ASSESSMENT OF PROTECTIVE PROPERTIES OF GLASSES WITH THE APPLICATION OF GOLMIUM OXIDE AGAINST GAMMA RADIATION

Authors

Speaker
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May 18-22, 2021
Yekaterinburg, Russia
Introduction

• At present, nuclear facilities are a promising direction for the development of energy in many countries of the world. This can cause danger to humans if they emit high levels of radiation.

• Currently, many scientists are trying to protect people and the environment from radiation exposure. For this purpose, in order to reduce the harmful effect on humans, shielding materials are needed, which must have effective properties to protect against gamma radiation.

• The glasses can become a promising material as radiation protection.

• The purpose of this work is to determine the methods of radiation-protective glasses 85TeO$_2$-(15-y)Bi$_2$O$_3$-yHo$_2$O$_3$, where y = (0; 0.1; 0.2; 0.3; 0.4; 0.5 mol.%) with different mass composition of holmium oxides for protection from gamma radiation.
Methods and Investigation Strategy

- To determine the capabilities of radiation-shielding glasses, radiation shielding parameters were calculated, such as:
  - MAC – mass attenuation coefficient - $\mu_m$
  - LAC – linear attenuation coefficient – $\mu$
  - HVT – half value thickness - $\Delta_{0.5}$
  - MFP – mean free path
  - Zeff – effective atomic number

- These parameters were calculated in the energy range 0.122–1,408 MeV.

- The study of glass shielding parameters under the influence of gamma radiation was carried out using the NIST XCOM databases and the Geant4 Monte Carlo simulation code.
Methods and Investigation Strategy

- In this work, Geant4 was used to simulate the passage of gamma rays through the studied glass samples: S1, S2, S3, S4, S5 and S6. To achieve this task, it was required to build an accurate three-dimensional model.
## Methods and Investigation Strategy

<table>
<thead>
<tr>
<th>Sample</th>
<th>Te</th>
<th>Bi</th>
<th>Ho</th>
<th>O</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>0.4556</td>
<td>0.38584</td>
<td>0</td>
<td>0.15856</td>
<td>6.175</td>
</tr>
<tr>
<td>S2</td>
<td>0.45585</td>
<td>0.38347</td>
<td>0.00203</td>
<td>0.15865</td>
<td>5.638</td>
</tr>
<tr>
<td>S3</td>
<td>0.45609</td>
<td>0.38111</td>
<td>0.00407</td>
<td>0.15873</td>
<td>5.631</td>
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<tr>
<td>S4</td>
<td>0.45634</td>
<td>0.37874</td>
<td>0.0061</td>
<td>0.15882</td>
<td>5.873</td>
</tr>
<tr>
<td>S5</td>
<td>0.45659</td>
<td>0.37637</td>
<td>0.00814</td>
<td>0.15891</td>
<td>5.697</td>
</tr>
<tr>
<td>S6</td>
<td>0.45684</td>
<td>0.37399</td>
<td>0.01018</td>
<td>0.15899</td>
<td>5.978</td>
</tr>
</tbody>
</table>

Chemical composition of each element (mol%)
Results and Discussion

- Mass attenuation coefficient (MAC) and linear attenuation coefficient (LAC) were calculated using the following formulas:

\[ \mu_m = \frac{\mu}{\rho} = \sum_i w_i \left( \frac{\mu}{\rho} \right)_i \]

where \( \left( \frac{\mu}{\rho} \right)_i \) - MAC \( i \)-th component, \( w_i \) - mass fraction of the \( i \)-th constituent element.

\[ \mu = -\frac{1}{x} \ln \left( \frac{I}{I_0} \right) \]

where \( I_0 \) – intensity of a radioactive source without shielding material, \( I \) – intensity of a radioactive source with shielding material, \( x \)- shielding absorber thickness (cm).

- HVT – half value thickness

\[ HVT = \frac{\ln 2}{\mu} \]

- MFP – mean free path

\[ \text{MFP} = \frac{1}{\mu} \]

where \( \mu \) - linear attenuation coefficient.
Results and Discussion

- Glass sample S1 with the highest Bi\textsubscript{2}O\textsubscript{3} content has the maximum value of the coefficient of mass attenuation in the low-energy region of 0.122 MeV.

- From the data obtained using Geant4 it follows that as the mass fractions of Bi\textsubscript{2}O\textsubscript{3} increased, the values varied from 1.699 to 1.665 g / cm\textsuperscript{2}.
- A further increase in the incident gamma ray energy results in a rapid decrease in LAC due to photoelectric interaction.
Results and Discussion

- Half-attenuation layer (HVL) and middle free path (MFP)
- The smallest value of the half-attenuation layer is observed in the low-energy zone up to 0.24 MeV, and a sharp increase in the half-attenuation layer is observed at energies from 0.245 to 1.408 MeV.
- The lowest MFP value is observed for the 85TeO₂-15Bi₂O₃ glass sample, which has the highest Bi₂O₃ concentration.
Conclusion

• Using the XCOM database and the Geant4 design code in the energy range from 0.1222 to 1.408 MeV, the radiation protective properties of 85TeO$_2$-(15-y)Bi$_2$O$_3$-yHo$_2$O$_3$ glass were estimated, y = (0; 0.1; 0.2; 0.3; 0.4; 0.5 mol%).

• Glass sample S1 with the highest Bi$_2$O$_3$ content has the maximum MAC value over the entire energy range from 0.1222 to 1.408 MeV and ranges from 1.699 cm$^2$/g to 0.0511 cm$^2$/g. LAC has a maximum value for glass sample S1.

• The best values of HVL and MFP indices have a glass sample S1, which is equal to 2.197 cm for HVL and 3.17 cm for MFP at an energy of 1.40 MeV.

• Among the investigated tellurite-bismuth glasses, sample S1 with a Bi$_2$O$_3$ content (15 mol.%) has the best radiation-shielding properties.
Thanks for your attention!