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Electrical Characterization of II-VI Thin Films for Solar Cells Application

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ABSTRACT

Cds and CdTe both are effective absorber semiconductors for thin-film solar cells. It is a naturally n-type material, which has a direct bandgap value of 2.42 eV at room temperature It has great importance in light detectors in this work, CdS thin films (TF) were synthesized on glass substrates by RF Magnetron sputtering technique in an inert gas atmosphere. The electrical properties of CdS were characterized by the Van Der Pauw method. The films showed p-type conductivity, while the films deposited at different annealed times exhibited n-type conductivity. The resistivity of the CdTe films decrease as the conductivity increased. As the source rate was increased, the hole concentration in the as-grown p-type CdTe films increased. It was also reported annealing process affects the electrical properties. Al doping CdS the value of resistivity becomes minimum as the resistivity becomes maximum although mobility has maximum value after an increase in Al doping the mobility value. As a result, the CdS/CdTe thin-film showed enhanced electrical properties for solar cell applications.

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1. INTRODUCTION

A thin film is the coat or layer of any material having its thickness changes from some micrometer to the nanometer. The thin film having a three-dimensional structure but looks like a two-dimensional structure. Thin films are formed by coating different materials on the substrates. It is the basic need for modem technology. There are excellent outcomes of thin-film technology in semiconductors physics, solid-state physics, and also in microelectronics engineering. By varying the thickness of the thin film, the properties of the thin film can be varied. Hence thin film as in crystalline form or amorphous form plays a very important role in recent technology like photoconductors, solar cells, superconducting films, magnetic sensors, optical devices, anti-corrosive, and decorating coating. Cadmium Sulphide, Cadmium Telluride and Zinc Sulphide, etc. are the elements of semiconductors of (II-V1). This film of semiconductors is very useful for designing a device.

Nowadays thin film is known as a two-dimensional nanostructure. Thin film is developed as two-dimensional nanostructures in the application of solar cells and electronics. There are many devices which are based on thin-film are fabricated in the industry of integrated circuits. Many optical devices can be attained by utilizing nanostructured thin film (Ottih & Ekpunobi, 2011).

CdS is an II-VI semiconductor material and physically occurred in yellow or brown color. It has two different minerals in nature as hexagonal greenockite and cubic hawleyite. CdS is naturally an n-type material with a direct bandgap of 2.42 eV at room temperature and are also used in light detectors. Thermally it is a stable pigment and has conversion efficiency and high absorption coefficient. For the applications of optoelectronics devices, CdS is a very interesting and helpful material like photo conducting cells, photosensor, and non-linear optical and integrated devices (Shaikh *et al*., 2019; Rosario *et al*., 2019).

2. METHODS

For sample preparation, we use RF magnetron sputtering for deposition of CdS thin film on a glass substrate. A thin film process, particularly when using semi-materials, is RF magnetron sputtering, often referred to as RF magnetron sputtering. A thin film is formed in this process on a surface that is put in a sealed jar. Effective magnets are used to ionize the metal target and allow it to settle in the form of a thin film on the substrate. The first step in the RF magnetron sputtering process in a sealed container is to inject a substrate material. The air is then removed, and in the form of a flame, the target substance, the substance that will make up the thin film, is released into the chamber.

Fragments of this material are ionized via the use of strong magnets. Now in the shape of plasma on the ground, the negatively charged target material lines up to form a thin film. From a few hundred to a few hundred electrons or molecules, the thickness of thin films can vary. Akbarnejad *et al*., (2017) in short, the synthesis involed: Steps Involved in RF Magnetron sputtering, Loading of substrate and target, Creation of vacuum pressure, Insertion of Argon gas, Production of glow discharge, Ejection of Target Atoms, Deposition on the substrate, Formation of CdS thin film.

3. RESULTS AND DISCUSSION

The goal of this study is to make CdS thin films and examine their electrical properties using Hall effect Measurements by the resistive heating method by RF magnetron sputtering.

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3.1. Hall effect Measurements

For the determination of mobility and carrier concentration in thin films, the measurement of Resistivity and Hall coefficients are necessary (Al-Jawad *et al*., 2017). Resistivity and Hall coefficients of the fabricated films were measure by employing Van Der Pauw Techniques (Ali *et al*., 2012).

According to Van Der Pauw, the specific Resistivity and Hall coefficients of a flat sample can be measured if the following condition is satisfied:

(i) The contacts are at the circumference of the sample.
(ii) The contacts are sufficiently small.
(iii) The sample is homogenous.

