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The Optical Constants of Amorphous Silicon Nanostructures

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Abstract. There is of great importance to know the values of the optical constants of materials due to their relationship with the optical properties and then with their practical applications. For this reason, it was proposed to study the optical constants of amorphous silicon nanostructures (quantum well, quantum wire, and quantum dot) because of their importance in the world of optical applications. In this study, it was adopted the Herve and Vandamme (HV) model of the refractive index because it was found that this model has very good optical properties for almost all semiconductors. Also, it was carried out by applying experimental results for the energy gaps of these three nanostructures, which makes the results of the theoretical calculations that were more realistic. The optical constants were studied as a function of the energy of the spectrum, which ranged from the ultraviolet region to the infrared region. The sizes of the three nanostructures ranged from 1nm to 10 nm. There are two important factors in determining the results, namely, the increase in the degree of quantum confinement of nanostructures and the decrease in the size of these structures, as it is noted that the absorption coefficient, refractive index, extinction coefficient, and the dielectric constant decrease by the influence of these two factors, taking into account the shifting of energy for each of these constants.

INTRODUCTION

Amorphous silicon differs greatly from crystalline silicon in terms of the arrangement of molecules and physical properties, as both have different properties from the other. Studies on amorphous silicon have been developed and many interesting aspects have been discovered, which led to the arrival of its technology that leads to the invention of many applications [1].To a state in which it can be considered as one of the basic and independent branches of physic [2]. One of these developments reached by studies of amorphous silicon is a technique for producing high-quality quantum structures to study various aspects of systems with low- dimensions systems[3]. The confinement of charge carriers spatially in semiconductors is the best way to reduce the dimensions of the system of the material [4]. It is considered an essential characteristic for such a type of material[5]. This confinement may occur in one, two, or three dimensions, depending on the type of nanostructure[6,7].

Many researchers have studied amorphous silicon nanostructures because of the importance of this material in terms of its practical applications.Takagahara1991 [8].was studied the effect of the dielectric constant on the nanostructures was studied and it was concluded that this effect appears more clearly in the quantum dots than in the quantum wire and the quantum well. Lin-Wang Wang and Alex Zinger1994 [9].they show through quantum calculations for a large number of atoms that the physical dimensions that restrict the electron pair are the gap, not the Coulomb forces, but provided that the diameter of the atom is less than 20 A°.E.G. Barbagiovanni, et al 2011 [10].they are applied the theory of effective mass, which is determined by the type of confinement, whether it is strong, medium, or weak. It was found that the best description of crystalline materials is medium confinement and for non-crystalline materials strong confinement. Nidhal M. Abdul-Ameer, Moafak C. Abdulrida 2011[11].they study the proposal of the coexistence and concordance between the effects of quantum and spatial confinement of amorphous silicon nanoparticles is highlighted. This is done through the transition mechanisms of the presented model a-SiQDs. Eric G. Barbagiovanni, etal. 2013[12].they are evaluated the nanostructures according to a variety of manufacturing methods and in terms of their structural and optical properties. It shows how these various methods lead to many differences in

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the nanostructures themselves. K. Jarolimek, etal.2014[13]. they study the quantum well consists of several layers of semiconductor materials with different values of energy gaps that can be controlled through quantum confinement. Where it was discovered that the effect of confinement is rather weak compared to experimental results that were taken for the same nanostructure. Hussein K. Mejbel, etal.2017[14].they study the decrease experienced by the dielectric constant in semiconductor nanostructures when moving from normal sizes to quantum dots. S.K.Ghoshal 2018[15].he study the optical behavior of a group of quantum dots of amorphous silicon material, where the optical absorption coefficient and the dielectric function of silicon clusters as a function of size through their energy gap values are discussed.

In this paper, we will study the optical constants of amorphous silicon nanostructures through experimental equations for the energy gaps for each of three structures quantum well, quantum wire, and quantum dot. Such a topic has been proposed due to the researchers' need for the values of optical constants for amorphous silicon nanostructures of various sizes.

THE MODEL

The Quantum Confinement Effect

The quantum effect of the atom can be noticing it in three dimensions, through which we can measure the optical and electronic properties of materials[16]. This happens through the use of the effective mass theory, through which it is possible to measure the Bohr radius of amorphous silicon, which was found to be (4.5) nm [16]. The Bohr radius can be defined as the spatial dimension of the particles, which determines the size of the spatial confinement, which is of three types [10,17, 18].

