Effect of Thermal Variations on Some Nanostructural and Optical Characterizations of Element Oxides Compound \((Y_2O_3/Fe_2O_3)\) Prepared Using Laser Ablation

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Abstract: In this study have been synthesis nano oxide composites \((Y_2O_3/Fe_2O_3)\) are prepared chemically and affected by Laser Neodymium –YAG ablation by energy (200 mJ), and number of pulses (200 pulses) at two different temperatures (4°C and 65°C) in distilled water. The structural, morphological, and optical properties of synthesized oxides were studied, (XRD) pattern showed that the oxides were highly crystallized in both hot and cold cases with variations in intensity values as they increased in the cold state than in the hot with additional peaks of intermediate compounds \([Y(OH)]_3; PLA\], monoclinic and cubic and the two phases (\(\alpha-Fe_2O_3\); \(\beta-Fe_2O_3\)). The (AFM) test indicate the roughness values that increased in the cold state than in the hot state. The results of the (SEM) showed a close approximaton in the hot & cold cases in cubic forms, conical sticks (like nanorods, whiskers) as a result of recrystallization, noting that the value of absorbance increased in the cold than in the case of hot. The sample was manufactured in a solar cell, by obtaining a I-V curve under the dark and its illumination. The results showed a significant change in the performance of the solar cell at the values of \((I_m=42 mA; V_m=0.21 V)\), when the iron oxide overlaps with the yttrium oxide with the best conversion efficiency of 7%.

Keywords: laser ablation, \(Y_2O_3/Fe_2O_3\) nanostructure, optical & structural properties

1. Introduction

Quantitative effects begin to control the behavior of the material in the nanospace, especially in the lower end, affecting the properties of electrical, magnetic and optical materials [1,2]. Nanomaterials for semiconductors are one of the richest classes of nanocompounds. Where it has played an important role in advancing research in the field of nanoscience and nanotechnology, leading to a new classes of semiconductor materials. Normally the current flow in conductors are due only to electrons but for the semiconductor material is caused by both the electron as well as any gap (electron-hole) [3]. This field is expected to open up new fields for science and technology in the preparation and application of nanostructure for metal oxides, which are one of the classes belonging to semiconductor nanomaterials and nanotechnology. Material oxides have proved to be a very promising future for a variety of practical applications. The good thermal and chemical stability of these inorganic materials enables them to be widely used in the fields of chemistry, physics and materials science [4]. Yttrium oxide is the most common yttrium compound, where the latter is a three-valence metal transition. Three electrons share their equivalence and yttrium oxide is an example. \((Y_2O_3)\) has attracted a lot of attention recently because of its interest in several physical properties, such as its crystalline stability up to 2325 °C (where its melting point is 2450 °C).
crystalline structure is cubic but there may also be hexagonal and Monoclonal. The high thermal conductivity is up to (0.131 W cm\(^{-1}\) K\(^{-1}\)), the large optical gap is almost (5.5 ~ eV), the relatively high electrical insulation constant is in the range (14-18), and the wide range of transmittance (8-0.29) μm. The refractive index is almost high (n=2) where it is perfectly suitable for waveguide applications and is used as a very good protective behavior when coated in interactive [5-6].

Iron oxides are widely used as inexpensive and durable dyes in paint, and concrete. Colors are usually available at the "earthy" end of yellow, orange, red, brown, black scale. Different stages of iron oxide (Fe\(_2\)O\(_3\)) are alpha (α-Fe\(_2\)O\(_3\)), beta (β-Fe\(_2\)O\(_3\)), gamma (γ-Fe\(_2\)O\(_3\)) and epsilon (ε-Fe\(_2\)O\(_3\)). It is clear above that iron oxides are metal-related metal oxides, because they possess multiple oxidation states that can be specifically tuned to a particular application [7].

The aim of the research is to prepare nanograins of materials of their oxides by combining the chemical method with laser fragmentation. Also synthesis of nanoparticles with the mixing of semiconductors for use in energy application.