Figure 1 shows that at 0 min annealing time resistivity. It shows a maximum value of 12.5 ohm-cm after increasing the annealing time. The resistivity gradually decreases at 300 annealing time. The resistivity shows the minimum value, which is 6.1 ohm-cm.

From **Figure 1**, it is concluded the conductivity increase with the increase in annealing time there is a direct relation between annealing and conductivity, at 300 the conductivity has the highest value which is 0.16 (1/ohm-cm).

Figure 2 shows that at 0-minute annealing time mobility value is minimum after increasing the annealing time the Mobility gradually increased. At 300 annealing time, the mobility shows a maximum value which 50.1 cm2/sec.

At 0-minute annealing time, carrier density shows a maximum value even at 20-min annealing time. The carrier density maintains its value after increase the anneal time the carrier density gradually decreases. At 300-min annealing time, the carrier density shows the lowest value.

Figure 3 shows that at 20°C, the resistivity shows the maximum value. After increasing the temperature up to 55°C, the resistivity value suddenly decreased. At 150°C, the resistivity shows the minimum value. It means that with the increasing temperature, the resistivity value will be decreased.

Figure 4 shows that at 20°C, the conductivity shows a high value. After increasing the temperature up to 55°C, the conductivity value suddenly increases. At 150°C, the conductivity shows the maximum value. It means that with the increasing temperature, the conductivity value will be increased. This increase might be due to the decrease of residual defects and the increase of crystallite size. The conductivity of the films increases with the increase of either grain size and/or films thickness up to a certain limit (Jassim *et al*., 2013).

Figure 5 shows that from 20 to 100°C, the mobility shows the minimum value. From 100°C to onward, suddenly mobility value increased. And it reached the highest value at 150°C. It is because the result of the mean free path of the carriers decreases and the total number of collisions per carrier to travel a certain distance increase, consequently decreasing the carrier mobility.

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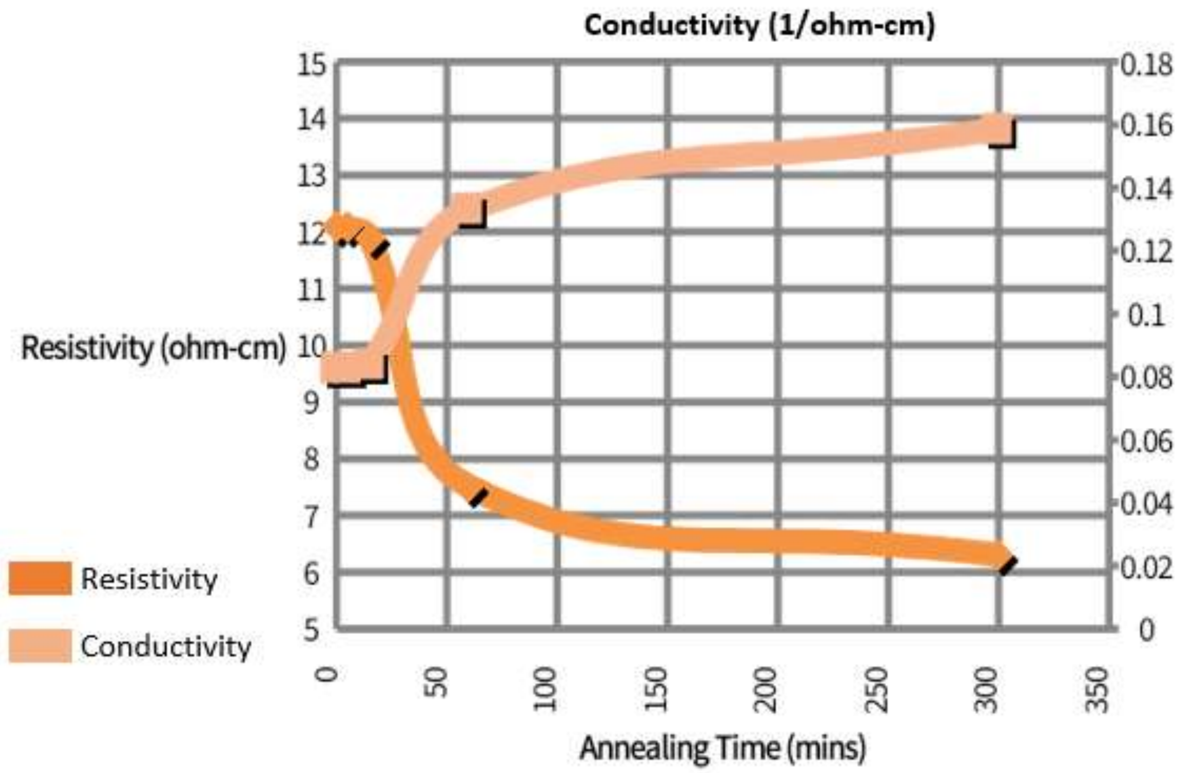

Figure 1. Effect of Annealing Time on CdTe Resistivity and conductivity.