- Weak confinement: This type occurs when the system dimensions are much greater than the Bohr radius of the electron (α_e) and the Bohr radius of the hole (α_h). The effective mass is calculated from:

$$M = m_e^* + m_h^* \tag{1}$$

  Where m_e^* and m_h^* are the effective mass of electron and hole respectively. Equation (1) is a latent term of the effective energy is by Coulomb energy.
- Medium confinement**:** It occurs when the dimensions of the system are much greater than the Bohr radius of the electron (a_e)and much less than the Bohr radius of the hole (a_h) also here the electrons are the only ones who are subjected to confinement. The relevant mass is simply m_e^* represents the effective mass of the electron, most materials belong to this type.
- Strong confinement**:** It occurs when the dimensions of the system are much smaller than the Bohr radius of the electron (a_e) and the hole (a_h), and here in this type both electrons and holes are subjected to confinement. The effective mass which is then reduced mass (μ) can be found through the equation:

$$\frac{1}{\mu} = \frac{1}{m_e^*} + \frac{1}{m_h^*} \tag{2}$$

THE ENERGY GAP OF AMORPHOUS NANOSTRUCTURES

It is known any change that occurs in the energy gap may cause a huge and radical change in the physics and chemistry properties of the material itself. This change occurs by reducing the dimensions of the material size to nanometer, therefore nanoscience must take into account the change in the values of the energy gap between it and bulk materials [3]. The quantum confinement is directly responsible for the change in the value of the energy gap for nanomaterial, According to many calculations and observations, the value of the energy gap of the material was exposed to the quantum confinement is calculated from equation [19]:

$$E_{Gap}(D) = E_{Gap}(\infty) + \frac{A}{D^2} \tag{3}$$

Where $E_{Gap}(D)$ represents the energy gap of the nanomaterial as a function of (D) which represents the diameter of the quantum dot or quantum wire or maybe acts thickness of the quantum well, where the confinement has three types: in one direction $(1D)$ and two directions $(2D)$, which are considered cylindrical coordinates, in addition to the third type of confinement which represents the restriction in three directions $(3D)$, which is considered a spherical coordinate [20]. $E_{Gap}(\infty)$ represents the energy gap value of the bulk material. (A) represents a parameter that expresses the degree and strength of the confinement, Because the dimensions of the system and particles are smaller than the Bohr radius of the electron and the gap[18]. It is noted that the value of *A* in Table (1) increases with the increase in the degree of confinement due to the effect of the Bohr radius for each case.

TABLE 1. shows the values of parameter A for the three nanostructures[18,20]

The quantum Confinement (Strong)	*A*
1D	0.89
2D	2.09
3D	3.57

THE OPTICAL CONSTANTS OF AMORPHOUS NANOSTRUCTURES

Refractive Index

The value of the refractive index has been calculated by several scientists and for many materials. Through these processes, several models were reached, the most prominent of which was the Moss model and the Ravindra model, which were among the most prominent models and attempts that appeared, but among all these studies, it has relied on the model Herve and Vandamme of refractive index.

Our work is based on the Herve and Vandamme model of the refractive index because it was found that this model has very good optical properties for almost all semiconductors. The results presented by this model are very close to experimental measurements[21, 22, 23]. The equation has been developed to calculate the value of the refractive index under the influence of changing the value of the energy gap, this equation is[24, 25]:

$$n = \left[1 + \left(\frac{\mathrm{A}}{E_{Gap}(D)+\mathrm{B}}\right)^2\right]^{\frac{1}{2}} \tag{4}$$

Where (A) is the ionization energy value of hydrogen which is 1.36 eV, (B) represents a value of 3.4 eV [24]. Hervey and Vandamme put this equation according to the theory of oscillation (which determines the solution of the ordinary differential equation as it oscillates because it contains an infinite number of roots) and also assumes that the UV resonance energy has a constant difference with the value of the energy gap[26].

