



The impact of PbF₂ on the ionizing radiation shielding competence and mechanical properties of TeO₂–PbF₂ glasses and glass-ceramics

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ABSTRACT

The influence of adding PbF₂ on the elastic properties and radiation shielding competences of nine different samples labelled as TPb10–TPb90 with the form of (100–X)TeO₂–XPbF₂: (where X = 10–90 in steps of 10 mol%) glasses and glass-ceramics was investigated via the bond compression model and WinXcom software. The average cross-link density (\bar{n}_c) increased from 2.2 to 3.8 and the average atomic ring size (l) decreases from 0.390 to 0.356 nm with the increase of Pb ions content in the TPb10–TPb90 samples. The K_{BC} increased from 84.47 GPa to 111.09 GPa and Young's modulus (E_{BC}) increased from 136.89 GPa to 199.60 GPa for TPb10 to TPb90 samples. Poisson's ratio (σ_{BC}) decreased from 0.229 to 0.200, while the hardness (H) increased from 10.02 GPa to 16.59 GPa. The MAC of the glasses follows the order throughout the energy spectrum: TPb10 < TPb20 < TPb30 < TPb40 < TPb50 < TPb60 < TPb70 < TPb80 < TPb90. The maximum value of LAC obtained at 15 keV were: 290, 348, 405, 462, 519, 575, 632, 688, and 744 cm⁻¹ for TPb10, TPb20, TPb30, TPb40, TPb50, TPb60, TPb70, TPb80, and TPb90, respectively. HVT and MFP are inversely proportional to LAC, hence, the highest and the lowest values of HVT and MFP were obtained for TPb10 and TPb90 samples at all energies. The TPb90 had the highest Z_{eff} while TPb10 had the least. The buildup factors of TPb10 was highest at all depths while TPb90 had the least buildup factors. The obtained results showed that the addition of Pb to the proposed samples improves their mechanical and radiation shielding properties. Therefore, TPb90 sample has a better photon, fast neutron, proton, and alpha particle absorber compared to the other eight glass species in this study.

1. Introduction

The discovery of radionuclides, different ionizing radiation, and subsequent adoption for different technological applications has improved the quality of human lives. Human lives has improved through the use of radioisotopes and artificial produced nuclear radiation for diagnosing and treating impaired health conditions; cheap and enduring electric powers are being produced in nuclear reactors scattered all over the world; improved yield in agricultural produce is possible through the use of radiation for seed culture; increase in food availability has been recorded through the use of gamma rays for irradiation as a means of preservation. These are some of the ways in which ionizing radiation has been contributing to the sustenance and improving the life of man on earth. The use of radiation shields for the protection of man and his environment from the dangers associated with uncontrolled exposure to

nuclear radiation has sustained these benefits. Different materials can be used as shields for ionizing radiation [1–4]. However, not all materials can be effective for this purpose. To assess the ability of a material with respect to shielding capacity, radiation shielding parameters of such medium must initially be determined. Many parameters can be adopted and used for this purpose; however, the choice of which parameter is most suitable would depend on other factors. These factors include type and energy of the radiation, geometry of radiation source, and type of shielding (either structural for controlled and uncontrolled areas or for small sized radiation sources [2–4]). For energetic alpha and protons particles, mass stopping powers and range in the material can be used as parameters to classify the relative shielding efficiency [4–7]. Also, for gamma-photon, mass attenuation coefficient, effective atomic number, half-value thickness, and buildup factors are some of the parameters that may be used. While fast neutrons, the macroscopic removal cross section

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