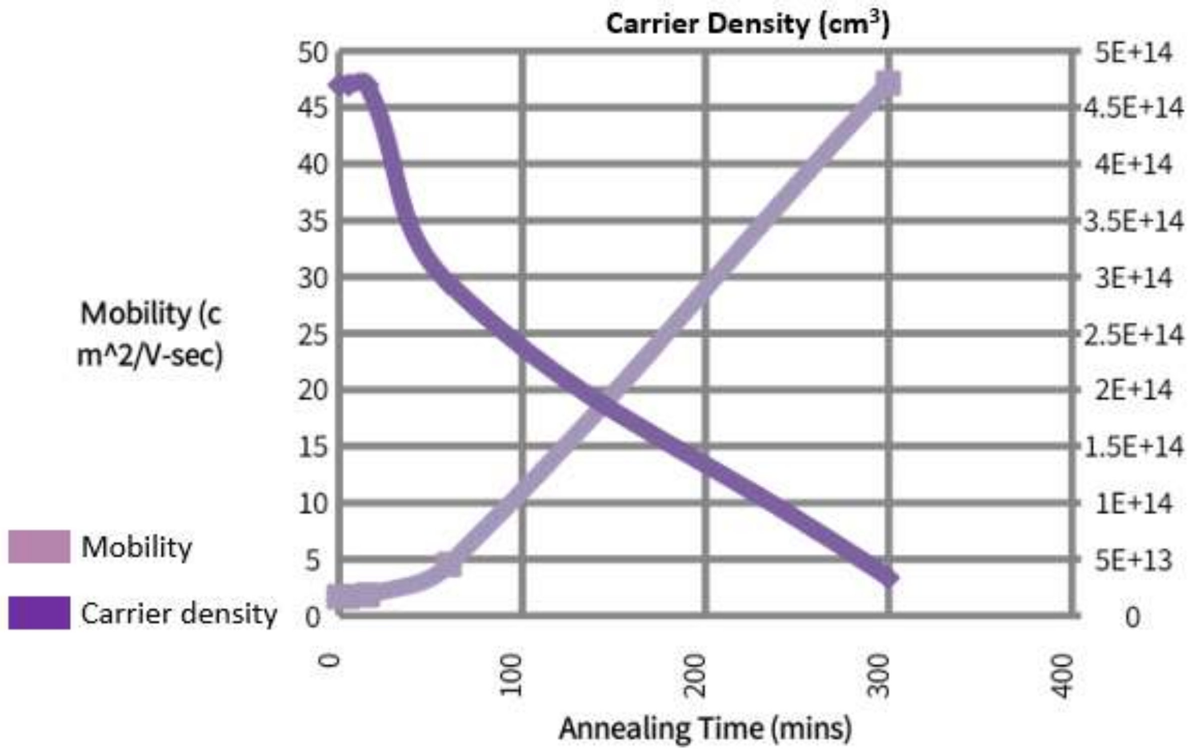

Figure 2. Effect of Annealing Time on CdS Carrier Density and carrier mobility.