2. Experimental

The monoxides materials (Y\(_2\)O\(_3\)/Fe\(_2\)O\(_3\)) were prepared by means of several processes, the first thermal ones to ensure the mixture. The process is by adding (4gm) of Y\(_2\)O\(_3\) to (3gm) of NaOH and adding it to (2gm) of FeCl\(_3\). Each of these substances dissolves in (100 ml) distilled water with continuous magnetic stirring for 24 hours, Then treat it thermally to produce the mixture as in Fig.(1).

![Figure 1](image_url)

Figure 1. An image the resulting material of the compound

Paragraph (1-1) describes the chemical path of the basic chemicals and mixes them to prepare for the target of the laser bombing and the outcome of this last operation.

\[ Y_2O_3 + NaOH + FeCl_3 + H_2O \rightarrow Y(OH)_3 + Fe(OH)_3 \]

The second process is laser ablation in liquids. As it is the main process to synthesize the required oxides. The basic process of laser ablation in the liquid phase is the reaction of the laser beam with the surface of the hard target that causes evaporation of the target and a small amount of liquid surrounding it. Chemical reactions between the removed parts and molecules in the liquid also occur as scattered fragments emitted electronically and transiently, and the reaction products are...
nanoparticles made up of target atoms and surrounding liquid, which is a collide solution in the liquid. As a result of the accumulation of these particles in the surrounding liquid (composed of a suspended solution) and the sustainability of the interaction with the laser beam leads to additional changes in the composition, size and shape of nanoparticles.

The plasma plume is composed of different thermal layers, atomic ionization and plasma plume formed by the laser beam of the material's target. Four groups of liquid and metal species can be identified due to different temperature, pressure and composition. In the process of laser ablation in the liquid, the plasma is confined to the liquid and produces a shock wave that travels through the target. When the target is absorbed for a part of the laser pulse it leads to a constant increment of evaporation of the parts of the solid target. In addition, the shock wave will produce additional pressure in the plasma caused by the laser. The plasma generated by the laser for high temperatures, high pressure and high density is generated at the surface of the solid-liquid surface when the surface of the solid is irradiated in the liquid by the laser pulse. In the case of a liquid solution up to 2ml as shown in Figure(2), then the laser pulse is bombarded at two different temperatures, the first high 65°C and the second low 4°C where the three samples of non-dried (solid solution) baker and immersed in (2ml) of distilled water of the same solution with nitrogen gas for 5 minutes to stir bubbles and uniformity of materials.

The morphological characteristics of nano oxides materials synthesized by the (AFM) and (SEM) systems. The structural properties were examined by the XRD in a range of 10-80 degrees. The structural properties are an important feature of the study of the crystalline structure of the oxides of (Fe₂O₃) prepared with the help of Yttrium oxide.

Figure 2. Laser ablation system on liquid contained compound materials

3. Results and Discussion

By Based the chemical formula (1-1), Figure 3 shows the X-ray diffraction pattern of the sample of the composites nano oxides (Y₂O₃/Fe₂O₃) prepared first. In a hydro-thermal method, a medium was recorded to obtain a solid solution in the medium-base liquidity phase to reach a solution containing compound and deposition material formed by the dissociation of compound Y₂O₃ / Fe₂O₃ compound and then to the laser ablation method in distilled water under hot (65 °C) and Cold (4 °C) during laser
pulses with the JCPDF universal card to verify the results and identify the material correctly. In the hot case, the iron oxide material when tested for X-rays is more crystalline than the colder case. Where the angles (32.8925°) (13.7274°) (22.1097°) (29.4440°) (31.8073°) at the crystalline planes (200) (220) (-411) (003) respectively, which belongs to the phase ε-Fe₂O₃ within card PCPDF # 16-0653. Therefore, the form of crystalline structure Orthorhombic system is consistent with the researchers [8]. There is also a small percentage of phase β-Fe₂O₃ at angles (24.8912°) (48.6529°) (19.8832°) for crystalline planes (2013) (017) (104) respectively, for card PCPDF # 40-1139.

