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EFFECT OF ATOMIC NUMBER AND MASS ATTENUATION COEFFICIENT IN Ni-Mn FERRITE SYSTEM

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Abstract

The investigation of composite materials' total photon interaction cross-section For the purpose of studying the total photon interaction cross-section, Ni0.5Mn1.5Cd0.2Fe2O4 spinel ferrite was manufactured using a normal ceramic procedure and analyzed using the X-ray diffraction method. The XRD pattern indicates that the prepared sample has a single-phase cubic spinel structure. The linear attenuation coefficient (μ), mass absorption coefficient (μ/ρ), total photon interaction cross-section (total electronic cross-section (-electronic), and effective atomic number for produced spinel ferrite composite materials were determined utilizing a fully collimated geometry setup. The measurements of the attenuation coefficient were made with a radioactive gamma scintillation detector using pure NaI. There is good agreement between the theoretically predicted mass attenuation coefficient value and the empirically measured value.

Key words: total photon interaction, MAC, and LAC.

Introduction

The study of photon interaction with diverse composite materials has become a subject of utmost relevance for radiation physicists due to the ever-increasing use of gamma rays in numerous industries such as industry, medicine, and agriculture. The effective atomic number, total photon interaction cross-section, mass attenuation coefficient, and total electronic cross-section are a few metrics of do symmetric importance. The fundamental understanding of photon interaction with composite materials is aided by these factors.[1,2]

The attenuation coefficient of the gamma ray for various elements and photon energy has been extensively studied.[4-6] A mixed rule for the photon attenuation coefficient has recently been employed by numerous researchers[7,10,11] using a variety of composite materials, including Bakelite, cement, high T_c superconductors, and biologically significant materials. There are studies in the literature that demonstrate there are reports in the literature, which show effects of gamma rays on physical properties of spinel ferrite.[12] Because they have the dual properties of being an electric insulator and a magnetic conductor, ferrites, a class of semiconducting

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materials, are extremely important in technology. They can be employed in radar-absorbing coatings, high-frequency transformers, field sensors, memory cores, and recording systems for field sensors.[13] Due to its low coercive field, high resistivity, and affordable manufacture, spinel ferrite is well suited for usage as a soft magnetic material in this context. To our knowledge, there are no reports in the literature on the measurement of mass attenuation coefficient in ferrite composite. Extensive work has been done on pure and mixed ferrite in order to study the electrical, magnetic, and micro structural properties and tailor them for suitable application.[14,15] The knowledge of photon interaction cross-section provides an important parameter for characterizing the penetration and diffusion of photon in multi-element materials. The data on attenuation coefficient is useful in various fields such as nuclear science, technology, and medical applications. Apart from this, the need of shields to protect against harmful radiation has led to the studies on attenuation coefficient measurement in different multi-element composite materials.[10,11,13]

Keeping this point in view attempt has been made to measure the linear attenuation coefficient, mass attenuation coefficient, total interaction cross-section and total electronic cross-section of spinel ferrite composite sample having chemical formula $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ of different thickness. The measurements of photon attenuation coefficient were taken. Under well collimated narrow beam geometry, which is well aligned by LASER beam. The present paper reports on attenuation of gamma rays and related parameters of $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ spinel ferrite composite materials

Experimental Part

The sample of $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ spinel ferrite composite system was prepared by standard ceramic technique, using AR grade (99.9%) oxide of corresponding metals (like NiO, MnO, CdO and Fe_2O_3). The constituent oxides of respective ferrite were weighted and mixed thoroughly. The mixture was well grounded for 5 hours using agate mortar and pestle, then homogeneous mixture was pressed into a circular pellet of 10 mm diameter and about 2 mm thickness using hydraulic press. The pelletized sample was sintered at 950 ^{0}C for 10 hours and slowly cooled to room temperature at the rate of 2 ^{0}C perminute. The pre sintered sample again crushed and reground to improve homogeneity for 5 hours. The dried mixture is compressed in circular pellet form by using (PVA) as a binder; the pellet was sintered at 1200^{0}C for 21 hours and cooled to room temperature. The final product obtained in the form pellet is hard, flat and crack free. The bulk density of prepared spinel ferrite composite is obtained by using mass volume relation is 3.5 $gm.cm^{-3}$ and the molecular weight of prepared sample is 231.21. The sample in the form of right circular pellet of uniform thickness is approximately 0.30 cm to 3.00 cm were used to find the linear attenuation and related parameter for various gamma ray energies under a well collimated narrow beam geometry using NaI detector with scintillation counter.