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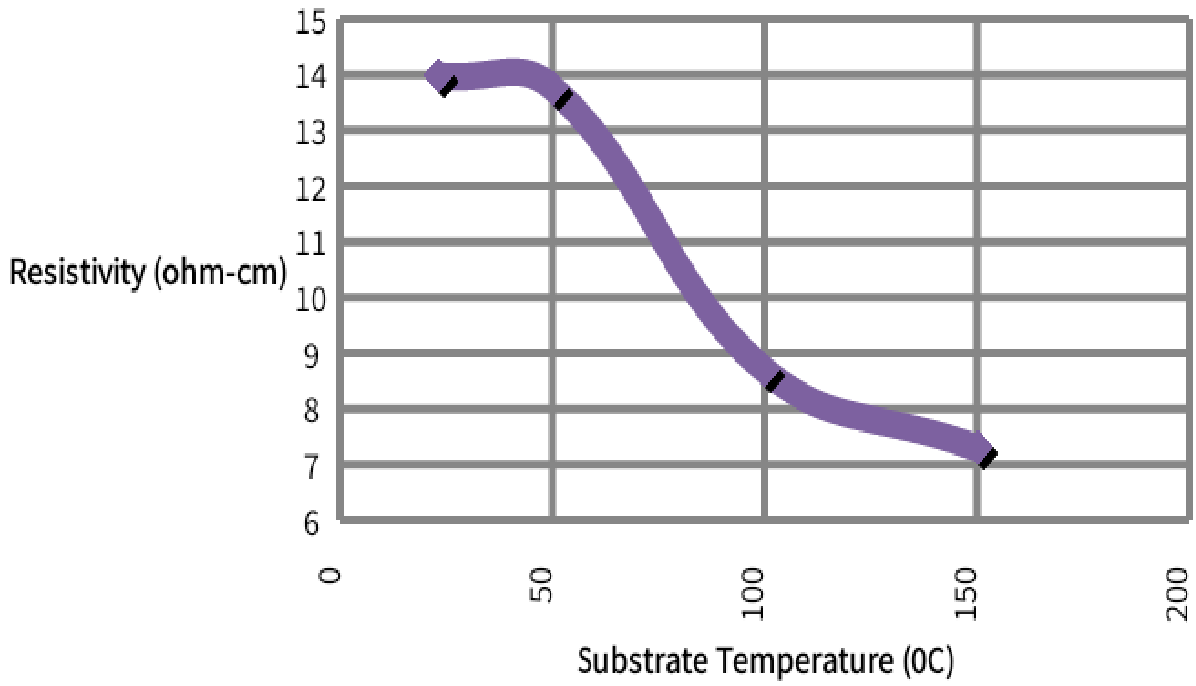

Figure 3. Effect of temperature on CdS carrier mobility.

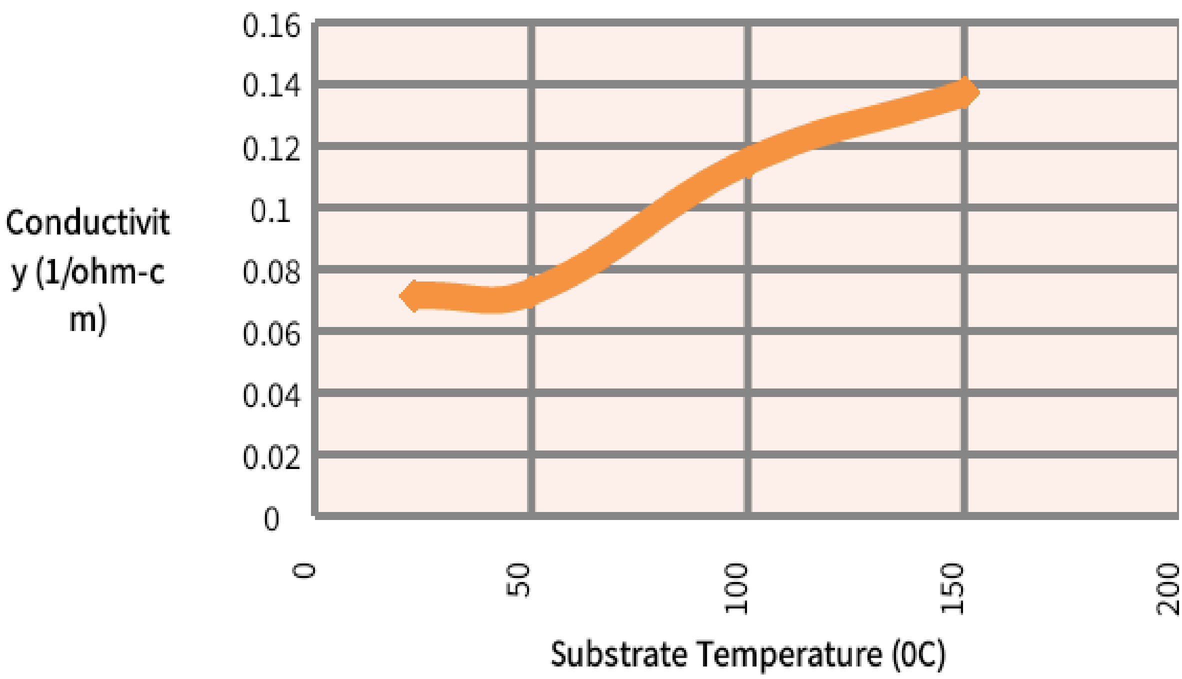

Figure 4. Effect of temperature on CdS Conductivity.