In addition to the yttrium oxide, the angles (29.2443°) (31.1180°) (40.3311°) (47.1729°) for crystalline planes (002), (108), (110) respectively corresponding to the world card (20-1412) shown, along with several corners of the card PCPDF # 43-0661. Note that ranges of the crystal size according to Scherrer formula as shown in Table 1 are from (32-80.50) nm in hot case. In the cold case, iron oxide is slightly less than hot at angles (13.2893°) (33.9042°) (32.9170°) at the crystalline plane (200) (200) (-411) (-420) respectively, according to the international card PCPDF # 16-0653. Also corresponds to the card PCPDF # 40-1139 for stage β-Fe₂O₃ at angles (21.4563°) (31.0820°) (48.6588°) degrees at planes (105) (113) (2013) respectively. And also a few percentages.

As for Y₂O₃ in the cold state, the peaks are at the angles (29.33042°) (40.3361°) degrees at the planes (002) (102), respectively. In the cold case, it was noted that FeₓCl₉(OH)₁₂+x is Iron Chloride Hydroxide at the angle (11.4264°) and crystalline plane (003) according to the card (PCPDF # 49-0095) and the iron chloride FeCl₃H₂O₂. According to the card PCPDF # 1-0132. Note that the crystal size according to Scherer formula as in Table 1 ranges from (25.20-57.10) nm. These differences between the peaks lead to the differences in crystalline of the monoxides in the two cases the hot and colder, because of the aggregation characteristics or coalescence property of materials that appear in hot case more than cold case. The (Y₂O₃/Fe₂O₃) compound give a new manner related to the intensity of peaks especially at (200) plan. The crystal size was calculated from Scherer’s equation[9].

\[
C.S = \frac{0.9 \cdot \lambda}{\beta \cdot \cos \theta}
\]

Where: C.S is the crystal size, \( \beta \) is the full width at half maximum (FWHM) in radians of the peak, \( \theta \) is the Bragg angle, (\( \lambda = 1.5406 \) Å) X-ray wavelength. It was noted that the size have the large crystal in the case hot than in the cold state, because of coalescence or adhesive of nanograins to form greater grains. The values of grain sizes of the compound (Y₂O₃/Fe₂O₃) in two thermal cases (hot and cold), was shown in table (1). The crystalline size of the sample is somewhat large and within the nanoscale of the hot case and smaller than the cold state due to the effect of the laser and because here the crystal size of the required materials was calculated only regardless of the other materials formed.
Figure 3. XRD of measured nano-oxide Y$_2$O$_3$ / Fe$_2$O$_3$ compound prepared composed by laser ablation at two different temperatures.

Table 1. The values of grain sizes of the compound (Y$_2$O$_3$/Fe$_2$O$_3$) in two thermal cases (hot and cold).

| Sample         | Thermal Case | 2-theta (deg) | FWHM (deg) | C.S (nm) |
|----------------|--------------|---------------|------------|----------|
| (Y$_2$O$_3$/Fe$_2$O$_3$) | HOT          | 13.3,22.1     | 0.19, 0.109 | 43.6, 80.5 |
|                |              | 31.8, 32.8    | 0.12, 0.2  | 71.2, 43.2 |
|                |              | 29.24         | 0.26       | 32       |
|                | COLD         | 40.33         | 0.12       | 70.7     |
|                |              | 13.28         | 0.272      | 30.9     |
|                |              | 29.30         | 0.346      | 25.2     |
|                |              | 29.5          | 0.15       | 57.1     |