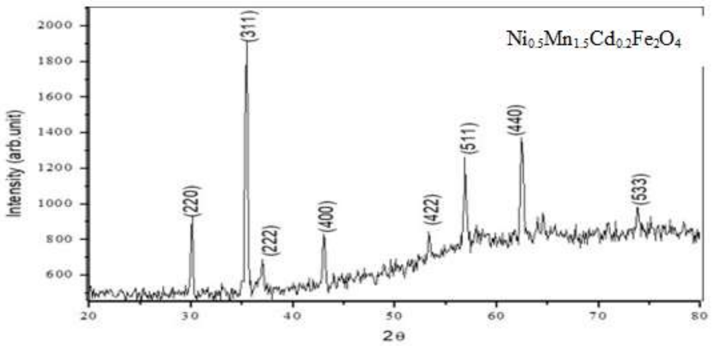

Fig. 1: X-ray diffraction patterns of spinel ferrite composite Ni0.5Mn1.5Cd0.2Fe2O4.

Results and discussion

X-ray diffraction

The single-phase cubic spinel structure of the spinel ferrite composite with the chemical formula $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ has been confirmed by the powder X-ray diffraction technique (XRD)at room temperature. The X-ray diffraction (XRD) pattern of sample were obtained using Philips X-ray diffraction (Model PW3710) using Cu-kα radiation (λ= 1.5405A^0). The XRD pattern was recorded in the 2θ range of 20^0 to 80^0 with a scanning rate 1^0 per minute. All the peaks in therecorded X-ray diffraction pattern are sharp intensive and diffraction patterns reflect clears picture of planes belonging to cubic spinel structure. Linear attenuation coefficient studied by the prepared $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ spinel ferrite composite sample in the form of circular pellets of uniform thickness has been used as an absorber. The thickness of the absorber was varied by staging.

the absorber. The linear attenuation coefficient (μ) for $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ for various energies 0.356 MeV to 1.54 MeV were calculated. The linear attenuation coefficient values were obtained from the slope of *ln (Io/I)* versus t and the measured value of linear attenuation coefficient (μ) are shown in table1. Similar resultswere reported in the literature.[17]

Table 1: Experimentally measured values of linear attenuation coefficient (μ), mass attenuation coefficient (μ/ρ), total photon interaction cross-section (σtotal), total electronic cross-section (σele) andeffective atomic number (Zeff) for collimated photon beam of 0.3cm diameter in the energy range (0.360 MeV-1.33 MeV) for $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ ferrite composite.

Energy (MeV)	μ (cm^{-1})	μ/ρ (cm^2/gm)		Percent.	σtotal (barn/atom)	σele	Zeff
		Theo.	Expt.	Devi.			
0.356	3.912	0.7164	0.791	±1.2	38.54	2.443	16.17
0.654	2.548	0.6125	0.621	±0.3	34.61	2.071	16.17
0.694	2.014	0.5147	0.451	±0.5	30.68	1.745	16.17
1.15	1.514	0.4169	0.281	±0.7	24.54	1.435	16.17
1.28	1.014	0.3191	0.111	±0.5	18.4	1.346	16.17
1.41	0.514	0.2213	0.111	±0.08	16.4	1.285	16.17
1.54	0.014	0.1235	0.111	±0.11	18.12	1.224	16.17

Mass attenuation coefficient

The mass attenuation coefficient was obtained by measuring the sample density using mass- volume relation. The calculated values of *(μ/ρ)* from the above relation are listed in table 1. Similar observations of mass attenuation coefficient are reported in the literature.[18] The plots of photon energy versus mass attenuation coefficient are in exponential nature which is shown in Fig.3.