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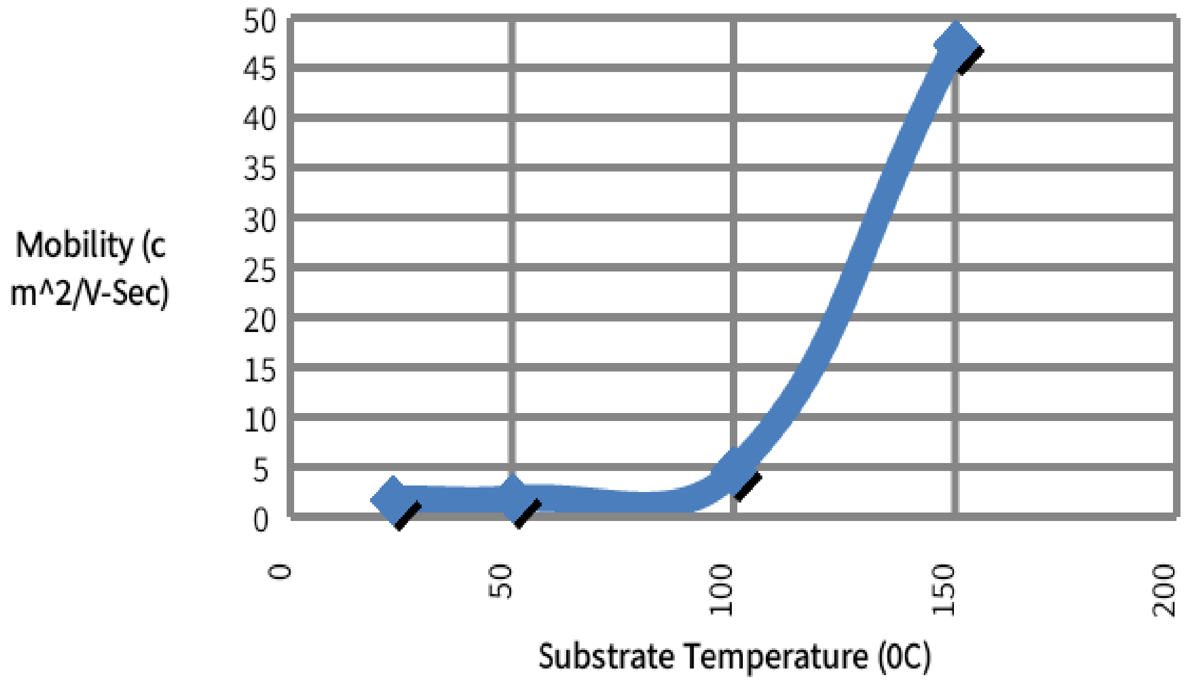

Figure 5. Effect of temperature on Cds carrier mobility.

Figure 6 shows that at 20°C, carrier concentration has the maximum value. After increasing the temperature, the carrier concentration value becomes lower and lower. At 150°C, carrier concentration has the minimum value.

Figure 7 shows that pure Al the value of resistivity is maximum. At 2, 4, and 6% of Al doping, the value of resistivity becomes minimum. When doping is increased up to 8%, the value of resistivity becomes increases and will be maximum. Up to 2% doping, conductivity remains the same. By adding more Al doping up to 6%, the conductivity will be maximum. At 8% of Al doping, the conductivity becomes decreased.

