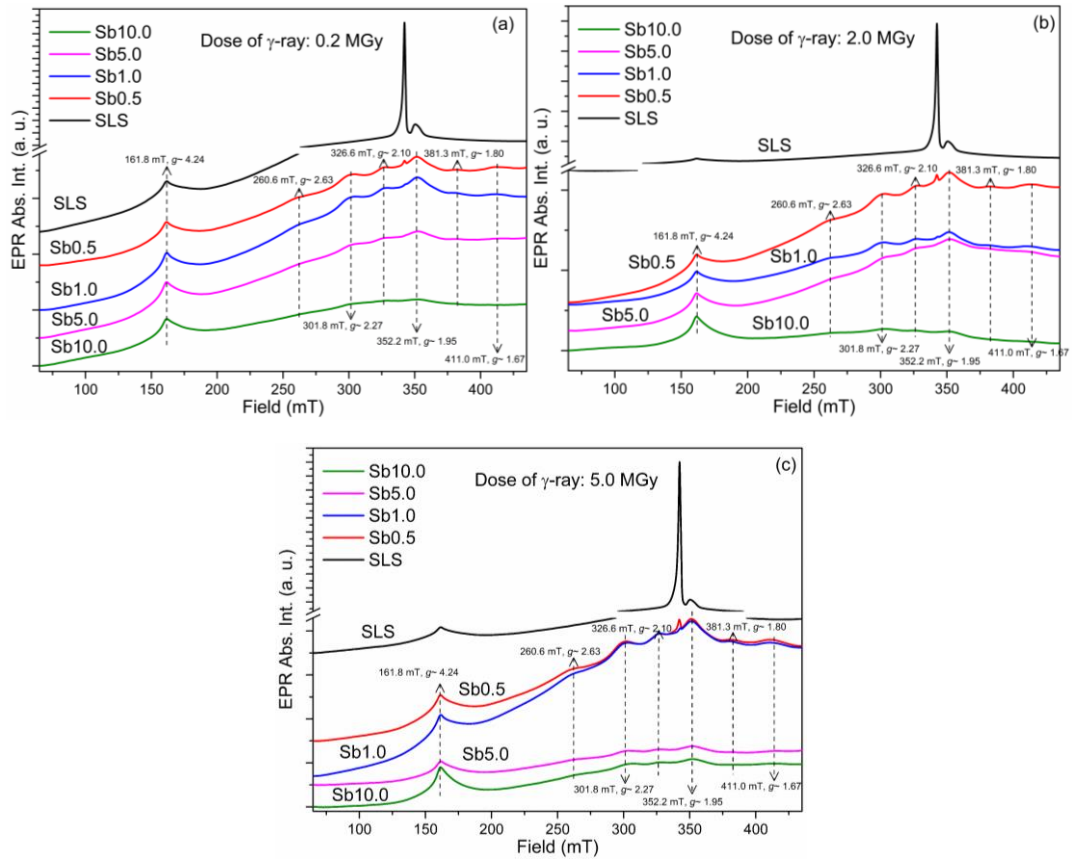
S – III: The integrated EPR absorption spectra of the measured first-order derivative of EPR signal of the glass samples irradiated with (a) 0.2 MGy, (b) 2.0 MGy, and (c) 5.0 MGy doses of γ-rays.

The EPR absorption signal has confirmed the formation of Sb^{4+}-ion related hyperfine splitting for the γ-ray irradiated and Sb_2O_3-modified glass samples.

S – 4: UV edge band tail and trace element absorption spectra
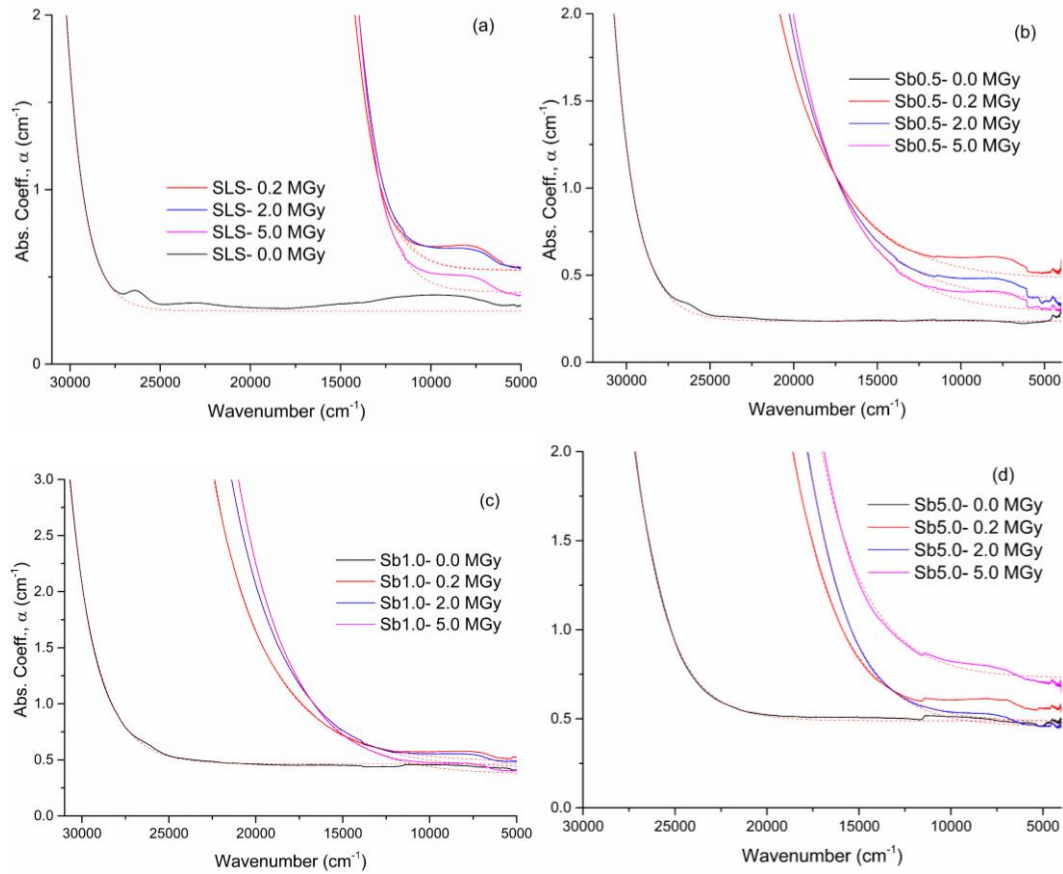
S – IV: UV edge band tail evaluation using exponential decay function for the low energy UV edge of (a) SLS, (b) Sb0.5, and (c) Sb1.0, and (d) Sb5.0 for various doses of γ-rays.