examining the surface topography of nano-oxide solutions prepared by laser ablation in distilled water on glass using an AFM microscope with high surface-imaging power as shown in Fig. 4 showing AFM images of binary (a), (b) and the accumulation statistical distribution (c) for hot noting the cumulative statistical distribution of the GCD, the surface roughness (Ra) and the square root rate (Rq). The highest cumulative percentage was 7%. The shape of the grain is spherical and the grain
volumes are between 40 and 160 nm. The thermal effect on the grain led to adhesions between the grains, which made the values of multiple grain sizes and different diameters. The increase in granular size, square root rate and surface roughness were observed due to the occurrence of covalent bonds of Y$_2$O$_3$ and Fe$_2$O$_3$ by heat factors (high and low temperature in the two preparation cases) and pressure in the hydrothermal process of the solid solution with the resulting compounds (In hot and cold conditions) through the two compounds (Y(OH)$_3$) and (PLA). Thus, a change in the molecule of the mixture will occur with a combined hybridization of oxidize as a result of the analytical medium. As well as the aggregation status of nanoparticles due to inter-particle intersections. The change in granular volumes due to the breakdown of iron oxide (Fe$_2$O$_3$) is due to vapor pressure and chemical reaction products and the association of its components again by laser radiation with saturation in the composition of the superconductor ($\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3$) within a crystalline structure as the assembly state increases the granular volume. The granular size of the structure is then increased to a floating majority within the solution.

![Figure 4. AFM images of nanoparticle oxides for hot sample Y$_2$O$_3$/Fe$_2$O$_3$ in (a) two dimensions (b) three dimensions (c) the cumulative statistics](image)

When examining the samples in the cold state of laser ablation and obtaining nano-oxides, it was noted that the crystallization and growth of nanoparticles with specific sizes was 8.5% with 40 nm grain diameters where the volumes are close to the proportions as shown in Fig.(5).
Figure 5. AFM images of nanoparticles of the cold sample (a) in two dimensions (b) three dimensions (c) the accumulation statistical distribution of nanoparticle oxide particles

Table 2 shows average grain size (Any all topography the sample is not only the size of the crystal), percentage, diameter of granule and surface roughness of a sample \((\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3)\) As each of the parameters mentioned in the values in the cold state from the warm state because of the impact of low temperature, which led to the difference in granular volumes, thus increasing the roughness.

**Table 2.** The values of average grain size, percentage, diameter of granule and surface roughness of a sample of \(\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3\).

| Sample     | Thermal Case | Grain size (nm) | G C D | Rq (nm) | Ra (nm) |
|------------|--------------|-----------------|------|---------|---------|
| \(\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3\) | HOTING       | 87.52           | 7.5% | 1.86    | 1.58    |
|            | COLDING      | 93.90           | 8.6% | 2.14    | 1.84    |

Fig. 6 shows the scanning electron microscopy images of a sample of the nanoparticle oxides of the hot compound \(\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3\) at the degrees 4°C and 65°C. The presence of vacancy due to the degradation of the nanotube by the heat, which leads to the possibility of a fusion between the nanoparticles of the compound.

Figure (6) and based on the chemical formula (1), the scanning electron microscopy images of the \(\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3\) compound of the hot state at (65)°C show the presence of voids due to the decomposition of the nanotube by heat. The integration of the nanoparticles of the compound and the
gaps between the nanoparticles and the appearance of the iron oxide by the installation of a clear cube shape.

Figure 6. Scanning Electron microscope image for sample of Y₂O₃/Fe₂O₃ for hot case.

Fig. 7 shows a change in the crystalline structure by a polycrystalline of the crystalline grains lead to growth, which leads to the formation of crystalline oxides of the crystalline grains around the majority of the grains collected. In addition, the effect of laser ablation affects the cold effect some compact. In the cold state of 4°C, a change in the crystalline structure shows a convergence between the crystalline granules due to the state of extinction, which leads to the nucleation of crystalline particle oxides, which accumulate around the majority of granules (i.e., partial shrinkage of the material). The effect of coldness, which helped to form the compounds of precipitation in the solution, which contributed to the development of crystalline volumes and raise their values and make them somewhat monolithic and free of spaces between the granules and thus the emergence of dendritic assembly and a clear nanometer scale and this enhances the results obtained in the examination (AFM), it should be noted that there is a clear crystalline tigers in both hot and cold conditions and in a preferred crystalline direction and is very similar to the whiskers which are formed when moving from the gaseous state to the solid directly. To this advanced growth, which is one of the reasons for crystallization and evidence of some points that represent the beginning of the crystalline development Whiskers, which researchers describe the composition of the cone with advanced growth and this is consistent with what other researchers [10]
Figure 7. SEM for sample of Y$_2$O$_3$/Fe$_2$O$_3$ for cold condition.

