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Estimate the value of CdTe thermal evaporation activation energy

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Abstract

This research describes the thermopower and electric conductivity of CdTe films produced using thermal evaporation technology; the energy activation value of this electrical and thermoelectrically properties are estimated. CdTe sheets have an electrical resistance of about (107. cm). Conductivity was studied, and it was found that the electrical conductivity increased with temperature. At low temperatures, there are two values of activation energy ($Ea1 = 0.337eV$) because of this dependence, but at high temperatures, ($Ea2 = 0.702eV$) is the only value of activation energy. The Seebeck coefficient (thermopower) was researched to find that it was temperature-dependent, and it was found that, as the temperature increased, the Seebeck coefficient decreased. The experiment results on thermoelectric power were summarized in a two-paragraph statement. The activation energy was measured to be ($ES = 0.561eV$), and the CdTe film was shown to be p-type conductive.

Keywords: Energy, CdTe, Thermal Evaporation, Seebeck coefficient.

1. Introduction

This is another incredible semiconductor compound containing tellurium and cadmium elements and built upon a crystalline cadmium telluride (Cd Te) matrix. The optical, electrical, and mechanical properties of this fantastic crystalline compound make it the best semiconductor compound for making thin-film solar cells. At a room temperature of 25 degrees Celsius, it has a 1.5oV direct tape gap and a 105 cm1 absorption coefficient. Only thin layers are needed; the film should be around a

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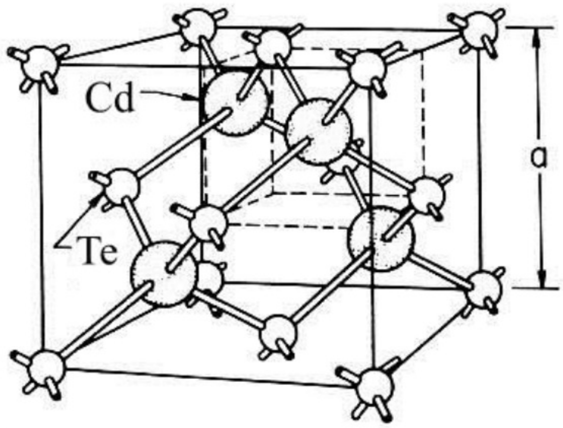

Figure 1: the zinc blend structure of CdTe compound

few microns thick for photons with solar energy higher than the band gap. Even at a broad range of temperatures, CdTe has consistently exhibited better optical properties than alternative substrates for the long-wavelength (i.e.,$> 18m$) transparent II-VI materials. At high temperatures, CdTe, which is inexpensive and moisture-resistant, can be used in place of filter membranes. Nevertheless, it's possible to cleave or scratch the softest II-VI the easiest. These traits imply that cheap manufacturing operations can be very productive [15].

Cadmium telluride is an II-VI semiconductor compound that has many applications in optoelectronic devices. The hexagonal wurzite phase or cubic zinc-blende phase can crystallize in these semiconductor materials [17]. However, theoretical features of cadmium telluride optical characteristics, notably in the "hexagonal wurzite phase", have been addressed infrequently, with the majority of published data relating to the "cubic zinc-blende phase"[15].Zinc-blend structure (ZB) is derived from the diamond structure and is composed of two interpenetrating cubic close-packed lattices. The zinc-blend structure is very similar to the structure of diamond, but it differs from the latter by the alternative of two different elements. The atoms of one element are located at the sites of face centered cubic (FCC) lattice, while the atoms of the second element occupy center of four (out of a total of eight) small cubic. The Cd atoms in CdTe compounds contain, in their ZB structure, four molecules per cell unit. Each Cd is encircled by four regular Te atom tetrahedral as shown in the fig 1 The structure of the zinc mix is the steady shape for bulk single CdTe crystals at atmospheric pressure, in contrast to several other II-vI semiconductor compounds, in which both zinc blended and rooted bulk crystals are used [1].

