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STUDY OF ELECTRICAL PROPERTIES OF CADMIUM SULPHIDE THIN FILMS WITH POLYANILINE FOR OPTOELECTRONIC APPLICATIONS

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ABSTRACT

A thin film of CdS and Polyaniline has been developed by vacuum evaporation technique for their electrical characterization in this paper. These prepared thin films then deposited onto glass as well as the metallic substrate. The glass substrate was thoroughly cleaned in aquaregia, washed in distilled water and isopropyl alcohol, prior to film deposition. The samples so prepared then subjected for their electrical measurements by using Keithley Electrometer. The conduction of charge across Polyaniline and CdS junction is typically a mixture of an electron from the n-CdS side and polaron & bipolaron from the p-PANI side. This heterojunction also holds the promise of being studied and converted into an active optoelectronic device for their application in the field. A relatively low value of fill factor and conversion efficiency can be attributed to the polycrystallinity of the CdS thin film and vacuum deposited PANI thin film, as they don't make extremely sharp and perfect heterojunction. The substrate has a strong influence on the surface morphology of the films. The junction characteristics of PANI/CdS thin films are complex of many conduction mechanisms and cannot be explained by simple theory.

KEYWORDS: *Heterojunction, Vacuum Evaporation, CdS, PANI*

Article History

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INTRODUCTION

The early development of semiconductors was centered on silicon, which gradually shifted to compounds semiconductors and much recently to an unexpected, entirely new class of material - the polymers. On the other hand, the polymers like plastics were rigidly regarded as insulators until Heeger, Mac Diarmid and Shirakawa discovered that these polymers can be made conductive - equivalent to metals [1]. The conductivity of polymers depends upon the doping with chains. This discovery fetched these scientists the Nobel Prize in Chemistry for 2000. The conducting polymers have numerous advantages over metals for being lightweight, flexible, relatively low cost and its possibility is much easier and simple. These can be processed at low temperatures than metals [2]. The semiconducting properties of polymers have triggered new enthusiasm in semiconductor physics, who have find application for optical & thermal sensors, chemical and gas sensors, solar cells, light emitting devices, thin flexible plastic display, conducting adhesive, transparent conducting and flexible conducting links, anti-static coating, electromagnetic shielding, molecular electronics, rechargeable batteries, conversion resistant coating etc [3-8]. Within a decade of time many polymers and their derivatives have emerged such as polythiophenes, phenylene-vinylene, polyfluorene etc. and are studied for their semiconducting properties [9].

The polyaniline has become the polymer of choice. It is a very stable processed and environment-friendly [10-11]. Its electrical properties can be customized easily. Recent research indicates its possible use in sensors, LED and other heterojunction devices [12]. The Polymeric thin films technology have already advanced to practical application in solar cells, detectors, sensors, optical memory devices, interference filters, xeroradiography, reflection, and anti-reflection coating etc. The heterojunction of n & p-type semiconductor is the criteria for photovoltaic, optoelectronic applications and sensors applications.

EXPERIMENTAL DETAILS

Sample Preparation

Cadmium Sulphide thin film on to highly cleaned glass as well as metallic substrate was prepared by employing vacuum evaporation technique, held at room temperature in a vacuum of the order of 10^{-5} torr. Cadmium Sulphide powder of 99.99% purity was evaporated at about 200°C from a deep narrow mounted molybdenum boat. The glass substrate was cleaned in aquaregia, washed in distilled water and isopropyl alcohol (IPA). The substrate was kept in a closed box with accuracy to avoid any dust particle on its surface.

Polyaniline is usually prepared by redox polymerization of aniline using ammonium perdisulphate, $(NH4)_2\ S_2O_2$ as an oxidant. Distilled aniline (0.02 M) is dissolved in 300 ml of pre-cooled HCl (l.0M) solution, maintained at 0-50°C. A calculated amount of ammonium perdisulphate, (0.05M) dissolved in 200 ml of HCl (1M), pre-coated to 0-50° C, is added to the above solution. The dark green precipitate (ppt) resulting from this reaction is washed with HC1 (l.OM) until the green colour disappears. This ppt is further extracted with terta-hydro furan and NMP (N-Methyl Pyrolidinone) solution by soxhelf extraction and dried to yield the emeraldine salt. Emeraldine base can be obtained by heating the emeraldine salt with ammonia solution. Simultaneously, the separate salt solution is prepared by dissolving the MX (M=Metal and X=Halide) in distilled water. The solution is then slowly added to the precooled polymer solution with constant stirring. The composite is then dried in an oven at a high temperature, to get the conducting polymer in the powder form. This powder is vacuum evaporated on to highly cleaned glass substrate as well as the metallic substrate.

Electrical Characterization

I-V Characteristics

To study electrical properties Schottky devised a model for metal-semiconductor contacts that is known as the Schottky barrier or effect. There are a variety of applications using metal-semiconductor contacts including the diode, transistor, FET etc. When a metal is brought into intimate contact with a semiconductor, the conduction and valence bands of the semiconductors are brought into a definite energy relationship with the Fermi level in the metal. The current-voltage measurements of semiconducting thin films with metal contacts reflect the diode characteristics. The I-V measurements are seen to closely follow the diode equation of Schottky barrier diodes. The current-voltage characteristics of CdS thin film on glass substrate is shown in figure 1.

The current-voltage characteristics of such type of sample in which the polymeric thin film of Polyaniline is evaporated on to the same sample as discussed above indicate a very interesting different type of conduction mechanism as shown in figure 2. Before illumination and after illumination junction characteristics illustrated in figure 3, indicate that these structures are a prerequisite for fabrication of microelectronic and optoelectronic devices.