In order to ascertain the components of the sample obtained by laser excretion in distilled water and in hot and cold cases, and based on the chemical formula (1) and the (SEM) test, the X-ray dispersion analysis measurements in table (3) is high value for each element (Y) at the shell (L) and (O) when the shell is K). The Fe element in both L and K is based on its electronic arrangement ($^{26}$Fe: 3d$^6$ 4s$^2$) and the last electron exists in a double state in the secondary orbit (d). In the iron element, there are two peaks with an atomic number ($Z =$26). The ratios are fairly close in both cold and hot conditions, and very few impurities are present for chlorine (Cl) and sodium (Na). Figure (8) shows the proportions of the elements and their mass and atomic percentages in the hot and cold cases, in addition to the impurities in the sample.

Figure 8. scheme The EDX for the colloid solution (Y$_2$O$_3$/Fe$_2$O$_3$).
Fig. 9 shows the absorption of yttrium oxide after the formation of iron oxide effect on heat and cold cases, noting that the value of absorbance increased in the cold with respect to the case of hot and the reason is that iron contains an abundance of electrons that increase absorption coefficient. In the case of cold operation is contrary to the behavior of the yttrium as the hot operation is higher. This is due to the cold working condition. The nanoparticles are more stable. However, when the temperature is raised, it will lead to disintegration of the material and thus less absorbance. After the wavelength (400 nm), the effect of visible radiation as the absorbance is greater than the hot state.

Table 3. The percentage of material elements shown in the EDX test.

| Composites | Case | Contents | Elements | Fe (L)&(K) | Impurities (C, Na, Cl, Ag) |
|------------|------|----------|----------|------------|---------------------------|
| Y₂O₃/Fe₂O₃ | Hot  | Mass %   | 38.72    | 32.11      | 16.88L 6.19K 6.1         |
|            |      | Atomic % | 14       | 64.52      | 9.72L 3.56K 8.26         |
|            | Cold | Mass %   | 44.21    | 27.73      | 6.84L 2.99K 18.23        |
|            |      | Atomic % | 29.29    | 24.81      | 13.96L 8.88K 23.06       |

**Figure 9.** Absorbance as a function of the wavelength of the Y₂O₃/Fe₂O₃ nanoparticle mixture for hot and cold cases (65 and 4°C).

It is observed from Fig. 10 that transmittance behaves in the opposite of absorbance behavior because the transmittance is inversely proportional to absorbance. The permeability in the cold state is less than warm due to the crystallization of the oxides due to the low temperature. This may also be due to the formation of levels of Fe and other impurities within the energy gap which lead to increased absorbance as observed in Figure 8 and thus decrease permeability. The spectrum of permeability depends largely on the amount of energy levels, the large role of which is related to the chemical and crystalline structure of the material. An important factor is the presence of surface defects, which
increase the dispersion of the radiation and thus decrease the permeability of the samples prepared in the cold state.

![Figure 10](image-url)

**Figure 10.** Transmittance as a function of the wavelength of the Y$_2$O$_3$/Fe$_2$O$_3$ compound of the hot and cold cases (65 and 4°C).