The Absorption Coefficient

The absorption coefficient represents the percentage by which the intensity of the incident rays (photon energy) on the material decreases, according to the distance and direction of propagation of the wave within the material[27]. The absorption coefficient depends on the energy of the incident photon, according to the condition of the transition, where the transition occurs only when the energy of the photon is equal or greater than the value of the energy gap according to equation $h\nu \geq E_g$ [3]**.**

To calculate the value of the absorption coefficient of amorphous silicon, it is used the Tuce equation is, which represents[28]

$$\alpha = \frac{B}{h\nu}\left(h\nu - E_g\right)^2 \tag{5}$$

(B) is a constant that depends on the nature of the material, (hv) is the energy of the incident photon, (E_g) represents the energy gap value of the nanomaterial. An exponential is taken a certain value depending on the type of material and the type of transition, where its value is equal to *2* [29]. In our study, the material is the amorphous silicon nanostructures, the type of transition is assumed indirect. Where the absorption coefficient in semiconductors with indirect transition gaps is usually low unless the photon energy is greater than the value of the energy gap, where the electrons and holes that are produced are unstable and lose their energy to the favor of the alloy and then move to the edges of both the conduction band and the valence band [29]**.**

Extinction Coefficient

The extinction coefficient refers to the effectiveness of absorbing light for a specific wavelength in the material, as a result of both the refraction and scattering to which the light is exposed upon entering the material and for the unit of distance[27,30,31].

$$K = \frac{\alpha\lambda}{4\pi} \tag{6}$$

It can see from the above equation, the number of losses and attenuation in the material depends on the absorption coefficient and the wavelength of the incident rays, where λ is the wavelength of the light falling on the material .and α represents the absorption coefficient of the material.

Dielectric Constant

The dielectric constant physically represents the amount of response of electrons in the material to the incident electromagnetic field, and its value depends on the frequency of the incident spectrum[31]. The dielectric constant is considered one of the basic and important optical constants of materials. It consists of two parts, the first is the real part that is related to the term referring to the amount of slowing down the speed of light falling on the material, the second is the imaginary part that shows how the material absorbs energy from the internal electric field due to the dipole motion, whether it is In the direction of the electric field propagation or makes a certain angle with it[32]. Where these two parts determine the loss factor as well as the loss in the beam of light falling on the material, where when the imaginary part (which represents the percentage of losses) is large, the greater the percentage and amount of energy lost inside the material[27].

The dielectric constant and its parts can be calculated from the following equations [26]:

$$\varepsilon = \varepsilon_1 + i\varepsilon_2 \tag{7}$$

ε is the total dielectric constant of the material, ε_1 represents the real part of the dielectric constant, $\boldsymbol{\varepsilon_2}$ represents the imaginary part of the dielectric constant.

The real part of the dielectric constant can be calculated using the following equation[26]:

$$\varepsilon_1 = (n^2 + k^2) \tag{8}$$

n is the material's total refractive index, k is the material's total attenuation coefficient.

The imaginary part is also calculated through the following equation [26]:

$$\varepsilon_2 = 2nk \tag{9}$$

It is noted through the real and imaginary partial rates that they depend mainly on the value of both the refractive index and the attenuation coefficient only.

RESULTS AND DISCUSSION

The optical properties of the nanostructure of semiconductors have begun to attract great attention in the recent period because it is expected to differ significantly and radically from the properties of the material if it was loose.

Where in small sizes ranging in diameter from a few nanometers to tens of nanometers, quantum size effects become dominant, and as a result of these effects the material will show distinct physical properties such as electronic states and nonlinear optical susceptibility that have been studied in practice[33].

Figure (1 a,b, and c) represents the relationship between the value of the energy gap and the size (eq.3) is an inverse relationship where the energy gap increases with the decrease in the size of the atom. It is seen that each size has its energy gap value, starting from the value (1.56 eV), which represents the energy gap of a bulk material [34]. this increase is due to the quantum confinement that appears it's affecting the material, which causes a change in most of the material's properties, including the optical properties [35]. As the occupied energy levels shift in the conduction band to the top and the unoccupied energy levels in the lower valance band fall, thus increasing the energy gap according to the resulting atom About the confinement[33,36].

It is noted that the quantum shifting of the energy levels is the highest possible when the confinement is with three directions because the confinement will cause shifting and go down of the energy levels greater than if it was the case with only two directions and in turn greater than the confinement with one direction only [33]. The value of the energy gap of quantum dots may be reaching its value of about (5.1 eV) while it decreases to become (3.7 eV) in the case of quantum wire until it reaches its lowest value in the quantum well starting from (2.5 eV) because it is the lowest degree in the confinement.