Films with CdTe can be found in several opto-electronic devices like:

1. Solar cell: To construct a p-n junction photovoltaic solar cell generally sandwiched with cadmium sulphide (CdS). Ferekides et al. today revealed that CdTe/CdS thin film solar cell was converted to 15.8% [10].
2. The ideal gamma-ray detector (CdZnTe) and flawless solid state X-ray [25] have all been combined with a small quantity of zinc by CdTe.
3. Mercury may be used to produce a multifunctional infraround detector (HgCdTe) [19].

2. Vacuum Evaporation Technique of CdTe Thin Film

Some of the preparatory procedures used to make CdTe films include vacuum evaporation [20], spray pyrolysis [9], electrodeposition [18], electro-free deposition [8], FF sputtering [6], close-space

sublimation [22]. Vacuum evaporation possesses a myriad of benefits, including a simplistic and inexpensive procedure for depositing a large amount of substance across a massive region. The contaminants in the soil will diminish, and there will be a huge drop in the oxides (an increase in oxygen concentration) [20].
However, CdTe film preparations with vacuum evaporation usually have small, small-grain minority life, high resistance due to their many grain boundaries.
Vaporization Resistive heating of CdTe thin films is done using a resistive heating boat or filament made of a refractory metal, usually "W, Mo, Ta, Nb." "Cubbles of quartz, graphite, alumina, and zirconia" are all different materials used for indirect heating. The main criteria that affect support material selection are the evaporation temperature and alloying and/or chemical reactivity with the evaporate. Most materials, including "Si, Al, Co, Fe, Ni," will not have their supports interfere with evaporation unless their supports are "very reactive."

3. CdTe Thin Film Electrical Characteristics

At higher temperatures, the thin layer semi-conductor gives lower resistance. These semiconductor films have a banned power strip that is categorically coupled to the valence and conduction strips. Many carriers are inactive at very low temperatures (very few free electrons in the conduction band and free holes in the valence band). Free electrons and free holes in the valence belt are more likely to be placed in the driving band as temperature rises, resulting in more free carriers contributing to conductivity and lowering resistance.

4. D.C. Electrical Conductivity

The capacity of the substance to oppose electrical current is measured by electrical resistivity. A low resistivity shows a substance that permits the electric charge to move easily. The electric resistivity SI unit is the (also known as the). The Greek letter è *di* is frequently represented (rho). The reciprocal amount of electricity resistivity is the electrical conductivity and evaluates the ability of a material to drive an electrical current. The Greek Letter DE is usually represented (sigma). Its SI unit is (alternatively.cm)-1.

$$\sigma = \frac{1}{\rho} \tag{4.1}$$

Many resistors and conductors are constructed of one material and have a uniform cross section with a uniform flow of electric current. The electrical resistivity () in this circumstance leads to:

$$\rho = R\frac{\mathbf{A}}{\ell} \tag{4.2}$$

Where:
A: is the cross-sectional area of the specimen (measured in square meters, m^2)
R: is the electrical resistance of a single material specimen (measured in ohms, die)
l: is the material part length length (measured in meters, m)
The temperature dependence of the electrical conductivity (σ) is given by Arrhenius equation [12]:

$$\sigma = \sigma_{\circ} exp\left(\frac{-(E_F - E_V)}{K_B T}\right) \tag{4.3}$$

Where:
$\sigma_{\circ}$: the pre-exponential factor

E_V: valance energy band (valance band edge)
E_F: The Fermi Energy Level
K_B: Boltzmann's Constant
T: The Absolute Temperature

The activation energy of the dark conductivity was discovered by fitting a linear relationship between the slope of ln(□) and (1/KBT), where the slope denotes the activation energy, and this value is reported in units of Joules (eV). In chemical terminology, activation energy is defined as the energy required to get a reaction started.

