Calculation Of Mass Attinuation Cofficients Of (SiO_2)

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Abstract
In this paper, the mass attenuation coefficient (μ/ ρ) of the compound (SiO_2) has been calculated by using a theoretical method depends on deferential cross section, for following interactions (photoelectric, Rayleigh and Compton scattering which taken from tables.
The energy band ranged from (1keV – 1 MeV). The graph mass attenuation coefficient verses the energy shows that the miximum mass attenuation coefficients appear at the energy value (1 keV).

I- Introduction
The attenuation coefficient is an important parameter which is widely used in industry agriculture, science, and technology, etc. The properties characterizing the penetration and diffusion of X-rays in composite materials such as (SiO2) are very important. (SiO2) has chemical properties as shown here: Density 2.65 (g/cm3), Melting point 1830 (°C), Thermal conductivity 1.3 (Wm-1 K), Resistivity 1012-1016 (Wm), Permittivity 3.8-5.4 (e'), Dielectric field strength 15.0-25.0 (kV/mm), Modulus of elasticity 70 (GPa).
The X-ray intensity transmitted through a dense material is given by:[1]

$$I=I_0 \exp(-\mu x) \quad \ldots\ldots\ldots\ldots (1)$$

where I is the transmitted X-ray intensity, I_0 is the incident X-ray intensity, I_0 is the linear attenuation coefficient (in cm^{-1}) and x is the thickness of the material (in *cm*). This equation shows that the X-ray intensity depends on the density of the material (the linear attenuation coefficient μ increases with density) and the thickness of the material.
The range of energy (1KeV-1MeV) responsible about three kinds of interaction (Rayleigh, photoelectric, Compton) and we will discuss it here [2].

II-Photoelectric Interactions
The photoelectric effect or photo-ionization, is a process in which an x-ray photon impinging on an atom transfers its entire energy to an inner shell (e.g. K shell) electron of the atom. The electron (named photoelectron) is ejected/excited/ionized from the atom. The kinetic energy of the ejected photoelectron is equal to the incident x-ray photon energy minus the binding energy of the electron. The vacancy resulting from the ejection is filled by an electron from an outer orbit (e.g. L shell) with lower binding energy, leaving a vacancy in this outer orbit, which in turn is filled by another electron from an orbit even further away (e.g. M shell) from the nucleus. The surplus energy liberated when an electron drops from its outer shell to a shell closer to the nucleus results in emission of characteristic radiation (e.g. K□ line). The energy of the characteristic radiation is equal to the difference in binding energies between shells. Figure 1 (a) depicts a simplified atomic structure with ejected electron under x-ray excitation.
The corresponding energy level diagram of an atom is shown in Figure 1 (b), illustrated the excitation of K, L, M and N shells and the formation of Kα ,Kβ, Lα and Mα emissions.[3]

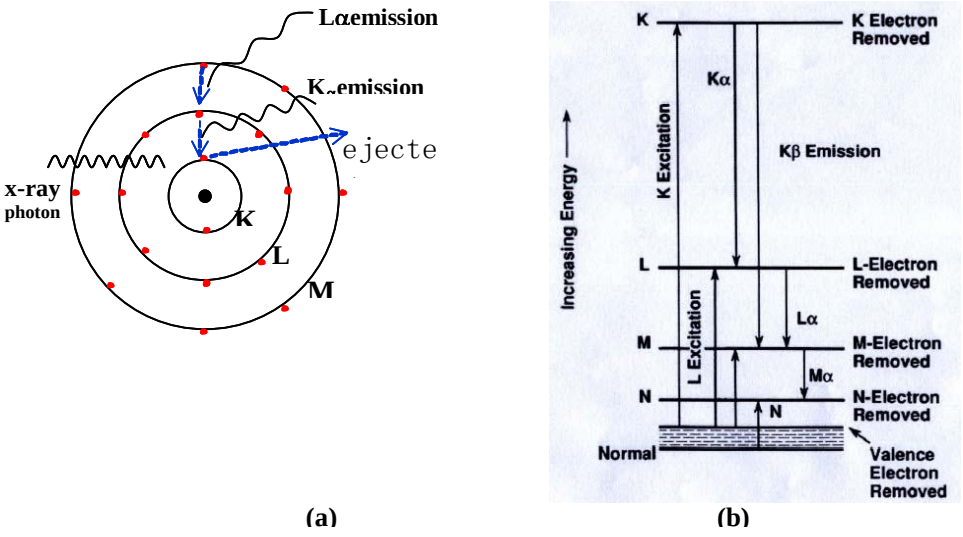

Figure 1 - (a) Atomic shell structure with ejection of inner shell electron under x-ray radiation. (b) The energy level diagram of an atom, illustrating the excitation of K, L, M and N shells and the formation of Kα , Kβ , Lα and Mα radiations.