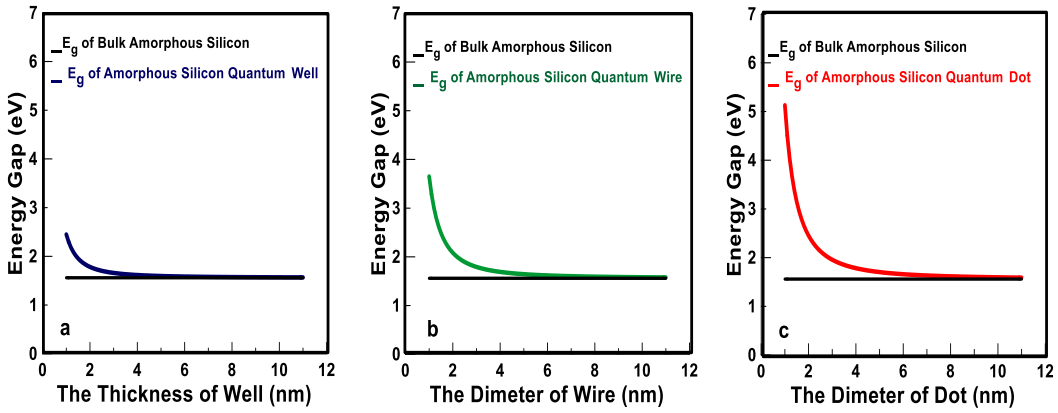

FIGURE 1. The Energy Gap for amorphous silicon Nanostructures as a function of size (a) for a quantum well (b) for quantum wire (c) for quantum dot.

From the observation of the size values, it is found that in the case of quantum dots, the values of the energy gap will stabilize and start steadily at the size (8nm), where the material after this size behaves like the bulk material, meaning that the dimensions that enter into nanoscience are the dimensions about (1-8) nm. In the case of the quantum wire, the size decreases to (7nm), meaning that the sizes that work in the nanoscience are (1-7) nm and above it, the material begins to behave as bulk material. In the case of the quantum well, the size is reduced to (6nm), meaning that the sizes used in nanoscience are (1-6) nm. It can be said that these ranges can be called effective ranges. It can be concluded that when the quantum confinement is larger, more effects of nanoscience appear in the material. The refractive index (n) is an important and basic property in semiconductors with tetrahedral surfaces and is related to the inner field of the material [33].

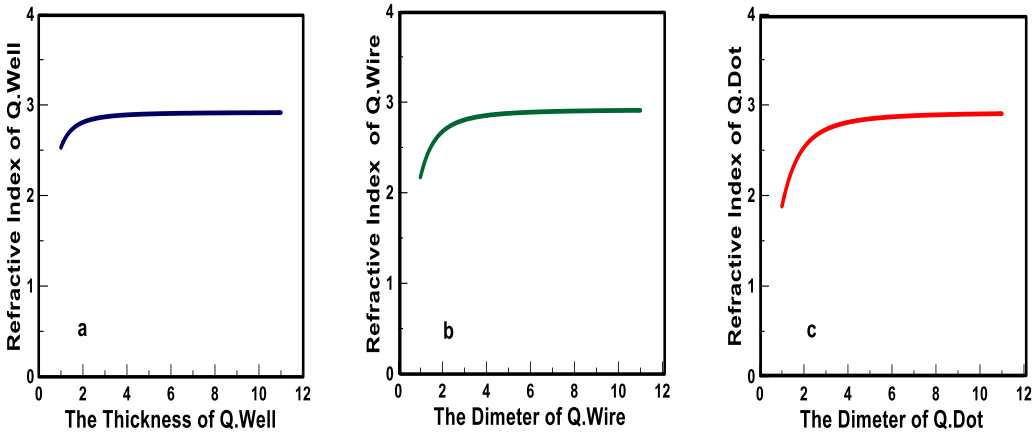

FIGURE 2. The Refractive index of amorphous silicon Nanostructures as a function of size for (a) quantum well (b) quantum wire (c) quantum dot