In Fig. 11 showed the change in the absorption coefficient within the range (190 - 800) nm is due to the change in the wavelength of the nano-oxide of the sample prepared in experimental conditions. It increases at short wavelengths (less than 300 nm) and decreases in values and stabilizes somewhat with increasing wavelength due to its suitability with absorption (Absorption behavior) and according to equation (2)[11], where the absorption coefficient is calculated from them. Since the absorption coefficient value is $\alpha < 10^4$ cm$^{-1}$. At the low energies, electronic transitions are indirect.

$$\alpha = 2.303 \left( \frac{A}{t} \right)$$

where: $A$: Absorbance , $t$: thickness, $\alpha$: absorption coefficient. It is observed that the calculated absorption factor values for most samples are between ($1 < \alpha < 10^4$) cm$^{-1}$ within the exponential absorption region. Therefore, the electron transitions from the valence packet to the conduction beam are within the edge. Where there is weak absorption and the electronic transitions in this region represent the tails within the energy gap. As we can see, the absorption coefficient is slightly at the long wavelengths, the transitions The values of the absorption factor at the edge of absorption are high in the direction of high energies.
Figure 11. Absorption coefficient as a function of the wavelength of the Y$_2$O$_3$/Fe$_2$O$_3$ nanoparticle mixture for hot and cold cases (65 and 4)$^\circ$C.

The optical energy gap is determined from the absorption edge because it indicates the electronic transitions from the equivalence beam to the coupling. The transitions of these samples are indirect because the absorption coefficient is less than $10^4$ cm$^{-1}$. The indirect optical power gap is calculated according to equation [12].

$$a\nu = B\left(\hbar\nu - E_g \pm E_p\right)^m$$  \hspace{1cm} (3)

Where: ($B$: constant, $E_g$: the optical energy gap for indirect transitions, $+E_p$: the phonon absorption process, $-E_p$: phonon emission process)

Variance in the values of the energy gap when the temperature changes and the material changes from one sample to another. In this sample, the decrease in the value of the energy gap, especially the cold state, is indicated by the warm state. This is confirmed by the results of AFM if the granular volume is colder than in the warm state. Decreasing is the entry of the positive ionic element into the crystalline structure to interfere with the atoms of the Y$_2$O$_3$, an increase in the number of positive ions. Consequently, internal levels within the energy gap will be formed, causing a decrease in its value, $E_g = 2.79$ eV for Hot, $E_g = 2.5$ eV Cold case.
Figure 12. The relationship between the indirect energy gap and the photon energy of colloidal nanoparticles at 4°C (Cold) and 65°C (Hot)

4. Application solar cell

Table (4) shows the effect of the hall of the sample membrane (Y₂O₃ / Fe₂O₃) in hot and cold conditions for preparation at temperature (65°C, 4°C). The Rₜ coefficient depends on temperature and semiconductor type. The conductor of the resulting overlapping oxides in the hot and cold cases is of type (n), so the vast majority of the conductivity is the electrons, while the temperature of the preparation (by increasing the temperature) is lower, because the temperature generates additional energy levels between the valence and the conductance bands. It was obtained from a decrease in the coefficient of Hole in the cold state than in the warm which was caused by a strong thermal shock in the low-temperature solid solution by the continuous laser pulse chain temperature, which gave the chemical bonds of the solution compounds a thermal content within it that is concentrated by the propagation. (μₜ) depends on the concentration of the carriers as the mobility decreases with the increase of the concentration of the carriers because the interstitial distance between the atoms decreases and thus impedes movement even though the traffic increases with increasing temperature. From Hall Impact Measurements, the velocity of the (v) and resistivity (ρ) and the lifespan of the carriers can be calculated as shown in the same table. The conductivity of the sample veneers (Y₂O₃/Fe₂O₃) in hot and cold conditions to prepare at temperature (4°C, 65°C) increases by increasing the temperature. Therefore, the temperature effect on the resistivity is reversed. The drift velocity increases by increasing the temperature and it is inversely proportional to the concentration of the carriers. The faster the drift, the less the concentration of the charge carriers is affected by the age of the charge carriers, which is increased by increasing the drift speed, making the free carrier paths decrease by increasing the carriers because the interstellar distance decreases with increasing concentration.

