V. H. N. SENTHIKUMARA NADAR COLLEGE (AUTONOMOUS)

(Affiliated to Madurai Kamaraj University, Madurai)

VIRUDHUNAGAR – 626 001, TAMILNADU

RESEARCH CENTRE IN PHYSICS

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Ph.D PUBLIC VIVA VOCE

As per the regulations of Madurai Kamaraj University, Madurai, **Mrs. K. DEEPALAKSHMI, (Reg. No. F8761),** Full Time Research Scholar, Department of Physics, V.H.N. Senthikumara Nadar College (Autonomous), Virudhunagar, will defend her thesis at a Public Viva-Voce examination through Video Conference mode using Google Meet Platform.

Title of the Thesis

PREPARATION AND CHARACTERIZATION OF THIN FILM FOR PHOTOVOLTAIC APPLICATIONS

Date & Time

29.06.2021 (Tuesday) at 11.00 A.M

Venue

Research Centre in Physics, V.H.N.Senthikumara Nadar College (Autonomous), Virudhunagar.

Video Conference Platform

Google Meet

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The Synopsis of the thesis is avilable in the College Website (www.vhnsnc.edu.in) and a copy of the thesis is available in the Department Library, for reference. Faculty members, Scholars and Students are most welcome to attend the Viva-Voce.

ALL ARE CORDIALLY INVITED

Place : Virudhunagar
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PREPARATION AND CHARACTERIZATION OF THIN FILM FOR PHOTOVOLTAIC APPLICATIONS

A thesis submitted to Madurai Kamaraj University, Madurai in partial fulfillment
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MADURAI KAMARAJ UNIVERSITY

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PREPARATION AND CHARACTERIZATION OF THIN FILMS FOR PHOTOVOLTAIC APPLICATIONS

SYNOPSIS

The renewable energy systems provide energy from sources that will never deplete. Among renewable energy sources solar energy attract more attention and many studies have focused on using solar energy for electricity generation. Here, in this study, solar energy technologies are reviewed to find out the best option for electricity generation. Using solar energy to generate electricity can be done either directly and indirectly. In the direct method, PV modules are utilized to convert solar irradiation into electricity. Even though the deployment of photovoltaic systems has been increasing steadily for the last 20 years, solar technologies still suffer from some drawbacks that make them poorly competitive on an energy market dominated by fossil fuels: high capital cost, modest conversion efficiency, and intermittency. From a scientific and technical viewpoint, the development of new technologies with higher conversion efficiencies and low production costs is a key requirement for enabling the deployment of solar energy at a large scale. A considerable amount of research has directed towards photovoltaic conversion solar energy cells using different types of materials like metals, metal oxides, chalcogenides etc.,

The thin films play a principal role in recent device technology. Thin film is a material layer having thickness from fractions of a nanometer to several micrometers. Thin films contain very large surface-to-volume ratio and therefore the surface generally influences the properties of the film significantly. Due to the compactness, better performance and reliability together with the low cost of production and low weight, thin film devices are favored more than its bulk counter parts.

The aim of this work is to grow cheaper and more efficient thin films. The attractive applications of thin films will also be considered in addition to their applications in agriculture, electronics and opto-electronic devices.

Cadmium Telluride (CdTe) absorber layer are one of the primary contenders for large-scale commercialization of the thin film photovoltaic. Cadmium Telluride is a compound semiconductor comprising of group II-VI elements having cubic zinc blend structure with a lattice constant of 6.481 Å. Many possible methods of depositing the CdTe layer, sol-gel dip coating has received the most attention.

For the fabrication of CdTe thin films with good surface, optical and structural properties and it is important to choose the deposition technique. Dip coating method is a simple and low-cost technique for the preparation of semiconductor thin films. The basic principle involved in dip coating technique is decomposition of salts of a desired compound to be deposited onto a substrate forming a single crystalline or cluster of crystallites as a product. It has ability to generate large area and high quality adherent films with uniform thickness. The deposition rate and the thickness of the films can be easily controlled by varying the dipping time. Doping is easy in this method with any element in any quantity and can be done simply by adding it in some form to the dipping solution. Due to the simplicity, cost effectiveness and the high-quality productivity on a large scale of this technique, it attracts the researchers for the fabrication of thin films.