The binding energy of a K-electron increases with increasing atomic number. It is only -13.6 eV in the lightest element hydrogen, but increases to 88 keV in lead. The probability of photoelectric absorption per unit mass of a material is approximately proportional to Z^3/E^3, where Z is the atomic number of the material and E is the energy of the incident photon.

Photoelectric absorption therefore increases with increasing atomic number and decreasing x-ray photon energy.

The chance of photoelectric interaction falls steeply and continuously with increasing photon energy, but at absorption edges (K edge, L edge, etc.) it suddenly increases due to photoelectric absorption of the photons.

III-Coherent scattering

The Rayleigh scattering, is an elastic process where a photon impinging on an atom is scattered without loosing its energy. The energy of x-ray photon is firstly completely absorbed and then re-emitted by electrons of an atom. The scattered photon has the same phase as the incident photon ($\lambda_{in} = \lambda_{out}$), however the direction of re-emission is totally arbitrary. The probability of this process increases with decreasing energy of the photons and increasing atomic number of the scattering atom. [4]

IV-Compton scattering

The incoherent scattering, can be considered as a collision between x-ray photon and one of the outer shell electrons of an atom. The outer shell electron is bound with very little energy to the atom and is easy to be ionized. The kinetic energy to help electron's ejection from the atom is transferred from the incident photon, leaving the scattered x-ray with less photon energy ($E_{out} < E_{in}$) and longer wavelength ($\lambda_{out} > \lambda_{in}$). The probability of this process falls gradually with energy of the photons and independent of atomic number of material.

Because energy and momentum are both conserved in this collision, the energy and direction of the scattered x-ray photon depend on the energy transferred to the electron. When the incident x-ray energy is high, the relative amount of energy lost to the electron is small, and the scattering angle is small relative to the initial direction. When the incident x-ray energy is small, the scattering is more isotropic in all directions. At x-ray energies on the order of 1 MeV, the scattering is mostly in the forward direction. At x-ray energies of near 0.1 MeV, the scattering is more isotropic.[5]

V-Theoretical calculation

The linear attenuation coefficient reflects the removal of X-ray photons from a beam by interaction with electrons of the material probed. The higher the electron density, the more interaction of X-ray photons with the sample material occurs. These interactions can be absorption of the photons (removal from the beam) or scattering (change of direction with reduction in energy). Therefore appropriate to scale the linear attenuation coefficient with the sample density. The linear attenuation coefficient can be rewritten as: [6]

$$\mu = \left(\frac{\mu}{\rho}\right)\rho \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where μ/ρ is the mass attenuation coefficient (cm^2/g) and ρ is the density (g/cm^3). The mass attenuation coefficient is approximately constant for different materials in a specified energy range, and therefore the linear attenuation coefficient is strongly determined by the density.

The linear attenuation coefficient is also strongly energy dependent. In general, lower energetic X-ray photons have a higher interaction probability. Since an X-ray device produces photons in a wide energy range, the transmission should actually be considered for the whole energy range.

For composite materials, the intensity is given by adding the individual contributions of each chemical element:

$I = I_o \exp(-\sum \mu_1 x_1)$ …… (3)

which can be rewritten as:

$$I = I_o \exp\left(-\sum\left(\frac{\mu}{\rho}\right)\rho_1 x_1 \ldots\right) \quad (4)$$

When the composite material is a homogeneous mixture of several elements, the sample is characterized by a single thickness. The linear attenuation coefficient can then be written as:

$$\mu_{mix} = \sum\left(\frac{\mu}{\rho}\right)\rho_1 \quad \ldots\ldots (5)$$

If the thickness of sample is known,it allows us to evaluate the density distribution of sample under study.