Table (4) shows the measurements of the effect of the sample membrane (Y₂O₃ / Fe₂O₃) in hot and cold conditions

| Sample Structure | Ty | Rₜ (Ω.cm) | μₜ (cm²/V.s) | σ (Ω.cm) | nₑ (cm⁻³) |
|------------------|----|-----------|--------------|----------|------------|
| pe               |   |           |              |          |            |
Figure (13) shows the voltage current of the two solar cells of sample \([Y_2O_3/Fe_2O_3:p-Si]\) in hot and cold conditions in the dark. In the case of anterior bias, the current flows relatively freely while in the opposite direction, the flow of current is very weak due to the flow of the majority and voltages applied to the majority carriers and the width of the region. The concentration of the majority and minority carriers is higher than the concentration of the base carriers, which generates the re-union current in the low voltage zone (0-3.0 Volt). This is because the electrons are raised from the valence pack to the conduction beam and then re-combined with the existing holes. The parity package and this is what explained a significant increase in the Union re-stream in the region is low-voltage while the case of the tunnel in the high voltage area occur. After that, there is a huge exponential increase in the value of the current with increasing voltage and this is called the propagation current. Which dominate the high voltage (> 0.2 volts). In the reverse bias area, the bias voltage increases the width of the depletion zone, leading to a reduction in the concentration of the majority and minority carriers. In the first low voltages (< 0.1 volts), the current increases slightly with the applied voltage increase and slightly dominates the current. In the second high voltage zone (> 0.1 volts), the current is dominated.

![Figure 13](image-url)

**Figure 13.** A voltage-current curve of the two solar cells of the sample \([Y_2O_3/Fe_2O_3:p-Si]\) in the case of darkness
The voltage-current values of the two solar cells of the sample \([\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3;p\text{-Si}]\) were examined at the intensity of the lamp (55.5 mW / cm\(^2\)) in hot and cold conditions in Figure (14). It shows the relationship of the photovoltaic current at the reverse bias voltage, as the photovoltaic current increases by increasing the voltages, and the optical current \((I_{ph})\) increases by increasing the intensity of the falling light, thus increasing the number of generated carriers and displaying the depletion area increasing with the increase of reverse bias voltages which increase absorption and generation Electron - hole pairs. At the front bias voltages, the current doubles exponentially with the forward voltage until the slope becomes more gradual. This is due to the high injection levels of the carriers as the voltage is no longer equal throughout the depletion zone. The short circuit current increases with the intensity of the incident light. It has been found that in the case of reverse bias of the voltages, the current is increased by increasing the applied voltages, which in turn increases the width of the attenuation zone. While in the case of the front bias of the voltages increase current by increasing the front voltages. Table (5) shows the voltage of the open circuit \((V_{oc})\), the short circuit current \((I_{sc})\), the greatest voltage \((V_m)\), the greatest current \((I_m)\), the filling factor coefficient \((FF)\) and efficiency \((\eta)\) of the sample solar cells \([\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3; (55.5\text{mW / cm}^2)]\), indicating that the solar cell efficiency of the cell of the sample \([\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3;p\text{-Si}]\) prepared in the hot state is (3.9%) which is less than the efficiency of the cell of the sample \([\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3;p\text{-Si}]\) prepared in the cold state, which is about 7%. Here, it is worth mentioning the role of the intermediate compounds resulting from the reaction, which enhanced the electronic content of the cells in the case of cold, as explained by the interpretation of the effect of Hall and encircled by the results of X-ray examination of the presence of these compounds, which in turn will generate additional energy levels between the valence and conduction bands, which gives more opportunities to obtain values of the current oscillating accuracy measured depending on the nature of bias and drift speed of carriers Applies even to measurements of current voltage values in the case of darkness as seen in Figs. (13) and (14).

