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Elharam Ali Eltahir
Phd, Physics, Jazan University K.S.A
El Arda collage, Physics Department
alharamm@jazanu.edu.sa
Faten Adel Mohammed
Phd , Physics, Jazan University K.S.A
Arda collage, Physics Department
Fabdulaziz@jazanu.edu.sa

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The Control of reflectance and Transmittance of glass using External Magnetic Field and Sound Waves Through Electrical Permittivity

Elharam Ali Eltahir
Faten Adel Mohammed$_2$
Department of Physics, El Arda Science
College Jazan University, Jazan, Saudi Arabia.

Abstract

Optical properties of matter are important in solar cells and smart windows design. The properties like reflection and transmition are very important in these applications. Therefore, this work is concerned with studying these properties using Maxwell's equations. Using the expression of reflection and transmition coefficient useful relations were found. It was found that complete transmittance occurs when one applies a strong magnetic field. While applying an appropriate magnetic field leads to complete reflection and generation of amplified light in a direction normal to the incident one.

Also, the thermal radiation can be reflected completely by applying sound wave having a certain frequency.

Key words: Transmition, reflection, magnetic field, sound waves, Maxwell's equation.

Introduction:

Electromagnetic wave plays an important role in human life. Light waves are important for vision and for plants. Plants transform light energy into useful chemical vital energy, which is important for human life and the life of living organisms [1]. Light energy from the sun is also useful since solar cells change them into useful electric energy [2]. Electromagnetic waves are also used in telecommunication widely. They are used for mobiles, internet, television sound and radios [3]. Thus for the efficient performance of all these devices, it is important to know how electromagnetic waves interact with matter. This includes absorption, transmittance, reflection and refraction [4]. Electromagnetic waves interact with matter through many processes like scattering, Compton Effect, photoelectric effect and pair production [5]. The interaction of electromagnetic waves (e.w) with bulk matter is described by Maxwell's equations which treat e. was waves. But for the interaction of e. w with individual atoms is described by using photon theory [6,7].

Intensive research has been made to increases the efficiency of solar cells [8,9]. One of the main factors that control the efficiency is the absorption, transmittion and reflection coefficients. The efficiency of the solar cell can be inc reased by decreasing reflection and transmition besides increasing absorption and increasing the efficiency of converting absorbed photons energies to electrical energy [10.11].

However, no intensive research had been made to see how to control and decrease reflection and transmittance using external effects. This is the aim of this work, where the effect of the external magnetic field and sound waves are exhibited in section 2. Section3 and 4 are devoted to discussion and conclusion.

Theoretical Model to Control Reflectance, Transmittance, and discussion:

According to electromagnetic theory the reflection coefficient Γ and the transmission coefficient T are given by

$$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \quad (1)$$

$$T = \frac{2\eta_2}{\eta_1 + \eta_2} \quad (2)$$

Where the impedances for the incident and reflection for medium 1beside transmition medium 2 are given by.

$$\eta_1 = \sqrt{\frac{j\omega\mu_1}{\sigma_{1+}+j\omega\varepsilon_1}} \quad , \quad \eta_2 = \sqrt{\frac{j\omega\mu_2}{\sigma_{2+}+j\omega\varepsilon_2}} \tag{3}$$

Thus the parameters that control reflection and transmition are the frequency f ($\omega = 2\pi f$), magnetic permeability μ, conductivity σ, and electric susceptibility ε. By finding a pathway to change some of these parameters, one can control reflection and transmition processes.

One of these important parameters is the electric permittivity which can be controlled by applying oscillating electric field E which is given by:

$$E = E_0 e^{-i\omega t} \tag{4}$$

The equation of motion of the electron under the action of constant magnetic field of flux density B, beside the electric field E in (4) is given by.

$$m\ddot{x} = eE + Bev \tag{5}$$

Consider a solution

$$x = x_0 e^{-i\omega t}, \quad v = \dot{x} = -i\omega t \quad , \quad \ddot{x} = -\omega^2 x \tag{6}$$

Inserting (6) in (5) yields

$$-m\omega^2 x = eE - i\omega Bex, \qquad (iBe\omega - m\omega^2)x = eE$$

$$x = \frac{-e(m\omega^2 + iBe\omega)E}{(m^2\,\omega^4 + Be^2\omega^2)}$$

Thus the electric dipole moment P is given by

$$P = enx = -e^2 n \frac{-e(m\omega^2 + iBe\omega)E}{(m^2\,\omega^4 + Be^2\omega^2)} = (\chi_e + i\chi_i)E$$

χ_e = Real electric susceptibility

χ_i = Imaginary susceptibility

Thus the real electric susceptibility is given by.

$$\chi_e = \frac{-e^2 nm\omega^2}{m^2\omega^4 + B^2 e^2\,\omega^2} \tag{7}$$

The electric permittivity is given by

$$\varepsilon = \varepsilon_0 (1 + \chi_e) \tag{8}$$

It is clear from (7) that for extremely large external magnetic field.

$$B \to \infty$$

$$\chi_e \sim -\frac{1}{\infty} \sim 0 \tag{9}$$

This physically means that the very strong magnetic field causes the electric dipoles to moves and induces electric field in a direction normal to the original direction.

Thus $\varepsilon = \varepsilon_0$ (10)

For non magnetic insulating material

$\mu_1 = \mu_0, \sigma_2 = 0$ (11)

$\eta_2 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \eta_1$ (12)

When the surrounding medium is air. Thus according to eqn (1) and (2).