5. Thermoelectric Effect

Can temperature shifts be immediately translated into voltage? A voltage is created if the thermoelectric device has a different temperature on either side. In this process, heated and cool gases separate to produce thermal steam. To generate power, measure temperature, and raise or lower the temperature of goods, it can be employed. When charging, it's important to know if you are going too hot or too cold. Being able to tell that when charging might improve your thermoelectric device's temperature management.
Thomas Johann Seebeck discovered in 1821 that a closed system of two metals, one at each junction with a temperature difference, would be magnetic and capable of producing a current when set up correctly. The procedure that Thomas Seebeck observed led to the naming of the Seebeck effect, a procedure to discover the development of electrical potential difference in the junction between two types of metals of differing temperatures. There's a term called "thermopower" (also known as "Seebeck coefficient") in materials science that relates the temperature variation in the material to the induced thermopower voltage. In terms of thermopower, a material in the "S" diagram shows how the thermopower can be calculated. (s) Although units in V/K measurements are more common, they are still widely used. A device that relies on charged carriers (electrical transmission) uses the thermopower symbol.
If the temperature difference ΔT between the two ends of a material is small, then the thermopower of a material is defined approximately as:

$$S = -\frac{\Delta V}{\Delta T} \tag{5.1}$$

ΔV: thermoelectric voltage is seen at the terminals.

Using this [13], you can treat the temperature dependence of the Seebeck coefficient in a p-type semiconductor as follows:

$$S = \frac{K_B}{q}\left[\frac{(E_F - E_V)}{K_B T}\right] + \mathbf{A} \tag{5.2}$$

So:
K_B: The Boltzmann's Constant
T: The Absolute Temperature
$E_S = E_F - E_V$: The Activation Energy for The Thermoelectric Power.

6. Electrical Characteristics of CdTe Films: A Historical Review

The findings clarifies the plot of Ln FREA versus 1000/T, Redwan et al [27] studied the electrical features of CdTe film made with a typical thermal evaporation process. The figure is divided into two linear parts, suggesting two free-flow driving energy. The value = 0.409 eV in the area with low temperatures and = 1.711 eV in the region with high temperature.
The CdTe thin film developed by Ali et al. [2], using Cd and Te as two distinct evaporators and Ag by using a two source evaporation technique using ion interchange procedures. The results demonstrate a decrease in electrical resistivity for film as deposited from (2.5 to108 to.cm) to (9.7 to104 to.cm) and a decrease in dark conductivity. "From (0.672 eV) to (0.527 eV) activation of energy" with increasing doping concentration of age.
Belyaev et al.[7] investigate the electrical properties of cadmium-telluride films in a thermal field with a temperature gradient. The properties show that conductivity temperature dependence is governed by a simple exponential rule with an activation energy of (0.7-0.72) eV. Low conductivity and high conductivity energy activation (0.7 eV) are characteristics of film CdTe (Table = 10-8 Table-1cm-1). The influence of deposition rate and substrate temperature on CdTe film characteristics is investigated by Yoshiji etal. [11]. The dependence of layer conductivity on temperature was investigated at different deposition rates. At a deposition rate of 19 $A°sec-1$ and 0.017eV at 5.9 $A°sec-1$, the activation energy in a low-temperature area was measured at 0.12eV. That is, the lower the film deposition rate is Cd-rich (n-type), while the more Te-rich film deposition is (p-type).
Research on Cd vacancies in CdTe sputtered films was done by Becerril et al. [6]. A resistivity (todd) of around 108 da.cm was seen in CdTe samples with a Cd failure. Materials with a higher Cd have a resistance (so) that reduces to 103 psi or below.
Jae-Hyeong Lee et al. [21] carried out research on the electrical and optical properties of CdTe film produced by vacuum evaporation with a small separation between the source and substrate. The results show that at a room temperature, the dark resistivity of CdTe films is decreased when grown at 300 degrees Celsius [4].
The CdTe thin film CSS has been prepared by Jacome et al. [16] and characterized by measurements of thermoelectric energy (S) and resistivity (Ne), the CdTe films' thermoelectric power (S) has been calculated based on thermoelectric voltage measurements (V) vs. (T); and it has been shown that it decreases at an increased temperature and the signal of the p-type co-value has been shown.
The new hypothesis of thermoelectric effects on CdTe is being used by Vackova et al. [30], with the rapid increase of Seebeck's coefficient in the CdTe with experimentally found decreased temperature and conductivity type p.
The authors of Winn et al. [31] revealed the characteristics of CdTe films that were created using compound vacuum evaporation, and when these films were subjected to the thermal Seebeck effect, they were found to exhibit p-type behavior.