The μ/ρ provided in NIST database rely heavily on theoretical values of the total attenuation cross section per atom, σ_{tot}, which is related to μ/ρ according to

$\mu/\rho = \sigma_{tot} / u \cdot A$ ….. (6)

where u is the atomic mass unit ($u = 1.66\times10^{-24}$ g) and A is the atomic mass of the target element. σ_{tot} is the total cross section for an interaction by the photon, frequently given in units of b/atom (barns/atom), where $b = 10^{-24}$ cm^2.

The attenuation coefficient, photon interaction cross section and related quantities are functions of the photon energy. Explicit indication of this functional dependence has been omitted to improve readability. The total cross section can be written as the sum over contributions from the principal photon interactions [7] :

$\mu/\rho = (\sigma_{pe} + \sigma_{coh} + \sigma_{comp}) / u \cdot A$ … (7)

where σ_{pe} is the photoelectric absorption cross section which taken from Scofield 1973[8], σ_{coh} was from Hubbell and Overbo 1979[9] and σ_{comp} was from Hubbell et al.[10].

VI-Results and discussion

By using equation (7) we can calculate the mass attenuation coefficients of each element (Si) and (O_2) separated by using the cross sections of each interaction (Rayleigh, photoelectric ,Compton) which depends on the incident photon energy. Then we substituting these values in equation (6) which represented the total mass attenuation of (Si) and (O_2) separated. Then we have used the fraction by weight of each (Si) and (O_2) in the compound (Sio_2) which is 53% and 47% for (Si) and (O_2) respectively.

Equation (5) which represented the final formula calculated the total mass attenuation coefficients by using (ρ =2.65 gm/cm^3).

In this research we have used the range energies (1k eV – 1 M eV) and we plotted the results in figure.2 which shows $\frac{\mu}{\rho}$ have a maximum value at 1.8 k eV.

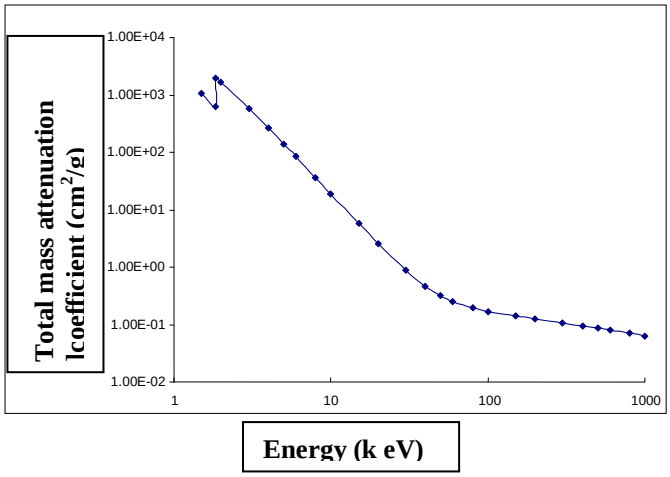

Fig.2 total mass attenuation coefficient(with coherent) verses energy.

Figure (2) shows total mass attenuation coefficient have a maximum value in the range about 1KeV then the values will decrease until it have a minimum values in the range of high energies . we can note a peak of attenuation in the range of energy about 5 KeV which is caused by the line Kα.

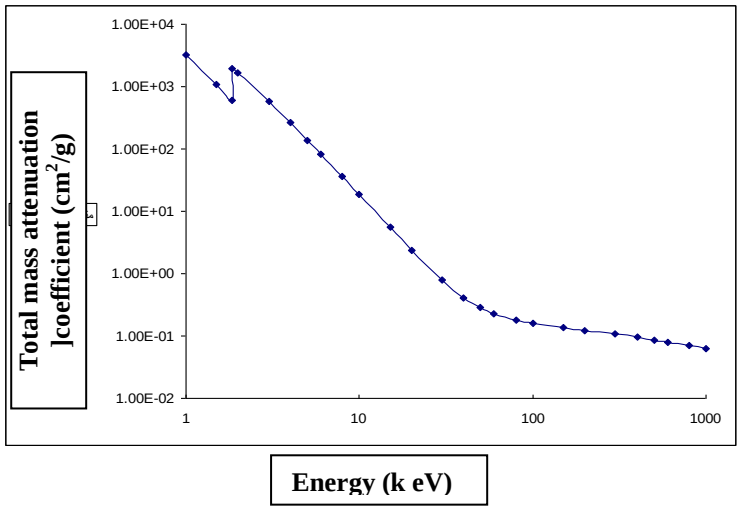

Fig.3: Total mass attenuation coefficient(without coherent) verses energy

Fig.3: which represents the values of attenuation (without coherent) shows the same of the above figure because the coherent attenuations have a very small values (inelastic interaction) which is contribute with small values because the photons didn't lose energy .

