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Silicon Photon Absorber (Photon Cross Section)

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Abstract- Our research is focused on theoretical study used to make silicon photon absorption (Si photon) cross section simulation study. This study is an attempt to demonstrate and explore the fundamentals of semiconductor photon absorption. Silicon photon plays a main role in our daily life. Photons are essential in some aspects of optical communication, especially for quantum cryptography and the applications of photons in the field of quantum optics, quantum computer, and the quantum entanglement of photons. The semiconductor materials are either elementary such as silicon. Silicon is the most used semiconductor for discrete devices and integrated circuits. Within the scope of this research we will see how and why silicon became the king of the semiconductors.

This paper includes a selective theory relating to photon cross section and is intended to provide a basis for further calculations and critical tabulations of photon cross section data. In this study we choose the silicon element to study the scattering coherent, scattering incoherent, photon electric absorption, total attenuation with coherent, total attenuation without coherent, mass energy absorption are also discussed.

Keywords- *Scattering, Coherent, Incoherent, Photon electric absorption, Total attenuation with coherent, Total attenuation without coherent, Mass energy absorption*

I. Introduction

In physics, absorption of electromagnetic radiation is the way in which the energy of a photon is taken up by matter, typically the electrons of an atom. Thus, the electromagnetic energy is transformed into internal energy of the absorber, for example thermal energy. The reduction in intensity of a light wave propagating through a medium by absorption of a part of its photons is often called attenuation. Usually, the absorption of waves does not depend on their intensity (linear absorption), although in certain conditions (usually, in optics), the medium changes its transparency dependently on the intensity of waves going through, and saturable absorption (or nonlinear absorption) occurs [1].

The cross section is an effective area that quantifies the intrinsic likelihood of a scattering event when an incident beam strikes a target object, made of discrete particles. In a completely classical setting, where a particle is nothing more than a hard object, the cross section is the area of the conventional geometric cross section, and expresses the probability of hitting the object with a ray. It is typically denoted σ and measured in units of area.

In scattering experiments, one is often interested in knowing how likely a given event is to occur. However, the rate depends strongly on experimental variables such as the density of the target material, the intensity of the beam, or the area of overlap between the beam and the target material. To control for these mundane differences, one can factor out these variables, resulting in an area-like quantity known as the cross section [2].

II. TOTAL CROSS SECTION

Cross section is associated with a particular event (e.g. elastic collision, a specific chemical reaction, a specific nuclear reaction) involving a certain combination of beam (e.g. light, elementary particles, nuclei) and target material (e.g. colloids, gases, atoms, nuclei). Often there are additional factors that can affect the cross section in complicated ways, such as the energy of the beam. For a given event, the cross section σ is given by [1]:

$$\sigma = \frac{\mu}{n} \tag{1}$$

where, σ is the cross section of this event (SI units: m^2), μ is the attenuation coefficient due to the occurrence of this event (SI units: m^{-1}), and n is the number density of the target particles (SI units: m^{-3}).

Equivalently, if the target material is a thin slab placed perpendicular to the beam, one may express the cross section in terms of flux:

$$\sigma = \frac{1}{n\Phi}\left(-\frac{d\Phi}{dz}\right) \tag{2}$$

Where, - $d\Phi$ is the amount of flux lost due to the occurrence of this event, dz is the thickness of the target material, and Φ is the flux of the incident beam.

For a target of finite area, the cross section is given by:

$$\sigma = \frac{1}{n\mathrm{IA}}\frac{d\mathrm{W}}{dz} \tag{3}$$

Where, $d\mathrm{W}/\mathrm{d}z$ is the rate at which the event occurs per distance traversed (SI units: $m^{-1}\ s^{-1}$), I is the particle flux (or intensity) of the incident beam (SI units: $m^{-2}\ s^{-1}$), and A is the area of overlap between the beam and the target (SI units: m^2) [2-8].

Schematically, an event is said to have a cross section of σ if its rate is equal to that of collisions in an idealized classical experiment where:

1. The beam is replaced by a stream of inert point-like particles.
2. The target particles are replaced by inert and impenetrable disks of area σ (and hence the name "cross section"), with all other experimental variables kept the same as the original experiment.

III. ATTENUATION

If a beam enters a thin layer of material of thickness dz, the flux of the beam Φ will decrease according to:

$$\frac{d\Phi}{dz} = -n\sigma\Phi \quad (4)$$

Where, σ is the total cross section of all events, including scattering, or to absorption, or transformation to another species. Solving this equation leads to the exponentially decaying behavior:

$$\Phi = \Phi_0 e^{-n\sigma z} \quad (5)$$

Where, Φ_0 is the initial flux. For light, this is called the Beer–Lambert law. This basic concept can then extended to the cases where the interaction probability in the targeted area assumes intermediate values, because the target itself is not homogeneous, or because the interaction is mediated by a non-uniform field [1,9-11].