From observing the figure (2 a, b, and c) for each of three nanostructures, their behavior of the refractive index (eq. 4) can be divided into three regions: The first region, which was described as the stable region, which varies from one structure to another. It is found that the quantum well is somewhat wide where it extends between the diameter of (10-5)nm, while it appears at the quantum wire between the diameter of (10-7nm), and the least the quantum dot about (10- 8)nm. The second region in which the curve begins to fall its constant value can be observed in the quantitative well between (2-5) nm, which is a rather narrow area compared to other structures, while the quantum wire is between (7-3)nm and at the quantum dot it is between (8- 4)nm. As for the third region, which is considered the most effective, it is found that at the quantum well, it is very narrow, ranging from (2- 1)nm, and it is wider when the quantum wire is from (3- 1)nm, while the quantum dot curve is more clearly compared to the other structures where its ranges between (4-1)nm.

The behavior of these three regions for each of the structures can be explained based on the quantum confinement, where the shifting of the energy levels for each structure occurs whenever the quantum size decreases (as it was clarified in the energy gap item), the least shifting of the structures for the energy levels is the quantum well while the most shifting at the quantum dot. This depends on the amount of energy in the structure, when the energy is large, it will contain many energy levels, while if the energy is low, the energy levels will be few, for this reason, it can be considered the refractive index is responsible for distributing energy levels[37]. At the same time, the refractive index represents the potential energy present in the material, therefore; when the shifting is more, the distribution of the levels be lower, this explains the low value of the refractive index of the three nanostructures.

Figure (3 a, b, and c) shows the absorption coefficient (eq. 5) for each of the nanostructures for amorphous silicon the quantum wells, the quantum wires, and the quantum dots respectively, for sizes from (1-10) nm for each type. Through the figures, it is clear that there is a general behavior that can describe three types and a special behavior that characterizes each type alone. From the general behavior, it is noted that the curves will be divided into two parts: the first is that the greater the incident energy, the lower the absorption. This is due to the type of transitions that occur [38].where the transitions can occur at one of the two bands (either of the conduction band levels or the valence band levels), which are what are called Internal transitions[39,40]. The transition may occur in the energy gap due to its local levels, where the randomness coefficient plays an important role in this case [41]. The absorption coefficient value continues to decrease until it reaches its lowest value. The reason may be that there are no energy levels to receive these energy amounts, or the number of transitions may be decreasing gradually so that many transitions do not occur. Then the second part of the behavior begins, which shows an increase in the absorption coefficient as the incident energy increases. These transitions can be explained according to the condition $E_g \leq hv$ [3].

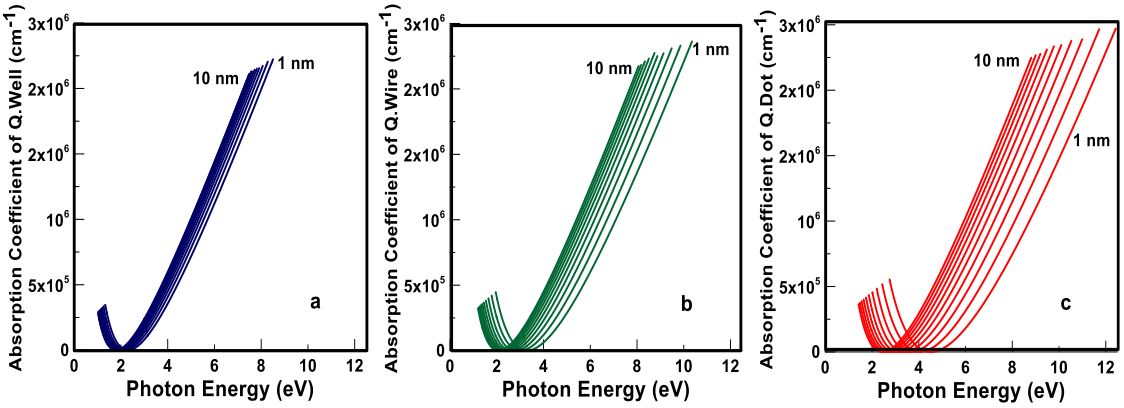

FIGURE 3. The Absorption Coefficient of amorphous silicon Nanostructures as a function of photon energy for (a) for quantum well. (b) for quantum wire. (c) for quantum dot.