The precursor solution 0.2 M of Cadmium acetate [$(CH3COO)_2$ $Cd.2H_2O$] was mixed with 50 ml of ethanol solutions were stirred for 30 mints to make a cadmium precursor solution. The color of the solution gradually changed into milky white and 10 ml of ammonia [NH_3] was added to this solution drop by drop to obtain a clear solution. 0.02M Tellurium salts were dissolved in concentrated H_2SO_4. Both the solutions were mixed in the 1:1 ratio and stirred for 7 hours. The appropriate solutions of Cd and Te mixed and homogenized by stirring at 60˚C. The final viscous mixture was used as a base solution for formation films. The complete description of the synthesis process is depicted and the synthesized products was used for further coating process.

Selection of substrates material plays vital role for the improvement of the CdTe lattice. The substrate material should have same ionic radii as the CdTe lattice. Glass, Fluorine tin oxide, silicon and porous silicon substrates are used to coat CdTe thin films.

In the present research work an attempt has been made to deposit, CdTe thin films on Glass, Fluorine tin oxide, silicon and porous silicon substrates by dip coating technique and a detailed study on the structural, surface morphological, optical and electrical properties have been done. The studies on photovoltaic properties of CdTe thin film on different substrates were done.

The CdTe thin films were prepared by sol-gel dip coating techniques on different substrates (Glass, FTO, silicon and porous silicon). The prepared CdTe films were characterized by XRD, SEM, AFM, PL, UV and I-V techniques. The summary of these results are given below.

CdTe thin films on glass substrate

CdTe thin films were coated on glass substartes and the prepared samples were annealed at different annealing temperatures 250ºC, 300ºC, 350ºC and 400ºC. From the XRD analysis has a cubic structure with higher peak intensity was observed in 400ºC annealed sample. The higher grain size and good crystalline nature was observed in 400ºC annealed sample. The grain size of the films was 49 nm. The SEM image revealed that the films have good morphological structure. The 400ºC have large grain boundaries.

The optical absorption study revealed that, the CdTe thin films, have allowed direct transitions. The optical band gap of the CdTe thin film coated on glass substrate annealed at 400ºC film exhibt the higher absorption and lower bandgap value of 1.64 eV. The high PL emission peak was observed in CdTe thin films coated on glass substrate with 400ºC annealed sample. Moreover, the observed electrical conductivity values indicate that the CdTe film on glass substrate prepared at 400ºC shows good electrical conductivity compared to other samples. From the above results, it is concluded that CdTe thin films were successfully deposited on glass substrate. Better result was observed at the annealing temperature of 400ºC.

CdTe thin films on FTO substrate

In order to improve surface morphology and structural properties, the CdTe thin films were successfully fabricated by the dip Coating method on Fluorine Tin oxide substrate (FTO) with different annealing temperatures 450^{o}C, 500^{o}C, 550^{o}C & 600^{o}C. The X-ray study reveals that the polycrystalline nature in all the films. The grain size of the films varies with annealing temperature from 33.62 nm to 69.55 nm. A sharp intense peak with good grain size was observed at 600^{o}C annealed CdTe thin film on FTO substrate.

The surface morphology of the film were studied using SEM and AFM. The entire surface area of the substrate is covered with large number of grains in all the films. The SEM analysis indicted that the spherical shaped particles are present at the 600^{o}C annealed CdTe films. The AFM results reveal the uniform topography of the films. The surface roughness of the films are about 36.43, 45.97, 49.56 and 53.27 nm respectively.

The decrease in optical transmittance and decreased energy bandgap values were observed at 600^oC annealing temperature of CdTe films on FTO substrate. The PL studies shows a higher emission peak at 690 nm in CdTe thin film on FTO substrate annealed at 600^oC. The band gap of the film changed into 1.57 eV to 1.52 eV for the annealing temperatures from 450^oC to 600^oC. The observed electrical conductivity values indicate that the CdTe thin films on FTO sample annealed at 600^oC shows good electrical conductivity and low resistivity than other annealing temperature of CdTe on FTO samples. The good UV response was observed in the CdTe film annealed at 600^oC sample on FTO substrate. Better result was observed at the annealing temperature of 600^oC.

