World Academy of Science, Engineering and Technology
International Journal of Health and Medical Engineering
Vol:19, No:02, 2025

Synthesis and Characterizations of Lead-free BaO-Doped TeZnCaB Glass Systems for Radiation Shielding Applications

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Abstract : The use of radiation shielding technology ranging from EMI to high energy gamma rays in various areas such as devices, medical science, defense, nuclear power plants, medical diagnostics etc. is increasing all over the world. However, exposure to different radiations such as X-ray, gamma ray, neutrons and EMI above the permissible limits is harmful to living beings, the environment and sensitive laboratory equipment. In order to solve this problem, there is a need to develop effective radiation shielding materials. Conventionally, lead and lead-based materials are used in making shielding materials, as lead is cheap, dense and provides very effective shielding to radiation. However, the problem associated with the use of lead is its toxic nature and carcinogenic. So, to overcome these drawbacks, there is a great need for lead-free radiation shielding materials and that should also be economically sustainable. Therefore, it is necessary to look for the synthesis of radiation-shielding glass by using other heavy metal oxides (HMO) instead of lead. The lead-free BaO-doped TeZnCaB glass systems have been synthesized by the traditional melt-quenching method. X-ray diffraction analysis confirmed the glassy nature of the synthesized samples. The densities of the developed glass samples were increased by doping the BaO concentration, ranging from 4.292 to 4.725 g/cm3. The vibrational and bending modes of the BaO-doped glass samples were analyzed by Raman spectroscopy, and FTIR (Fourier-transform infrared spectroscopy) was performed to study the functional group present in the samples. UV-visible characterization revealed the significance of optical parameters such as Urbach's energy, refractive index and optical energy band gap. The indirect and direct energy band gaps were decreased with the BaO concentration whereas the refractive index was increased. X-ray attenuation measurements were performed to determine the radiation shielding parameters such as linear attenuation coefficient (LAC), mass attenuation coefficient (MAC), half value layer (HVL), tenth value layer (TVL), mean free path (MFP), attenuation factor (Att%) and lead equivalent thickness of the lead-free BaO-doped TeZnCaB glass system. It was observed that the radiation shielding characteristics were enhanced with the addition of BaO content in the TeZnCaB glass samples. The glass samples with higher contents of BaO have the best attenuation performance. So, it could be concluded that the addition of BaO into TeZnCaB glass samples is a significant technique to improve the radiation shielding performance of the glass samples. The best lead equivalent thickness was 2.626 mm, and these glasses could be good materials for medical diagnostics applications.

Keywords : heavy metal oxides, lead-free, melt-quenching method, x-ray attenuation
Conference Title : ICRSD 2025 : International Conference on Radiation Science and Dosimetry
Conference Location : Mumbai, India
Conference Dates : February 15-16, 2025