| Solar Cells | \(V_{oc}\) (V) | \(I_{sc}\) (mA) | \(V_m\) (V) | \(I_m\) (mA) | FF | \(\eta\) % |
|-------------|----------------|----------------|-----------|-------------|----|----------|
| \([\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3;p\text{-Si}]\) | Hot | 0.29 | 42 | 0.16 | 34 | 0.44 | 3.9 |
| \([\text{Y}_2\text{O}_3/\text{Fe}_2\text{O}_3;p\text{-Si}]\) | Cold | 0.39 | 44 | 0.22 | 45 | 0.57 | 7 |
Figure 14. The current - voltage of the two solar cells of sample [Y$_2$O$_3$/Fe$_2$O$_3$: p-Si] in the case of a 55.5 mW / cm$^2$ light bulb

5. Conclusions

It is concluded the following:

1- The thermal effect led to adhesions between the grains, which made the values of grain sizes multiple and different diameters.

2- The presence of vacancy due to the degradation of the nanotube by the heat, which leads to the possibility of a fusion between the nanoparticles of the compound.

3- Absorption increased in the cold than in the case of hot.

4- In the hot and cold cases, the results showed that the Hall coefficient depends on the temperature, the nature of the intermediate compounds formed, and the type of semiconductor of the two samples, which is of type (n). The electrons are the predominant carriers, and the drift velocity increases as the concentration of the charge carriers decreases due to the time life of the charge carriers, which increases with the speed of drift, making the free carrier paths decrease by increasing the carriers.

5- In the hot and cold cases in the dark mode, the behavior of the two cells was found to be non-linear. This indicates that the coupling mechanism is non-ionic and that the current flows relatively freely at the forward bias rather than the flow current at reverse bias, which is very weak due to the applied voltages for injection of the flowing majority carriers as well as the display of the attenuation zone.

6- It is observed the relationship of the photovoltaic current to the reverse bias voltage. The $I_{th}$ is increased by increasing the voltages. The intensity and intensity of the incident light, which increases the number of carriers generated. In the case of front bias voltages, the current doubles exponentially with the forward voltage until the slope becomes more gradual. This is due to the high injection levels of the carriers.
7-The efficiency of the solar cell in hot state is (3.9%), and the efficiency of the solar cell in the cold state (7%) 

6. References 

[1] Saha, S. A. T. Y. A. J. I. T., & Bera, S. R., “Growth and characterization of CdTe nanostructures grown by chemical reduction route.”, Int. Journal of Metallurgical of materials Science and Engineering, Vol.3, No. 1, (2013).
[2] Jose, A. R., & Marcos, F. G., “Synthesis, Properties, and applications of Oxide Nanomaterials”, Wiley, New Jersey (2007).
[3] Fierro J. L. G., “Metal Oxides: Chemistry and Applications, CRC Press”, Florida Fierro, Jose Luis G., ed. Metal oxides: chemistry and applications. CRC press, (2005).
[4] Munoz, R., "Co-precipitation of Y2O3 powder.” M.Sc., Thesis, Division of Ceramics, Department of Materials Science and Engineering, KTH Stockholm, Sweden, INSA Lyon, France, (2011).
[5] Larimi, Z. M., Amirabadizadeh, A., & Zelati, A., "Synthesis of Y2O3 nanoparticles by modified transient morphology method." Proceedings of the International Conference on Chemistry and Chemical Process IPCBEE, IACSIT Press, Singapore, pp. 86-90, (2011).
[6] Drbohlavova, J., Hrdy, R., Adam, V., Kizek, R., Schneeweiss, O., & Hubalek, J., “Preparation and properties of various magnetic nanoparticles”. Sensors, Vol. 9, No. 4, pp. 2352-2362, (2009).
[7] Ling, C. C., Fung, S., Beling, C. D., & Huimin, W. “Defect study of Zn-doped p-type gallium antimonide using positron lifetime spectroscopy”. Physical Review B, Vol. 64, No. 7, pp. 75201, (2001).
[8] Hollas, J. M., “Modern spectroscopy.” John Wiley & Sons, (2004).
[9] Kittel, C., McEuen, P., & McEuen, P., “Introduction to solid state physics”, Vol. 8, pp. 323-324, (1996).