The reason for the high absorption coefficient value can be attributed to the presence of energy levels that can be receiving the optical photon, and then the absorption occurs, as well as the probability of the number of transitions increases as the incident energies increase.

It can be seen that the three nanostructures for amorphous silicon have a blue-shifted when moving from a size of (10) nm to size (1) nm As shown in figure (4). On the other hand, by comparing the three cases, it is seen that the narrowest shifting is for the well, which is characterized by quantum confinement in one direction only, while the widest shifting is for the dot, which is the quantum confinement in three directions.

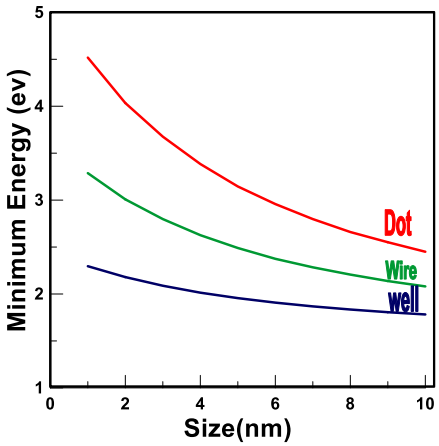

FIGURE 4. The Minimum Energy for energy levels as a function of sizes.

If we return to the division of the energy gap, this division matches our results for the absorption coefficient, where it is seen that: at large sizes (for the three structures) a large convergence between the curves, it is found that the quantum well is more convergent than in the other two structures, where the figure shows a more compressive of well This can be explained by the convergence of the energy range at which the transition occurs. While this range diverges as the quantum confinement increases as it is seen in the quantum dot, this leads to the appearance of less compressive curves. At small sizes, the spacing is relatively clear for each type. However, due to quantum confinement, a local increase will occur in the electron-hole pair, which will be arranged better than in the case of bulk random carriers and thus will receive more radiation and energy, thus increasing the absorbance [39].

The extinction coefficient is a measure of the refraction of light lost due to scattering, absorption per unit distance of the participating medium and also represents the imaginary part of the complex refractive index[31, 42].

Figure (5 a, b, and c) show the extinction coefficient as a function of the photon energy (eq. 6) for the three nanostructures (quantum wells, quantum wires, and quantum dots) respectively, where it is noticed that; at low

energies, the value of the attenuation coefficient gradually decreases with the increase in the photon energy and that is due to the decrease in the number of vibrational transitions that are within the energy levels due to the absorption of the infrared part of the electromagnetic spectrum, where the value of the absorption energy ranges (0.82_1.77) eV from the energy of the photon[43]. Then the value of the extinction coefficient reaches its lowest value at the energies that the energy values of the photon are equal to the values of the energy gaps, this is because the transition condition is not fulfilled, so there are not many transfers of electrons.

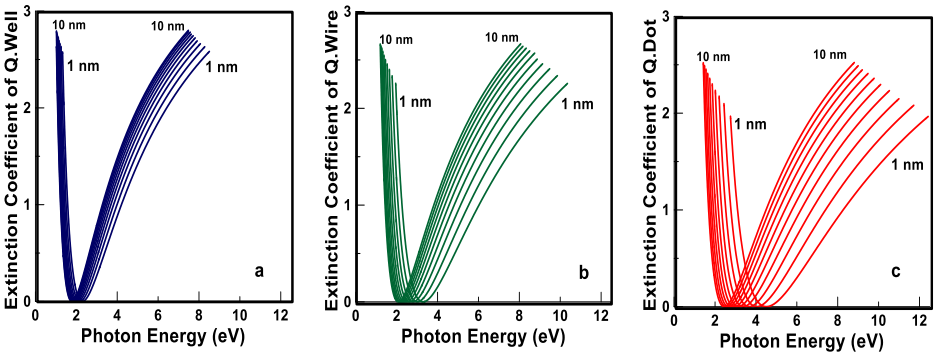

FIGURE 5. The Extinction coefficient of amorphous silicon Nanostructures
(a) for quantum well. (b) for quantum wire. (c) for quantum dot.

