การศึกษาทางทฤษฎีของค่าสัมประสิทธิ์การลดทอนเชิงมวลรวมและย่อยของระบบแก้ว ลูทีเซียม-โซเดียม-บอเรต

Studying Theoretical of Total and Partial Mass Attenuation Coefficients on Lutetium-Sodium-Borate Glass Systems

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บทคัดย่อ

วัตถุประสงค์ของงานวิจัยนี้เพื่อศึกษาสัมประสิทธิ์การลดทอนเชิงมวลรวมและสัมประสิทธ์การลดทอนย่อยแบบต่าง ๆ ของระบบแก้วลูทีเซียม-โซเดียม-บอเรต ที่มีสัดส่วนของลูทีเซียมที่แตกต่างกันตามสูตรเคมี xLu_2O_3:$20Na_2O$:$(80\text{-}x)B_2O_3$ *(เมื่อ x เท่ากับ 5, 10, 15 และ 20 ร้อยละโดยโมล) โดยค่าสัมประสิทธิ์ดังกล่าวสามารถคำนวณได้ด้วยโปรแกรม WinXCom ในช่วงพลังงาน 1 กิโลอิเล็กตรอนโวลต์ ถึง 100 จิกะอิเล็กตรอนโวลต์ ผลจากการศึกษาพบว่าสัมประสิทธิ์การลดทอนเชิงมวลรวมและสัมประสิทธ์การลดทอนย่อยแบบต่างๆ จะมีค่าเพิ่มขึ้นตามปริมาณของลูทีเซียม ซึ่งการแปรค่าของสัมประสิทธิ์ทั้งสองเกิดขึ้นเนื่องอันตรกิริยาหลักที่ทำหน้าที่ลดทอนรังสีแกมมาในช่วงพลังงานที่แตกต่างกัน ได้แก่ ปรากฏการณ์โฟโตอิเล็กตริกสำหรับในช่วงพลังงานต่ำ (1 ถึง 500 กิโลอิเล็กตรอนโวลต์) ปรากฏการณ์กระเจิงแบบคอมพ์ตันสำหรับพลังงานในช่วงกลาง (500 กิโลอิเล็กตรอนโวลต์ ถึง 1 เมกะอิเล็กตรอนโวลต์) และปรากฏการณ์แพร์โปรดักชันในช่วงพลังงานสูง (1 เมกะอิเล็กตรอนโวลต์ ถึง 100 จิกะอิเล็กตรอนโวลต์) ตามลำดับ*

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Abstract

The aim of this research is to study the total and partial mass attenuation coefficients of lutetium sodium borate glasses in composition xLu_2O_3:$20Na_2O$:$(80\text{-}x)B_2O_3$ *at different concentration (x = 5, 10, 15 and 20 mol%). The theoretical calculating was investigated by WinXCom program at energy range for 1 keV to 100 Gev. The result shown that, the total and partial mass attenuation coefficients of glasses were increased with increased lutetium content. The variation in this parameters occurred from the change interaction process at different energy range. These processes are photoelectric absorption, Compton scattering and pair production at low (1–500 keV), medium (500 keV–1 MeV) and high (1 MeV–100 GeV) photon energy, respectively.*

Keywords: glasses, mass attenuation coefficients, lutetium

1. Introduction

Presently, photons and neutrons are two kinds of most frequently interested and always found for studied for the shielding radiation (Shamshad et al., 2017). The parameters in the field of radiation shielding such as mass attenuation coefficient, effective atomic number and electron density are major gamma ray interaction parameters and many researchers were studied and investigated of the different gamma ray shielding parameters of the various glasses (Kumar, 2017). Among of various glasses, borate glasses are popular and great glass forming material (Limkitjaroenporn et al., 2011). Due to, the properties of B_2O_3 such as heat of fusion, smaller cation size and higher bond strength, and it can form glass by itself at lower melting point, thermal stability, good transparency, and high chemical durability (Yasaka et al., 2014).

Lutetium once of rare earth series, has favorable physical properties, such as high melting point, wide band gap, high density and high atomic number (Lojpur et al., 2012) and can be found general in house such as color television, saving energy lamp, fluorescent lamp and glass, and using lutetium were used continuous (Dorabei et al., 2013).

In this context is the theoretical study for total and partial mass attenuation coefficients of glasses with contains Lu_2O_3, Na_2O and B_2O_3 which determined by using WinXCom program for total and partial interactions in the energy range 1 keV to 100 GeV.

2. Theoretical Basis

The total and partial mass attenuation coefficients of glass system have been determine by WinXCom program which developed by L. Gerward. For multi-element material such as chemical compound or homogeneous, the interaction coefficients and the mass attenuation coefficients (μ_m) is given by "mixture rule" (Kaewjaeng et al., 2012: Chanthima & Kaewkhao, 2013)

$$\mu_m = \sum_i w_i (\mu_m)_i \quad (1)$$

where w_i and $(\mu_m)_i$ are weight fraction and mass attenuation coefficients of ith constituent, respectively.