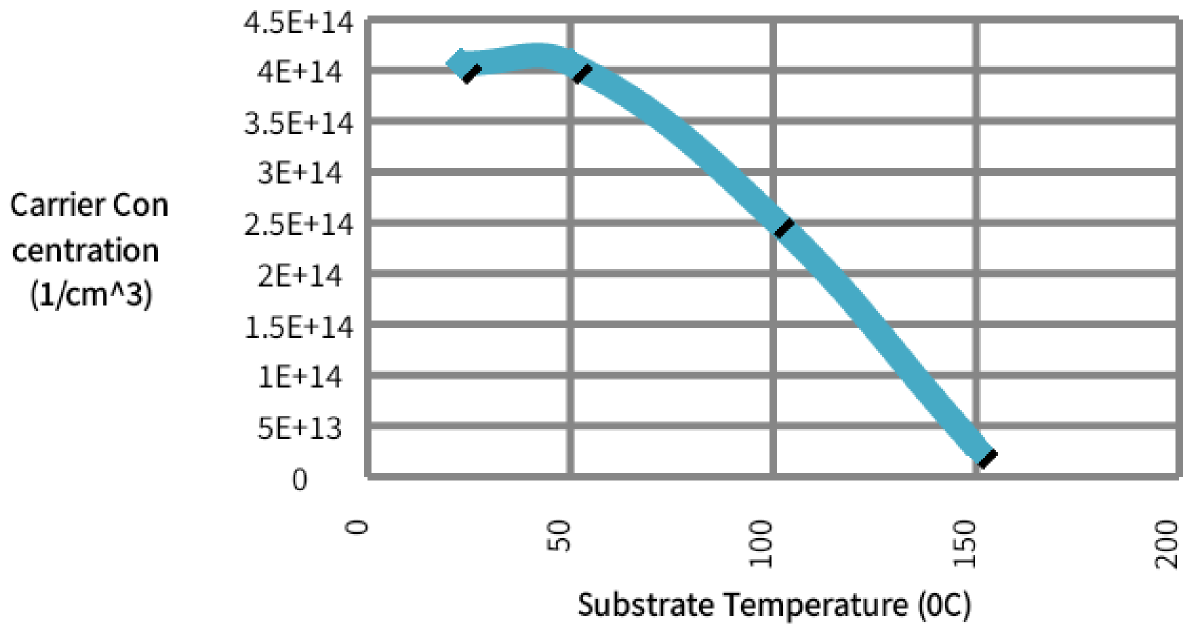

Figure 6. Effect of temperature on CdS carrier concentration.

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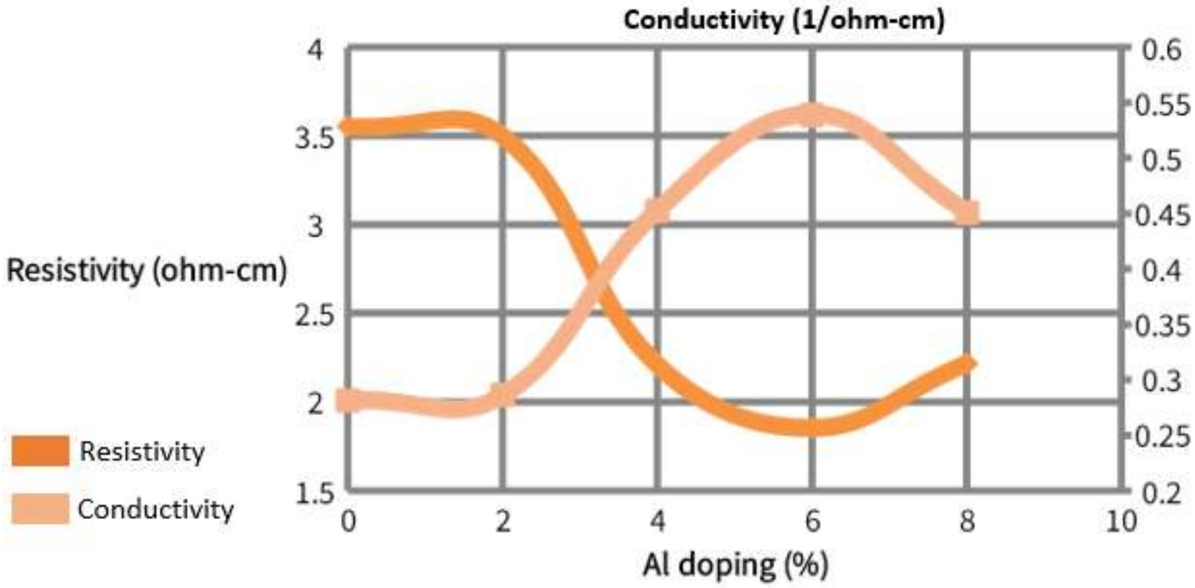

Figure 7. Resistivity conductivity Plotted versus Al doping (Al-doped in CdS).

Figure 8 shows that at 6% Al doping, the mobility has the maximum value. After increasing Al doping, the mobility value becomes decreased.
At 0 and 2% of Al doping, carrier concentration shows maximum value. At 6% of Al doping, carrier concentration has the lowest value. After increasing doping concentration, the carrier concentration value becomes increased.

Figure 9 shows that at pure the resistivity is maximum, but after doping, the value of resistivity becomes decreasing. At 8% of in doping, the value of resistivity becomes increasing. At 6% of in doping, conductivity shows maximum value. After that, the value of conductivity starts decreasing.