After that, the extinction coefficient begins to increase gradually with the increase in the energy of the photon, due to the increase in the electronic transitions that are between the beams, so these transitions require high energy that they do not provide to the two regions of visible light that are absorbed in the range (1.77_3.1) eV and the region of ultraviolet rays that are absorbed in the range (3.1_12.4) eV of the photon energy ranges at which it is observed that the behavior has an exponential decreasing [44]. Also, the extinction coefficient increases by increasing the photon's energy gradually due to the reduction in the wavelength. As the wavelength decreases, the scattering and scattering ratio increases because it depends inversely on the wavelength and directly with the increase in the size of the molecule because it will become easier to scatter it, therefore; it is seen that the extinction coefficient increases regularly with increasing sizes from (1-10) nm in all nanostructures [27,45].

By observing the figure, by moving from the size of (10) nm to (1) nm, the shifting will be towards higher energies (towards the short wavelengths), that is, a blue shifting, which confirms that they have high energies and short wavelengths By comparing the three structures, it is found that; the largest amount of losses (the largest value of the extinction coefficient) is in the (quantum well) structure and the lowest value is in the (quantum dot) structure, because the effect of quantum confinement is in one direction only in the case of (quantum well), while it is in three directions in the case of (quantum dot), which makes the charge carriers restricted. More than the first case[18]. It is also noticed that the extinction curves are more compressed in the case of quantum well, its behavior approximates that of bulk material. This is due to the convergence of the values of the energy gaps of different sizes, thus energies of close values are needed to achieve the purpose of transmission and absorption, so the curves of the attenuation factor appear more compressed and closer than they are in the cases of quantum wire and quantum dot. Referring to the curves for the three nanostructures, it is found that; for the size (10) nm, the value of the extinction coefficient is the least possible (that is, the losses are the least possible) at (1.77 eV) in the case of (quantum well), (2.0 eV) in the case of (quantum wire), and (2.45 eV) in the case of (quantum dot) for the same size. In addition, the losses are minimal in the case of quantum well with the projected photon energy, less than in the cases of (quantum wire) and (quantum dot). Therefore, as a result of the losses that constitute the extinction coefficient, it is possible to consider the extinction coefficient as the same as the absorption coefficient if it is neglected the scattering of the particles [46]. It is also noted that when the degree of quantum confinement is higher, the curves are towards high energies, this is what is called the blue shifting.

The dielectric constant may be defined as the ability of the material to store energy when exposed to the electric field[47]. It consists of two parts, real and imaginary. The real approximate to the refractive index, which is considered as the gain, while the imaginary close to the attenuation coefficient, which is the loss [37, 47].

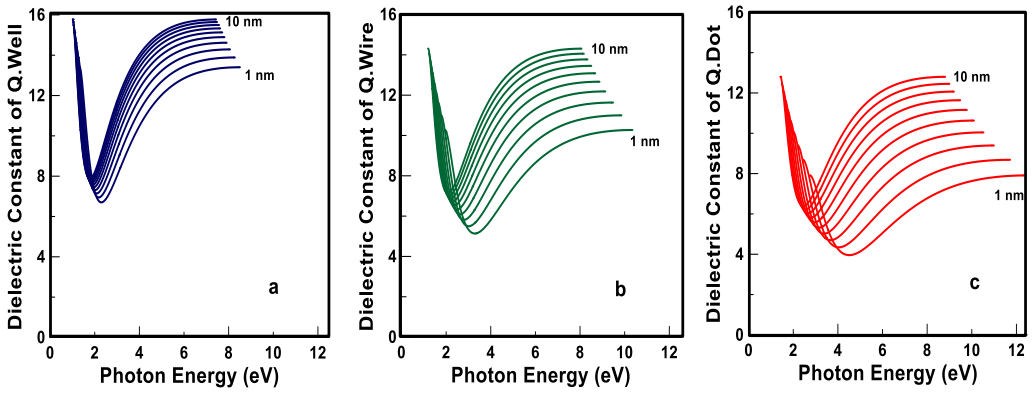

FIGURE 6. Dielectric constant for amorphous silicon Nanostructures as a function of photon energy (a) for quantum well. (b) for quantum wire. (c) for quantum dot.

Figure (6 a,b, and c) is represented the dielectric constant (eq. 7) for the three nanostructures the quantum wells, the quantum wires, and the quantum dots, respectively with different sizes from (1nm) to (10nm), where the dielectric constant is acting the degree of polarization to which the material is exposed and the amount of charging current required. The dielectric constant is the sum of these two parts, according to the following equation $\varepsilon = \varepsilon_1 + i\varepsilon_2$ [47].