3. Results and Discussion

Fig. 1 shows the results of total mass attenuation coefficients of lutetium sodium borate glasses for all lutetium compositions with the photon energy and Fig. 2 shows only results from the glass doped with 20 mol% of Lu_2O_3 on the variations of the mass attenuation coefficient for total and partial photon interactions. From figure, for different energy ranges, there are three partial interaction processes: photoelectric absorption at low energies (1–500 keV), incoherent (Compton) scattering at intermediate energies (500 keV–1 MeV) and pair production at high energies (1 MeV–100 GeV). At low energies, the curve is not continuous that because of absorption edge of lutetium at M (M_5: 1.588×10^{-3} MeV, M_4: 1.639

$\times 10^{-3}$ MeV, M_3: 2.024 $\times 10^{-3}$ MeV, M_2: 2.263 $\times 10^{-3}$ MeV, M_1: 2.491 $\times 10^{-3}$ MeV), L (L_3: 9.244 $\times 10^{-3}$ MeV, L_2: 1.035 $\times 10^{-2}$ MeV, L_1: 1.087 $\times 10^{-1}$ MeV) and K (6.331 $\times 10^{-2}$ MeV) energy level and absorption edge of sodium K (1.072 $\times 10^{-3}$ MeV) energy level.

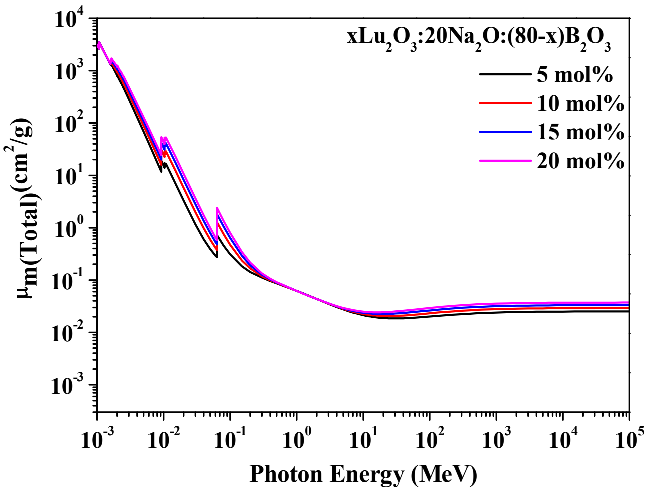

Fig. 1. The variation of mass attenuation coefficient of lutetium sodium borate glasses with photon energy for total interaction (with coherent).

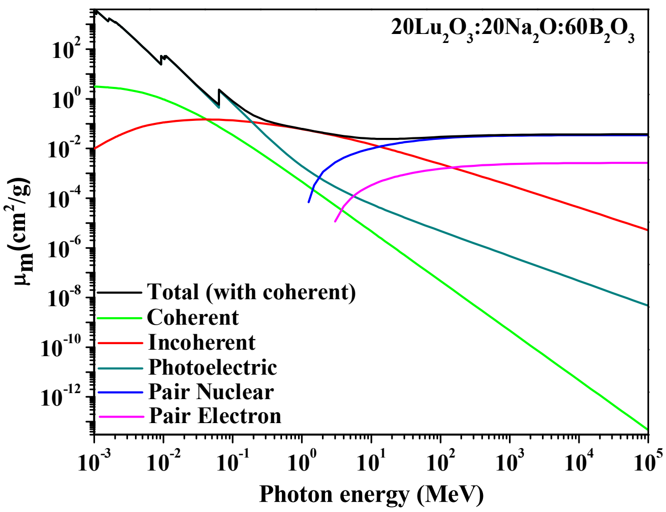

Fig. 2. The variation of mass attenuation coefficient of $20Lu_2O_3$:$20Na_2O$:$60B_2O_3$ glass with photon energy for total and partial photon interactions (with coherent).

From Fig. 3 (a) – (b), for energies more than 10 keV, mass attenuation coefficients for coherent scattering and incoherent (Compton) scattering were decreased sharply that because of both are inverse variation with photon energies. The change of mass attenuation coefficient for Compton scattering occurs the composite of chemical but it same the mass attenuation coefficient for coherent scattering.