7. Thermal Evaporation–System

The deposition of CdTe material has been using thermal evaporation system type (Balzers BAE 080), which consists of two parts (vacuum chamber and vacuum system).
Ohmic contacts has been employed to achieve the lowest contact resistance. we used in (indium wire) as suitable ohmic contacts for p-type CdTe thin films.

Figure 2: Thermal evaporation system.

8. Optical–Interference Method

In close proximity to two reflector surfaces, interference fringes are formed which allow for a direct calculation of the thickness and high precision of the film surface topography. The thickness was measured by dropping a beam of laser helium-neon with wavelength (632.8nm) on the surface of thin film at an angle (45°) relative to the column above the surface of the thin film and the reflected beam passed through the lens to fall on the screen. The interference pattern (fringes) formed by the presence of a difference in phase between the beams reflected from the surface of the upper and lower thin film which can be seen on the screen, thickness can be measured by the following relation:

$$t = \frac{\Delta x}{x} \cdot \frac{\lambda}{2} \tag{8.1}$$

Where:
Δx: width of the dark fringe, X: width of the bright fringe, λ: wavelength (nm)

9. Electrical Measurements

The electrical measurements are included D.C. conductivity and Seebeck effect measurements for CdTe sample deposited on a glass substrate with in electrodes.

10. Electrical Resistivity

The resistivity of the Cd Te film is calculated from the slope of the horizontal line by the application of a voltage of (2-50 V) and by taking current readings as shown on the circuit (2).

11. D.C. Conductivity Measurements

In this experiment, researchers used a Keithley 602 to conduct CdTe film resistance measurements between 303-433K. The researchers used a digital electrometer to measure the resistance while heating the CdTe films.

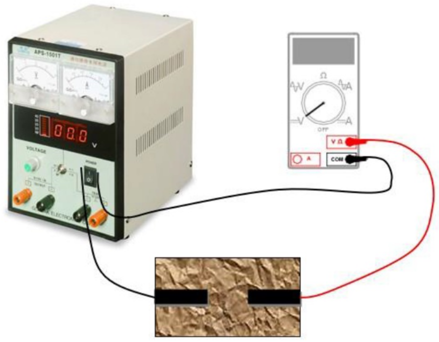

Figure 3: Electrical resistivity measurement system.

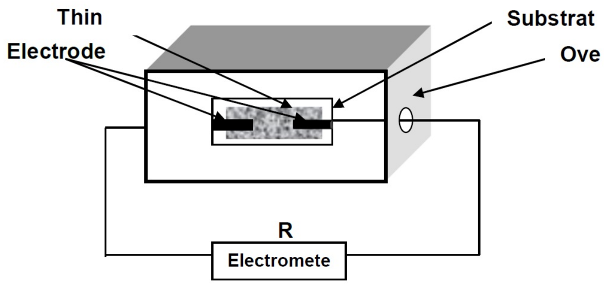

Figure 4: D.C. conductivity measurements system

12. Seebeck Effect Circuit

The experimental setup has been illustrated schematically in fig 5. This instrument was built to measure the film's Seebeck coefficient by using a temperature gradient along the film surface.

To regulate the left side of the device (the hot zone), the researchers used a temperature gradient ($30°C - 80°C$) regulated by an electrical supply with an output controlled heating. The cooler, or "wet" region, of the fluid water device was kept at a temperature of $17°C$.
The two K thermocouples, which were on the film's surface, were used to measure the temperature gradient with an accuracy of $2°C$. An electronic thermometer measured the thermoelectric voltage caused by the heat. The Seebeck coefficient was measured by finding the Seebeck voltage ΔV and using it to measure ΔT as a function of ΔV. The Seebeck coefficient can be calculated using the slope of the change in voltage over change in temperature.