$\Gamma = 0,\ T = 1$

Thus total transmition takes place

While the adjustment of B such that

$B^2 e^2 \omega^2 + m^2\omega^4 = e^2 nm\omega^2$ (13)

Gives see eqn (7)

$\chi_e = -1$ (14)

$\varepsilon = \varepsilon_0 (1 - 1) = 0$ (15)

For non magnetic material which acts as insulator

$\mu_2 = \mu_0, \quad \varepsilon_2 = 0, \qquad \sigma_2 = 0$

Thus $\eta_2 = \infty$ (16)

In view of eq (1) and (2)

$\Gamma = 1,\ T = 2$ (17)

Since T is the ratio of transmitted to the incident wave amplitude, it follow that the magnetic field induces double amplified wave in the normal direction.

Another way of controlling the electric susceptibility by applying sound vibrating waves in the direction of the vibration, to exert a force of.

$F_S = -m\omega_0^2 x = -k_0 x$ (18)

On charge carriers. Thus the equation of motion of electrons is given by

$m\ddot{x} = F_2 + eE$

$m\ddot{x} = -k_0 x + eE$ (19)

Sometimes the term $(k_0 x)$ may represent natural oscillation

Assuming the solution of e.q (6) gives

$-m\omega^2 x = eE - k_0 x$

$(k_0 - m\omega^2)x = eE, m(\omega_0^2 - \omega^2)x = eE$ (20)

$$x = \frac{e \quad E}{(\omega_0^2 \ -\omega^2)m} \quad (21)$$

$$P = enx = \frac{e^2 n \quad E}{m(\omega_0^2 \ -\omega^2)} = \chi_e E \quad (22)$$

Thus the electric susceptibility and permittivity are gives by.

$$\chi_e = \frac{e^2 n}{(\omega_0^2 - \omega^2)m} \quad (23)$$

$$\varepsilon = \varepsilon_0 (1 + \chi_e) = \varepsilon_0 (1 + \frac{e^2 n}{\omega_0^2 - \omega^2}) \quad (24)$$

With frequency $\omega = \omega_0$

For vibration

$$\varepsilon = \varepsilon_0 (1 + \frac{e^2 n}{0}) \ \rightarrow \infty \quad (25)$$

Thus one can easily control the electric permittivity by attaching two very thin magnets to the sides of the transparent materials which are parallel to the electric prating field direction, or by applying sound waves from a source in the direction of electric field vibration as shown in Fig (1).

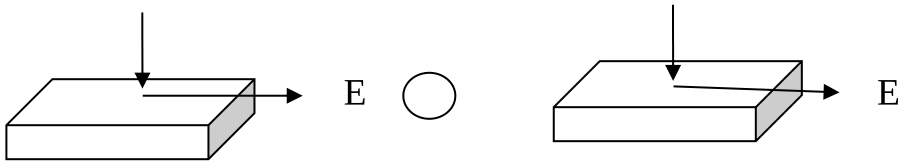

Fig (1): How to apply Magnetic Field or Sound wave

Consider the case when the incident medium is air, in this case

$$\sigma_1 = 0, \quad \mu_1 = \mu_0, \quad \varepsilon_1 = \varepsilon_0 \quad (26)$$

Hence equation (3) gives

$$\eta_1 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \quad (27)$$

For glasses which have very small conductivity i.e

$$\sigma_2 = 0 \quad (28)$$

Equation (3) gives

$$\eta_2 = \sqrt{\frac{\mu_2}{\varepsilon_2}} \quad (29)$$

To makes the glass reflecting light or infrared waves. This requires

$$\varepsilon_2 \rightarrow \infty \quad (30)$$

This can be a achieved according to equation (25) by applying sound waves such that,

$$\omega_0 \sim \omega \qquad (31)$$

to get

$$\eta_2 \sim 0 \qquad (32)$$

Thus according to equation (1) and (2)

$$\Gamma = -1,\ \ T = 0 \qquad (33)$$

For infrared with frequency ω_i one requires

$$\omega_0 \sim \omega_i \qquad (34)$$

Therefore the glass can reflect a certain color completely, beside all frequencies near ω_0 .Thus for example it can reflect infrared radiation completely.

For very high conducting materials like silver one has

$$\sigma_2 \to \infty \qquad (35)$$

Thus equation (3) gives

$$\eta_2 = 0 \qquad (36)$$

Again $\Gamma = -1, T = 0$

Therefore high conducting materials are highly reflecting.

To make any material highly transmitting, this requires

$$\eta_2 = \eta_1 \qquad (37)$$

For glass

$$\sigma_2 \sim 0 \qquad (38)$$

To make

$$\eta_2 = \eta_1$$

On requires controlling ε_2 by any means such that: [see e. q (36)].

$$\frac{\mu_2}{\varepsilon_2} = \frac{\mu_0}{\varepsilon_0}$$

$$\varepsilon_2 = \frac{\mu_2 \varepsilon_0}{\mu_0} \qquad (39)$$

According to equation (3), one gets

$$\Gamma = 0 \quad , \quad T = 1 \qquad (40)$$

As a result the material becomes highly transparent.

Equation (1), (2) and (3) shows that the reflection and transmission properties are highly dependents on electromagnetic frequency, conductivity and electric permittivity. The reflectivity and transmition can be controlled partially by the electric permittivity. The electric permittivity itself can be controlled by applying a constant magnetic field or sound waves as shown by equations (7 - 21).

The material becomes highly reflecting for highly conducting material or the ones having very large electric permittivity as equations (30-33) indicates. The glass becomes highly reflecting for large electric permittivity, which can be controlled by applying magnetic field or sound waves. The high transmittance for glass can be made by adjusting the electric permittivity by applying the magnetic field of sound waves, as equations (37 – 40) indicates.

Conclusion:

The reflection and transmition of glass can be highly controlled by adjusting the electric permittivity. This can be done by applying the external magnetic field or sound wave.

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