IV. SCATTERING

For light, as in other settings, the scattering cross section is generally different from the geometrical cross section of a particle, and it depends upon the wavelength of light and the permittivity, shape and size of the particle. The total amount of scattering in a sparse medium is proportional to the product of the scattering cross section and the number of particles present.

In terms of area, the total cross section (σ) is the sum of the cross sections due to absorption, scattering and luminescence:

$$\sigma = \sigma_a + \sigma_s + \sigma_l \quad (6)$$

The total cross section is related to the absorbance of the light intensity through the Beer–Lambert law, which says absorbance is proportional to concentration:

$$A_\lambda = C\ell\sigma \quad (7)$$

Where, A_λ is the absorbance at a given wavelength λ, C is the concentration as a number density, and ℓ is the path length. The absorbance of the radiation is the logarithm (decadic or, more usually, natural) of the reciprocal of the transmittance [12, 13]:

$$A_\lambda = -log \quad (8)$$

V. SIMULATION RESULTS AND DISCUSSION

In this section, we study the results of:

1. Scattering – Coherent.
2. Scattering – Incoherent.
3. Photon Electric Absorption.
4. Total Attenuation with Coherent.
5. Total Attenuation without Coherent.
6. Mass Energy Absorption.

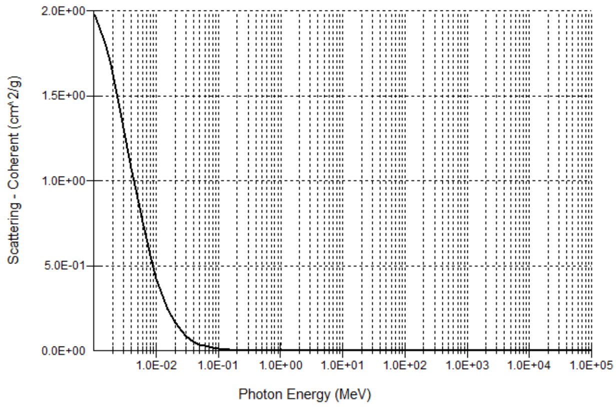

Figure 1. The exponential relationship between scattering – coherent and photon energy.

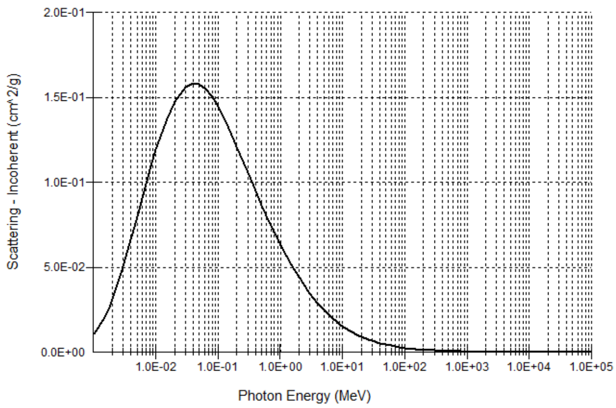

Figure 2. The Gaussian relationship between scattering – incoherent and photon energy.

Figure 1 and Figure 2 shows the exponential and Gaussian relationship between photon energy and scattering-coherent and scattering-incoherent respectively. Coherent scattering (also known as unmodified, classical or elastic scattering) is one of three forms of photon interaction which occurs when the energy of the X-ray or gamma photon is small in relation to the ionization energy of the atom. It therefore occurs with low energy radiation.

Upon interacting with the attenuating medium, the photon does not have enough energy to liberate the electron from its bound state (i.e. the photon energy is well below the binding energy of the electron) so no energy transfer occurs. The only change is a change of direction (scatter) of the photon, hence 'unmodified' scatter. Coherent scattering is not a major interaction process encountered in radiography at the energies normally used. Coherent scattering varies with the atomic number of absorber (Z) and incident photon energy (E) by Z^2 / E. Coherent scattering is important for low kilo voltage photons, and increases with increasing atomic number.

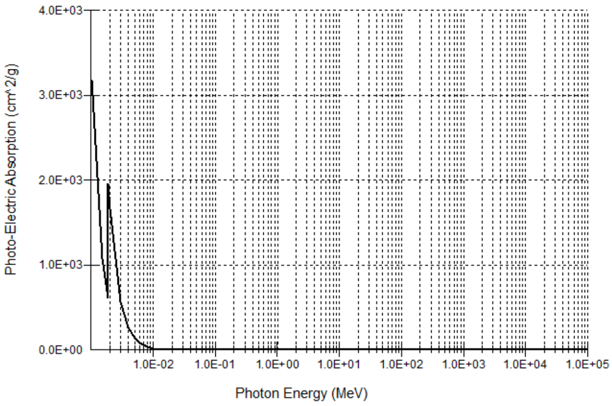

Figure 3. Photon electric absorption of Si versus photon energy

In the atomic photo effect, a photon disappears and an electron is ejected from an atom. The electron carries away all of the energy of the absorbed photon, minus the energy binding the electron to the atom. The K-shell electrons are the most tightly bound, and are the most important contributions to the atomic photo effect cross-section in most cases. However, if the photon energy drops below the binding energy of a given shell, an electron from that shell cannot be ejected. Hence, particularly for medium- and high-Z elements, a plot of photon electric absorption versus the photon energy exhibits the characteristic saw tooth absorption edges, since the binding energy of each electron subshell is attained and this process is permitted to occur. These feature can be seen well in Figure 3, above which shows the relationship between the photon electric absorption and the photon energy.