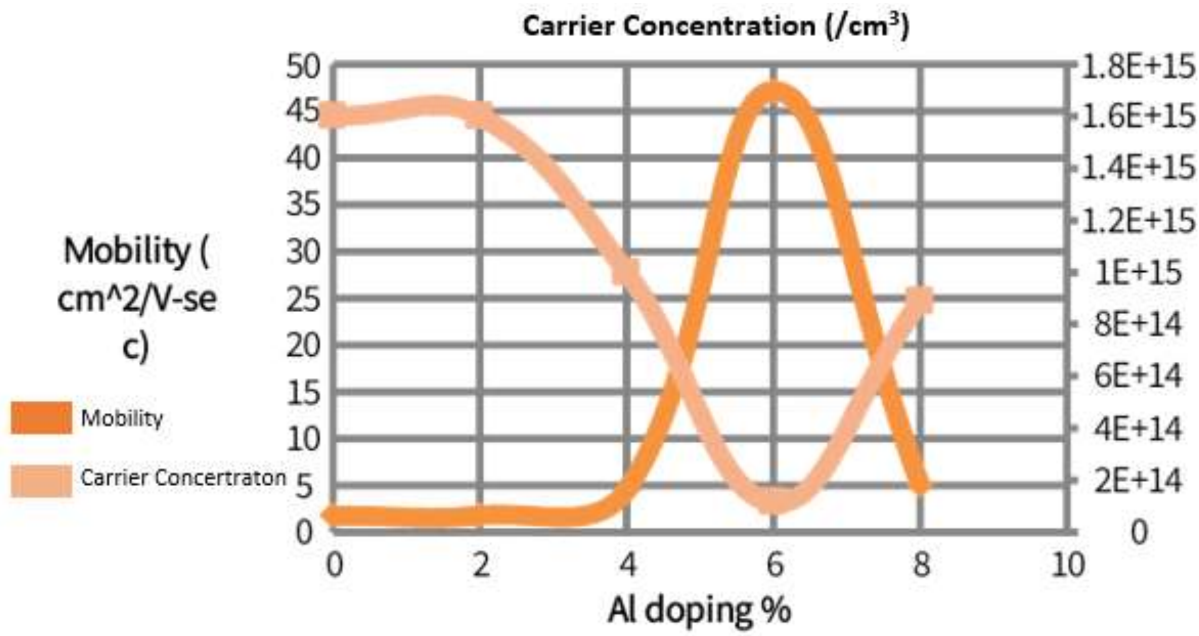

Figure 8. Mobility and Carrier concentration Plotted versus Al doping.

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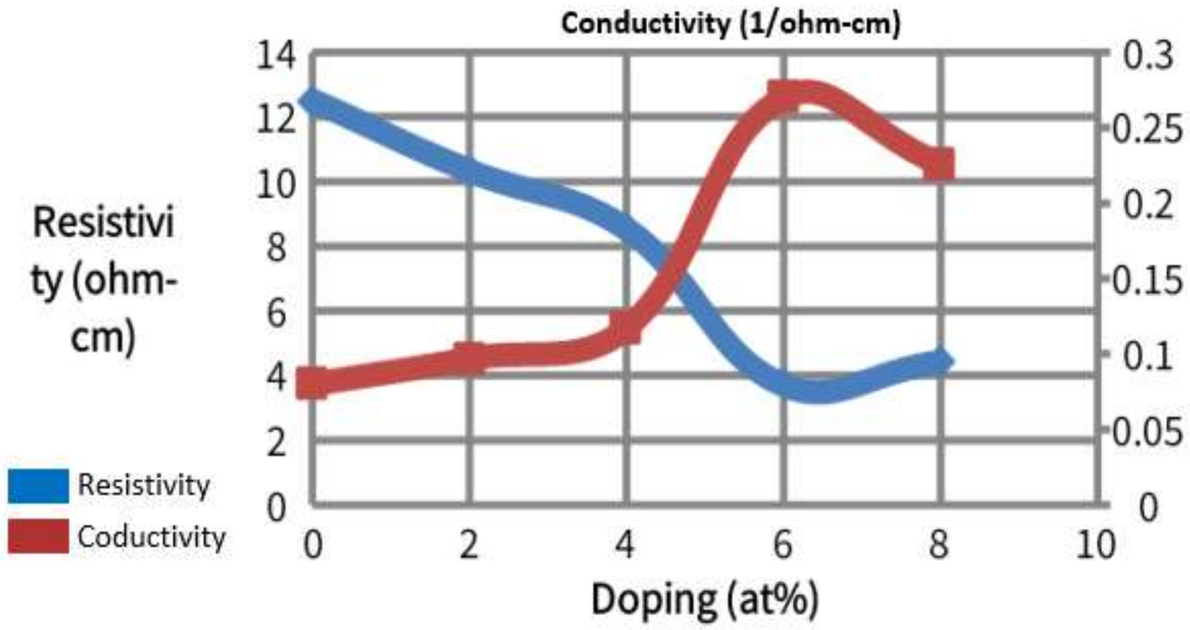

Figure 9. Resistivity and conductivity plotted versus in doping.