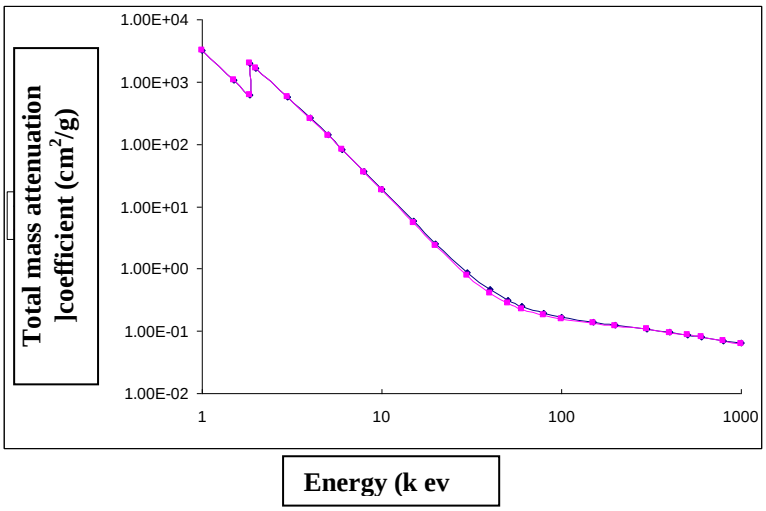

Figure 4: The different in the values between the total mass attenuation coefficient(without coherent) and (with coherent) verses energy which shows a the same behavior .

References:

[1] D. V. Raji & L,M. Chaudhari. Bulg. J . Phys. 37, 158-164 (2010).

[2] Arthur .Beiser. "Concepts of modern physics" Ed.6th . McGraw-H (2003).

[3]1. J. Wang and T. Blackburn. "**X-ray image intensifiers for fluoroscopy**". Radio Graphics, vol 20, p1471 (2000).

[4] Heyward, R.W. "**nuclear electromagnetic radiations**" chapter 9-6 in hand book of physics, in condon, E. U. and Odishaw. H., Eds., McGraw- Hill, New York (1958).

[5] Evans, R.D., " **Compton Effict**", encyclopedia of Physics, vol. XXX Id, Part II, springer- verlag, (1958).

[6] Wilams, B., Ed55., "**Compton scattering**", McGraw-H (1977).

[7] N.J. Caron. " **An introduction to the Passage of Energetic Particles through Metal**", Crc Press, Taylor and Frances group. (2007).

[8] Scofield, J. H. "**Theoretical photoionization cross sections from 1-1500 keV, Lawrence live more laboratory report Usel-51326**"(1973).

[9] Hubbell, J.H. and Overbo, I. "**Relativistic Atomic Form Factors and Photon Coherent Scattering Cross Sections**", J. Phy. Chm. Ref. Data 8, 96-105 (1969).

[10] Hubbell, J.H., Veigele, Wm. J., Briggs, E.A., Brown, R.T. Cromer, D.T. and Howerton, R.J., "Atomic form factors, Incoherent scattering function, and photon scattering cross section, J.phy. Chem. Ref. Data4, 471-538 (1975); erratum in 6, 615-616 (1977).

حساب معامل التوهين الكتلي لمركب (SiO_2)

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الملخص

تم في هذا البحث حساب معاملات التوهين الكتلي لمركب **(Sio_2)** باستخدام نموذج نظري معتمدين فيه على مساحة المقطع العرضي للتفاعلات **(**الظاهرة الكهروضوئية، واستطارة رايلي وظاهرة كومبتون والمأخوذة قيمها من الجداول.

وكان مدى الطاقة المستخدم من **(**1keV – 1 MeV**)** ورسمت القيم بين معاملات التوهين الكتلي والطاقة والتي اظهرت ان اعلى قيمة لمعامل التوهين الكتلي تقابل الطاقة (1keV).