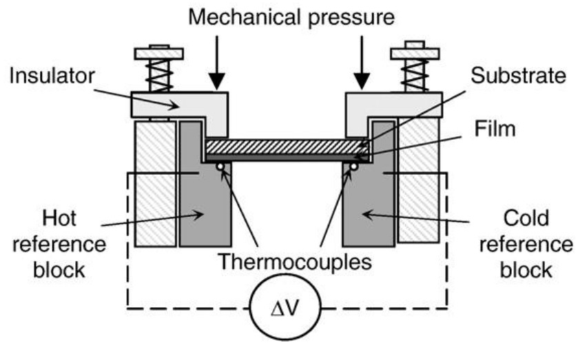

Figure 5:

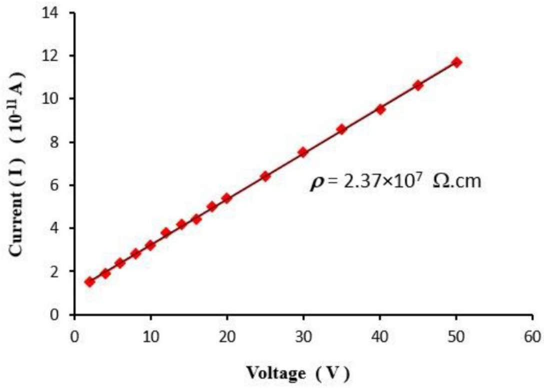

Figure 6: current – voltage plot of CdTe thin film

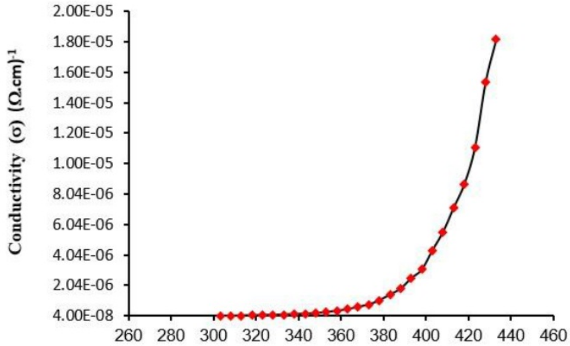

Figure 7: Variation of DC conductivity σ with temperature

13. Expermental Work

13.1. Current – voltage measurements

Using voltage ranging from 2 to 50 V, the CdTe film's resistivity was estimated from the voltage and current readings seen in figure 6, and was found to be ($4.73 \times 1011\Box$), or ($2.37 \times 107\Box.cm$). There is a strong p-type conductivity with high resistance in all unannealed and undoped as-grown films [5].

13.2. D.C. Conductivity measurements and energy activation

Figure shows the variations in temperature conductivity (move towards T) for CdTe figure 7. Conductivity in the low-temperature zone (303-373) K has been reported to increase slowly, but in the case of higher temperatures, conductivity increases with a considerably sharper temperature [14]. At normal temperature the conductivity value increases to ($1.82\pounds 10 - 5\ digits = 1 - 1cm$) at (433)K from (4.21 to 10-8 digits).

A ln versus $1.000/T$ plot in CdTe films' dark electrical conductivity was measured with sample temperatures ranging from 303 to 433 K in Fig 8. [6, 27]. A low activation energy caused the CdTe film data to be examined over a range of temperatures. However, a high activation energy value occurred in the data when temperatures rose, making the results of a carburetary emitter appear at 353K.