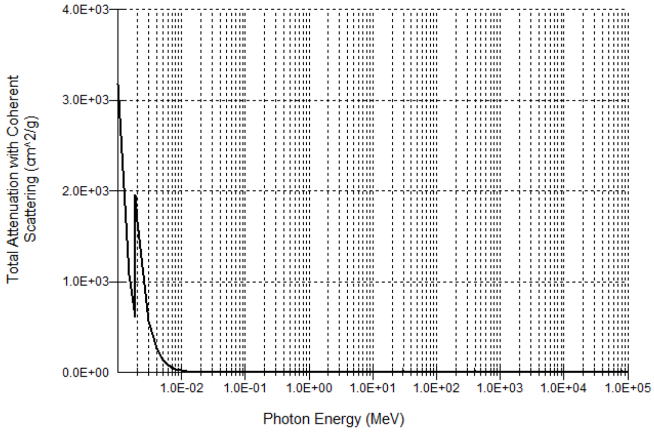

Figure 4. Relationship between total attenuation with coherent and photon energy

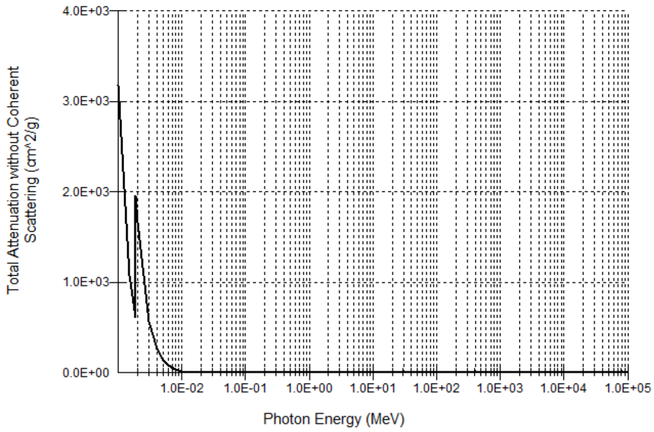

Figure 5. Relationship between total attenuation without coherent and photon energy

Figure 4 and Figure 5 show the relationship between photon energy and the total attenuation with and without coherent respectively. Attenuation is the progressive loss of energy by a beam as it traverses matter. A photon beam may be attenuated by any of the processes described in the previous section. There are some more useful concepts when considering the attenuation of photon beams.

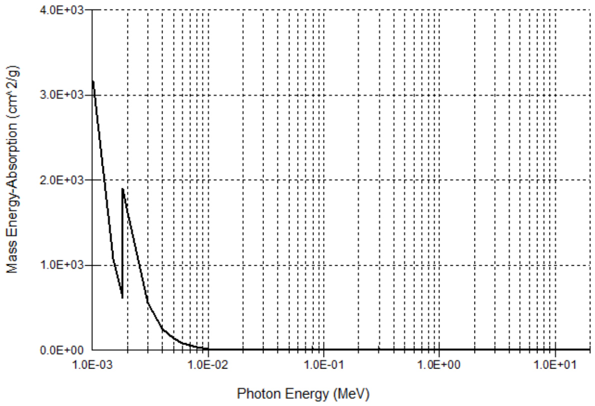

Figure 6. Relationship between mass energy absorption and photon energy.

Figure 6 show the relationship between mass energy absorption and photon energy. The mass incoherent scattering attenuation coefficient is similar for most values of Z, but decreases slowly with increasing beam energy. It is most dependent on the electron density.

VI. CONCLUSIONS

1. The cross section was decreases with increasing the silicon energy and the values compatible in the theoretical calculations.
2. Changing the attenuation values, means change all of the thickness and the photon energy, where the linear and mass attenuation commensurate with the increase in thickness and photon energy.
3. The mass attenuation coefficient has a similar behavior to the coefficient of linear attenuation, i.e., proportionality between them.
4. The atomic cross section area of materials mentioned above decreases with an increase in the photon energy, where the atomic cross section values depend on the electronic area section.
5. Silicon is a semiconductor. It has a negative temperature coefficient of resistance, since the number of free charge carriers increases with temperature. The electrical resistance of single crystal silicon significantly changes under the application of mechanical stress due to the piezoresistive effect. The semiconductor materials are either elementary such as silicon and germanium or compound such as gallium arsenide. Silicon is the most used semiconductor for discrete devices and integrated circuits. One of the prominent German scientists wrote in an article about silicon that this era is the silicon era since silicon impacted and still affecting the modern civilization development very much.

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