Figure 10 shows that at 6% In doping, carrier concentration has the maximum value. By increasing doping concentration, the value of carrier concentration starts decreasing. Mobility shows a little higher value than carrier concentration at 6% of in doping value. By increasing doping concentration, the value of mobility starts decreasing.

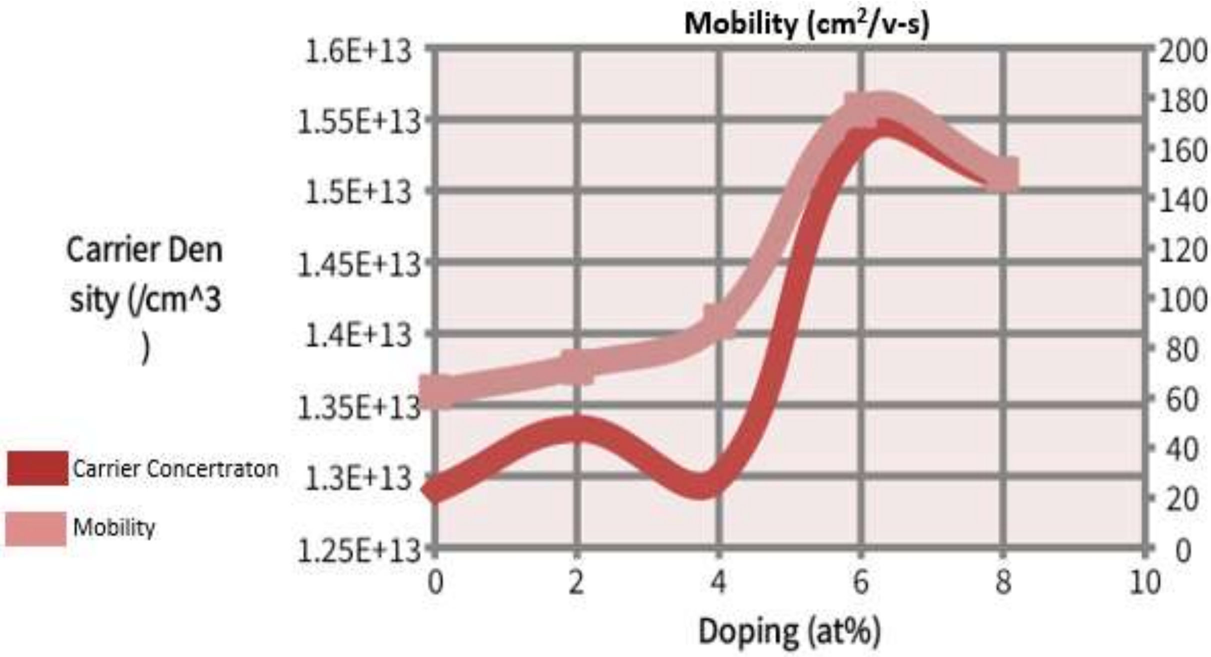

Figure 10. Carrier concentration and Mobility plotted versus in doping.

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4. CONCLUSION

The electrical properties of different functional layers, as well as the performance parameters of CdS and CdTe solar cells, may observe. The direct phase transition between the CdTe solid and gas state occurs congruently in the resistive heating technique. The key objective was to study resistivity, conductivity, mobility, and temperature. For different sources and substrate temperatures, both the p-type and n-type conductivity of CdTe was determined. The carrier mobility of the CdTe increased considerably as the source temperature increased from 20 to 150 degrees Celsius, whereas the Cds resistivity dropped as the source temperature increased. At 6% Al doping the Mobility have a maximum value after the increase in Al doping the mobility value becomes decreased. At 0 and 2% of Al doping, carrier concentration shows maximum value. At 6% of Al doping, carrier concentration has the lowest value. After increasing doping concentration, the carrier concentration value becomes increased. The electrical properties of the CdTe at 150°C of source temperature were found to be better than the counterparts deposited in dynamic condition.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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