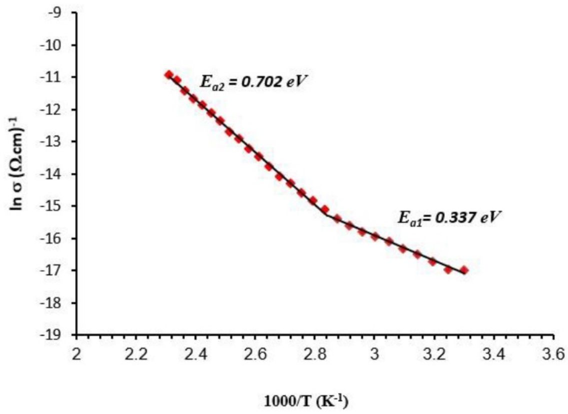

Figure 8: Variation of DC conductivity $\ln \sigma$ with $1000/T$ for CdTe films.

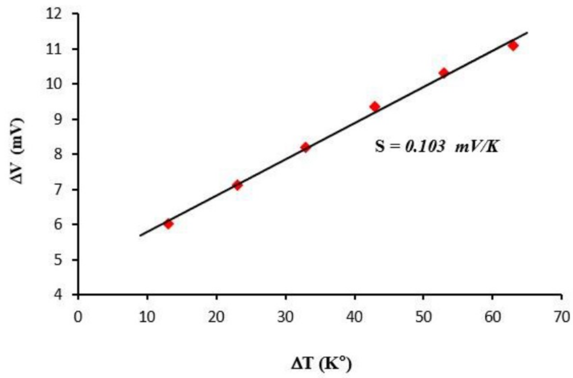

Figure 9: A typical Seebeck coefficient data.

13.3. Thermoelectric power/Seebeck coefficient

Any mutation or distortion of the material's Fermi level is especially vulnerable to heat power. The difference in temperature between the sample ends causes transporters to move from hot to cold, which results to electrical field and heat voltage. In the semiconductor, the temperature differential is precisely commensurate with the thermal voltage created. In order for Seebeck's thin film coefficient (thermal energy) to be computed, a plot of Seebeck voltage measurement was employed against the specimen temperature difference ($S = V/T$) [24]. Fig. 9.

The data from a straight line with a ΔV intercept of nearly $0mV$ at $\Delta T = 0$.
The value of Seebeck coefficient (S) is ($0.103 \times 10^{-3}V/K$), the thermo emf voltage was found to be positive in sample. Hence the sign of the Seebeck coefficient was positive, indicating that the electrons are the minority charge carriers and the studied samples have p-type conduction [13, 28].

14. Conclusion

The temperature range (303-353) K of the thermoelectric power of the movies CdTe was measuring, the terminal cool of the movie at 290K was maintained with flowing water. This equation suggests that a linear plot of thermoelectric power of films with reciprocal tempro is to be achieved with the fast increase of Seebeck coefficient in the CdTe with a decreasing temperatures found experimentally [30], the temperature dependency of p-type semi-conductive thermoelectric power (5). The value of thermoelectric power decreases at room temperature from (0,462 to 10-3 V livres) to

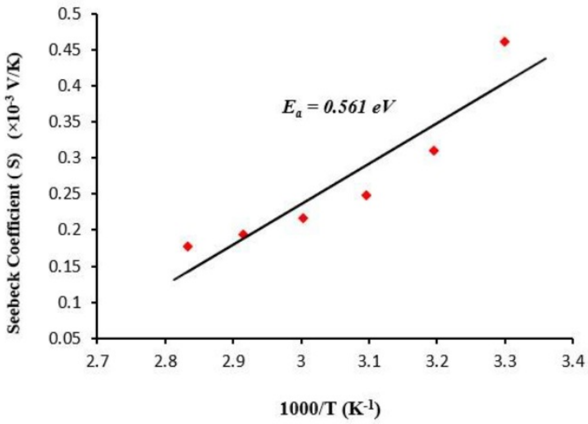

Figure 10: Temperature dependence of Seebeck coefficient for CdTe film

(0,177 to 10-3 V livres) at (353) kilometers. The value of activating energy (0.561eV) for thermostat power is calculated and shown from the linear components of Figure 10.

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