The estimation of trace element contribution in the absorption coefficient spectra is essential to understand the oxidation states of various trace elements in the glass network. However, the UV band tail masked the absorption bands of transition metal ions present as trace element in glass network. The low energy tail of the UV edge in silicate glasses containing iron obeys Urbach's rule and can satisfactorily be described by an exponential function [2]. We considered that the use of an exponential function to fit the low-energy tail of the UV edge, thereby allowing determination of actual Fe^{3+} d–d peak positions, involved acceptably low errors for the purposes of this study.

The background compensated absorption coefficient spectra has been estimated for
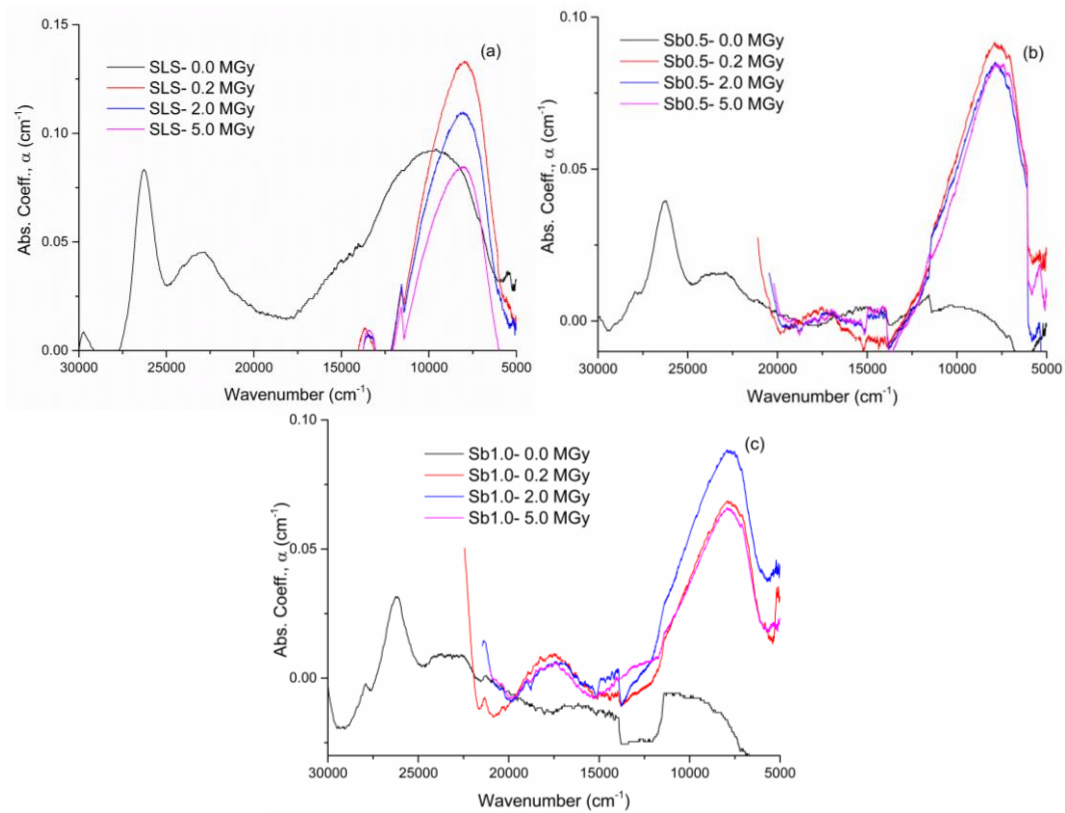
S – V: Background compensated absorption coefficient spectra of (a) SLS, (b) Sb0.5, and (c) Sb1.0 samples for various doses of γ-rays.

pristine and various doses of γ-ray. However, the exponential function has not fitted with the low energy UV edge of Sb5.0 and Sb10.0 samples. Therefore, we have considered for SLS, Sb0.5, and Sb1.0 samples only.

References:

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