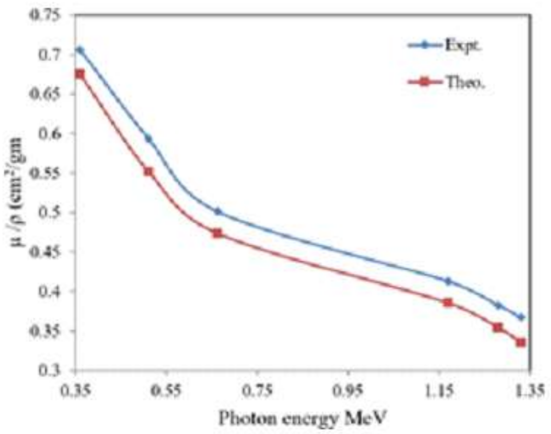

Fig. 2: Plots of photon energy versus mass attenuation coefficient of spinel ferrite composite Ni0.5Mn1.5Cd0.2Fe2O4

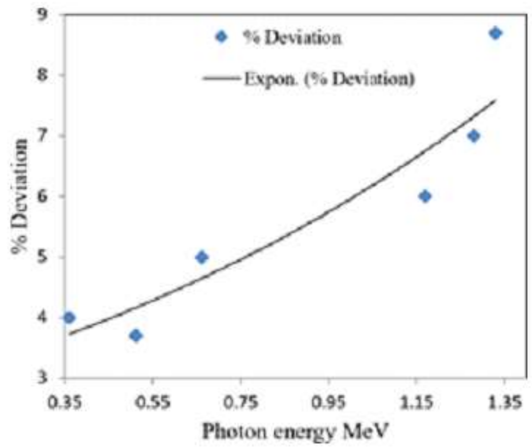

Fig.3: Plots of photon energy versus % deviation of theoretical and experimental valuesof mass attenuation coefficient of spinel ferrite composite Ni0.5Mn1.5Cd0.2Fe2O4

From Fig. 2, it is clear that the theoretical and experimental values are fairly agreed to each other. The percentage deviation of theoretical and experimental values is shown in Fig. 3.

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Total photon interaction cross-section

The values of mass attenuation coefficient were used to calculate the total photon interaction cross-section *(σtot)* for the prepared $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ composite material. The values of total photon interaction cross-section for $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ composite spinel ferrite are given in table A. From table A it is clear that as energy of gamma ray increases, the total photon interaction cross-section decreases with materials.

Total electronic cross-section

The total electronic cross-section for $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ composite spinel ferrite was calculated by using the following relation.[14,19] The values of atomic mass of $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ composite spinel ferrite were used to calculate the total electronic cross-section (σele) and are listed in table1.

Effective atomic number

The effective atomic number parameter has a physical meaning and allows many characteristics of material to be visualized with a number. Several attempts have been made to determine the effective atomic number (*Zeff)* for partial and total gamma ray interaction in composite material.[20-23] In account to make use of fact that, scattering and attenuation of gamma radiation are related to the density and effective atomic number of the material. The total atomic cross-section and electronic cross-section are related to the effective atomic number *Zeff* of the compound through relation reported in the literature.[24,26] Using the values of *σtot* and /, the values of effective atomic number were calculated for various energy of $Ni_{0.5}Mn_{1.5}Cd_{0.2}Fe_2O_4$ spinel ferrite composite which is listed in table1. It is observed that *Zeff* remains almost, perhaps in lower energy region we may obtain variation in *Zeff* values. The variation of *Zeff* depends on the composition of composite and their properties, and range of atomic number of the elements from which the compound is composed. From Fig. 4. It is observed that *Zeff* is directly proportional to the atomic number of the elements.

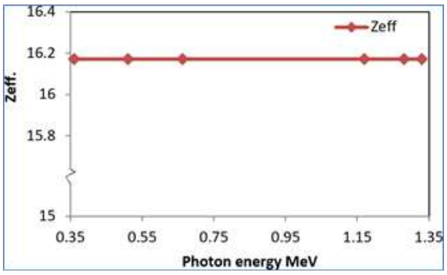

Fig. 4 Graph of Energy Vs Zeff.

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Conclusions

The spinel ferrite composite, which is very important to this research project, was gradually created using a conventional ceramic process. X-ray diffraction was used to confirm that the Ni0.5Mn1.5Cd0.2Fe2O4 composite had formed in a single phase. This Ni0.5Mn1.5Cd0.2Fe2O4 spinel ferrite composite mass attenuation coefficient and related parameter data should be useful for dosimetry, appropriate shielding, material density determination, and technical applications. As photon energy increases, the linear attenuation coefficient, mass attenuation coefficient, and total photon interaction cross-section all fall exponentially.

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