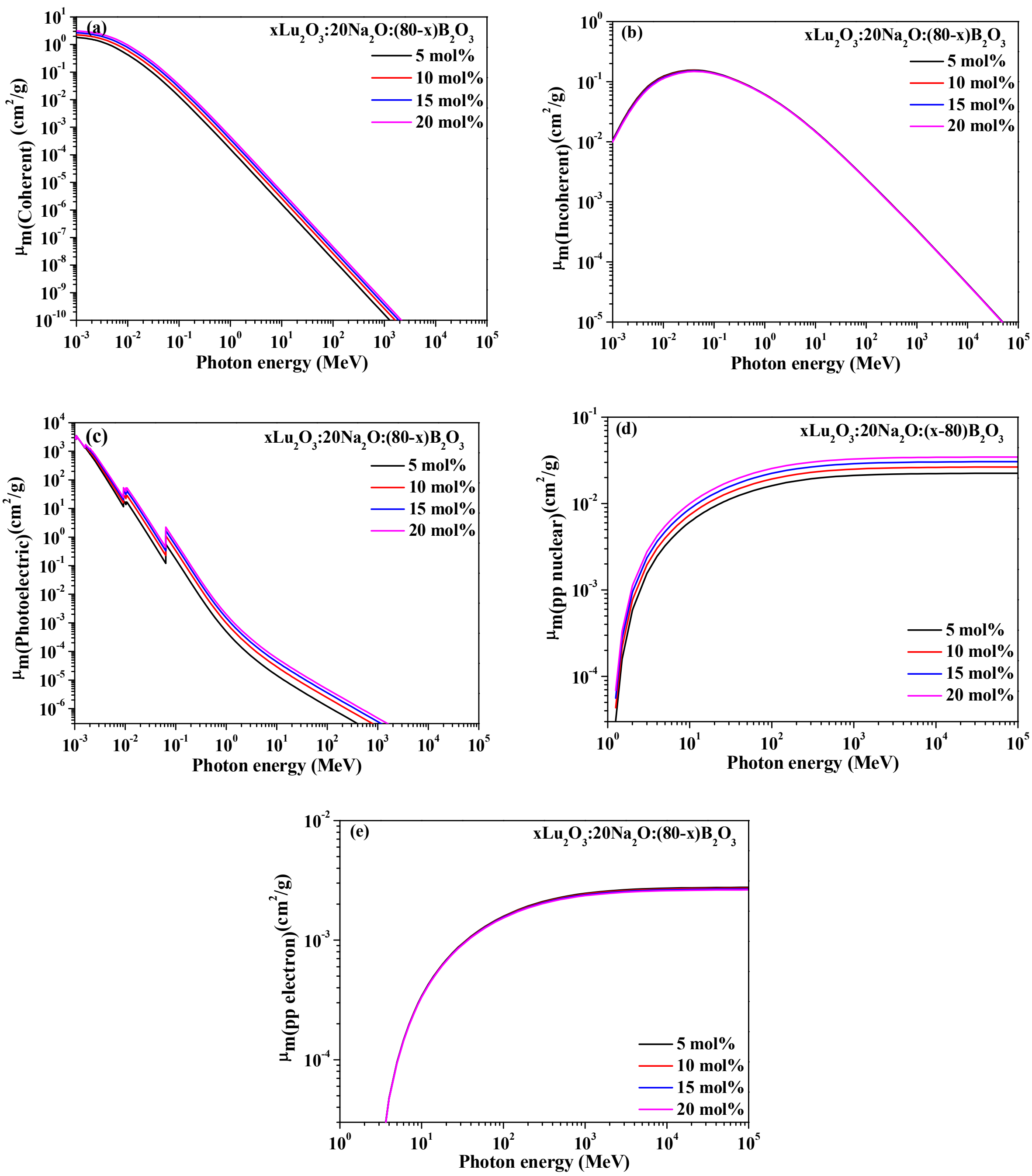

Fig. 3. The variation of mass attenuation coefficient of lutetium sodium borate glasses with photon energy for partial interaction (a) coherent scattering (b) incoherent scattering (c) photoelectric absorption (d) pair production in nuclear field and (e) pair production in electric field.

Fig. 3 (c), mass attenuation coefficient for photoelectric absorption was decreased rapid with increased photon energies that may be because of occurred from the change in cross section of photoelectric by inversely proportional of photon energies $E^{3.5}$. The chemical compositions of oxide glass are important due to mass attenuation coefficient for photoelectric absorption dependence on atomic number of material by interaction is Z^{4-5} (Chanthima & Kaewkhao, 2013: Oto et al., 2015).

Fig. 3 (d) – (e) shown mass attenuation coefficient for pair production in nuclear field and pair production in electric field. The mass attenuation coefficient was increased to 400 MeV and therefore it nearly constant that because of the mass attenuation coefficient for pair production was direct variation with log E. The pair production in nuclear field was dependence on Z^2 as pair production in electric field nearly linear constant.

4. Conclusion

The studying mass attenuation coefficient of lutetium sodium borate glasses system with photon energy for total and partial photon interactions (with coherent) were investigated at photon energies from 1 kev to 100 GeV. The results show that these parameters were increased with increased lutetium content. For different energy ranges, at low energies, photoelectric absorption is dominant interaction process, at intermediate energies incoherent (Compton) scattering is predominant interaction process and pair production becomes dominant for high energies.

5. Acknowledgement

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