It is distinguished from the figure three different regions, the first behavior at low energies, where the dielectric constant begins to decrease gradually with the increase in the energy of the photon. This behavior represents the real part of the constant, which is estimated that the vibrations at low energies are few, which indicates the low polarization experienced by the charge carriers, then It reaches the minimum value of the dielectric constant at given photon energy, where the behavior of the active region begins to appear, which represents the second region in this figure. In this region, it indicates the stability of the dielectric constant, from which it gets the best value for the dielectric constant when it is at its minimum value and for the longest possible period. In the third region, in which a clear increase of the dielectric constant curve is observed at high energies, in this case, the photon energy gradually increases until the dielectric constant reaches its maximum value. By observing the figure, it is seen that; the maximum value of the dielectric constant is in the quantum well, where the polarization here is in the highest possible for it, while the minimum value of the dielectric constant is in the quantum dot, where the polarization is less than in the other two structures. This is due to the quantum confinement as is mentioned in the paragraph Previous. Also, it is noted that the minimum value of the dielectric constant is different in the three structures, and for different energies as well, it is the lowest possible in the dot structure, in addition, has an effective region wider than that of the other structure. Whereas, the structure of the well has a dielectric constant higher than the dot structure, with a smaller effective region with lower energies, which makes it behave similar to bulk.

Also, it is noted that the value of the dielectric constant in size (10 nm) is greater than that of the size (1nm) due to an increase in the number of atoms whenever the size is larger, which creates more charge carriers and more polarization ratio. Also, due to the increase in the size of the molecule and the increase in the percentage of polarization. On the other hand, it is noted that; the value of the dielectric constant for size (10nm) is greater than that of size (1nm) due to an increase in the number of atoms whenever the size is larger, which creates more charge carriers and more polarization ratio, besides the increase in the size of the molecule that increases in the polarization.

It can say that: It is possible to obtain any required value of the dielectric constant, by controlling the volume and the power applied to obtain the appropriate and desired results.

CONCLUSIONS

In this work, the optical constants of amorphous silicon nanostructures were studied, the effect of quantum confinement and its three types was analyzed and explained. The following are the most important conclusions obtained: the energy gap has an inverse relationship with the size of the material, as the value of the energy gap increases whenever the size of the material is small for the three nanostructures. On the other hand, the energy gap has a relationship with the degree of quantum confinement, where the energy gap is increasing with the increase in the degree of restriction in quantum confinement in dimensions of the material until it reaches the highest possible when the structure of quantum dot (which is confinement in three directions), while it is at lowest as possible when

the structure as a quantum well (which is in one direction only). This indicates that the quantum dot structure is more useful than other structures because it provides more options to select the material required to manufacture any semiconductor application. The refractive index will be as low as possible when the structure is the quantum dot, while its value is greater in the quantum well structure. It is noted that the refractive index may reach values of less or equal to 2 at small sizes at both the quantum dot structure and quantum wire structure which indicates that these materials were characterized by transparency or half transparency. Taking into account that the sizes that have this characteristic in quantum wire structure are less than in quantum dot structure, but this characteristic is unclear at the same of sizes by its quantum well structure. The absorption coefficient, depending on the value of the energy of the incident photon, it was found that the absorption coefficient of the quantum dot structure has the ability to the tuning of energy more than the quantum wire structure and less in the quantum well structure. The least attenuation for all three structures of all sizes is when the incident energy is equal to the energy gap. If the incident energies are less than the energy gap, the attenuation decreases as it approaches the energy gap value. But if the incident energy is greater than the energy gap, the attenuation increases with its increase

It is clear from the behavior of all-optical constants that any optical parameter for any material, its behavior depends on the value of the energy of the incident photon, because it will thus determine the type of transitions that occur and also the part that needs to be absorbed from the parts of the electro-optical spectrum, including the real and imaginary parts dielectric constant. When the sizes get smaller, the dielectric constant decreases, also at a higher degree of confinement, the dielectric constant will be reduced. This means that, in both cases, the permittivity of the material will decrease, therefore the susceptibility to polarization will decrease too. This study is considered the closest to reality because of the reliance on practical equations to restrict the energy gap.

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