CdTe thin films on Silicon substrate

The CdTe thin films were prepared on Silicon substrate with different annealing temperatures 450^oC, 500^oC, 550^oC & 600^oC by dip coating method. The XRD studies reveals that all the films exhibit polycrystalline nature. The higher (111) peak intensity was obtained in the CdTe thin film on Silicon substrate annealed at 550^oC. The grain size are 23.24, 34.14, 48.78 and 44.36 nm respectively for the annealing temperatures 450^oC, 500^oC, 550^oC & 600^oC. The plate-let like surface region begins to disappear and the film surface morphology gets modified with densely packed petal shaped grains are seen in the SEM images. This surface morphology may be due to the presence of some defects present in material along with siicon substrate.

The recrystallization process was observed at the annealing temperature of 550^oC sample. From the AFM results, the uniform morphological structure was observed in the 550^oC annealed sample. The lower optical bandgap was observed for the annealing temperature of 1.55 eV, which is observed from UV studies.

The PL studies shows the energy band gaps of prepared thin films. The energy bandgap of the film annealed at 550°C was ~ 1.8 eV with red emission peak. From the I-V studies, the CdTe thin films on Si substrate annealed at 550°C shows good electrical conductivity and low resistivity than other annealing temperatures of CdTe thin films coated on silicon substrate. The resistivity of the CdTe thin film on silicon substrate annealed at 550°C exhibit the higher conductivity value 0.0226 x 10^4 (mho m^{-1}) and lower resistivity value of 39.56 x 10^{-4} ohm/cm.

CdTe thin films on Porous Silicon substrate

In this chapter the porous silicon substrate were prepared from silicon substrate, by electrochemical anodic etching method. The CdTe thin films were deposited on prepared porous silicon substrates using dip coating technique. The CdTe thin films coated on PSi were annealed at temperatures from 450ºC to 600ºC. The XRD peak intensity is maximum at the annealing temperature of 600ºC. The grain size of the films are 11.45, 14.26, 15.51 and 21.82 nm respectively for the various annealing temperature.

The SEM studies reveales that the CdTe films coated on porous Silicon exhibits agglomerated grains with rod like structure over the entire surface of the substrate at 600ºC annealing temperature. This is reflects the tendency of the CdTe particles to minimize the surface energy and it's strongly influenced with crystallization process accure. The crack free topography results shows in AFM study.

The optical band gap of the CdTe thin film coated on PSi substrate annealed at 600ºC film exhibt the higher absorption and lower bandgap value. The PL study of the samples for all the samples shows good emission peak at 657 nm and the PL intensity increased with annealing temperature. The observed electrical conductivity values indicate that the CdTe thin films on porous silicon substrate shows good electrical conductivity and low resistivity than other annealing temperatures. From these above all conclusion, the substrate and annealing temperature of the films change the surface morphological property, optical and electrical property of the CdTe thin films on different substrates (glass, FTO, Si and PSi).

Heterojuctions

The metal conducts were given to the optimized CdTe/FTO, CdTe/Si CdTe/PSi hetero junction samples. I-V characteristics of the samples were made at under dark and UV light illumination condition. The good photo response value was observed for CdTe/PSi heterojunction. It confirms the CdTe thin films on porous silicon sample annealed at 600^{o}C shows good photo sensitivity. This film also have high photoconducting property compering with other substrate samples. The structural morphology, optical and electrical property of the substrates have vital role for these samples. The solar cell efficiency of the CdTe films on different substrates are also calculated.

The CdTe/PSi based photovoltaic device with 600^{o}C annealing temperature showed the better performance as compared to other two heterojuction. Comparing to other samples CdTe/PSi heterojunction has higher quantum efficiency (η) of 46% and the fill factor of 0.28. It is mainly due to the grain boundaries or crystallinity of the substrate, the passivation of grain boundaries, reduction in optical loss, internal strain recovery and reduction in lattice mismatch of the substrate as well as it improves the interface behavior. The annealing temperature and the lattice constant of the substrate also involved in the film formation. It also modifies the electrical, morphological and microstructural properties of CdTe thin films that enhances the performance of photovoltaic cells. So the CdTe/PSi structure can be a good candidate for designing of p-n heterojunction material can be used in photovoltaic cells.

As the future prospects, Mercury (Hg), Zinc (Zn) like dopants can be added to CdTe solution and to develop, doped CdTe/PSi heterojunction, which may have some good improvement in the performance in the photovoltaic applications.