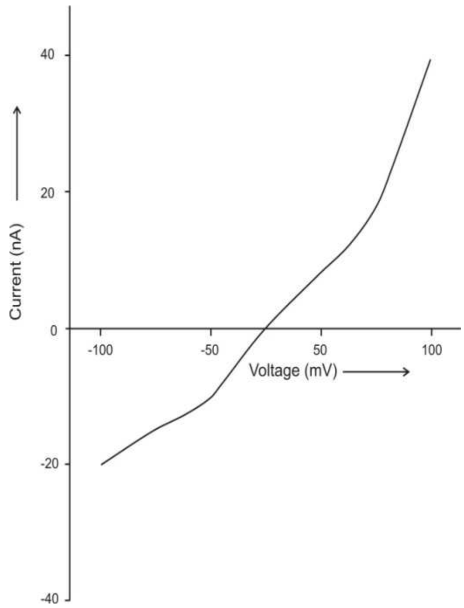

Figure 1: I-V Characteristics of CdS / Glass Substrate

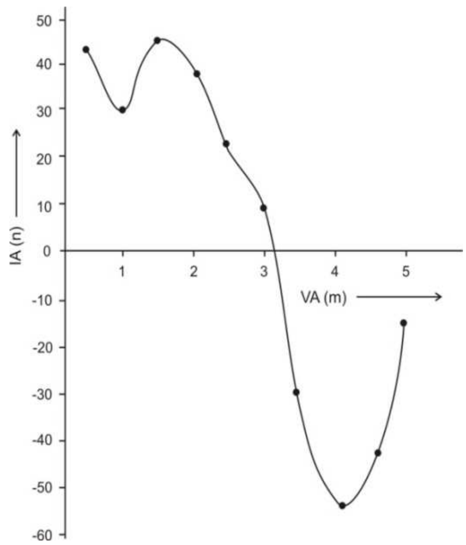

Figure 2: I-V Characteristics of PANI/CdS/Glass Substrate

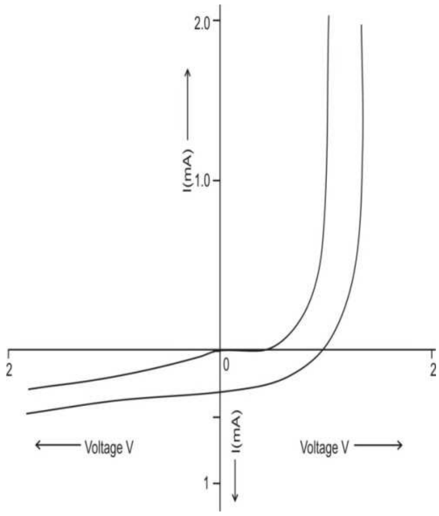

Figure 3: I-V Characteristics of Pani/CdS Junction

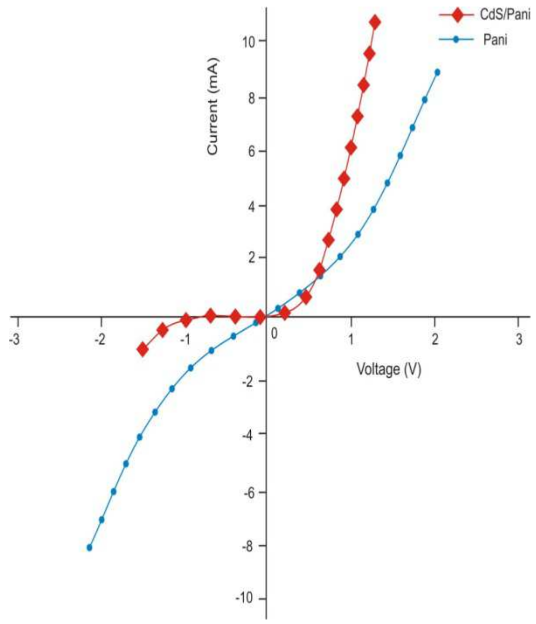

Figure 4: I-V Characteristics of Pani & CdS/Pani Heterojunction

PANI/CdS Thin Film Junction

In addition to the work done on Polyaniline/CdS thin films as discussed above, we have also tried junction of CdS thin film and Polyaniline pallet. The I-V characteristics of Pani and CdS/Pani junction are shown in fig. 4.

Polyaniline has been synthesized using Sol-Gel technique with chemical oxidation process. Thermal and environmental stability of the synthesized sample of PANI is investigated by measuring the thermal transport properties of the samples at different temperatures and time using Transient Plane Source (TPS) technique. The results indicate that the PANI shows excellent thermal and environmental stability. Chemically prepared Cadmium Sulphide has been printed on a pallet of conducting Polyaniline (of 1.2 cm diameter and 2 mm thickness). This pallet of CdS coated conducting Polyaniline has been sintered at 150° for six hours for ensuring better adhesion. The I-V characteristics of CdS, conducting Polyaniline and CdS coated conducting Polyaniline have been recorded at room temperature using Keithley electrometer. The results indicated that I-V of CdS is ohmic whereas that of conducting Polyaniline is observed to be non-ohmic. PANI is a p-type material and CdS is an n-type material. The junction formed in CdS coated PANI is a p-n junction. I-V characteristic of this junction shows a diode characteristic. This confirms that a good diode can be fabricated by using such a simple technique.

RESULTS DISCUSSIONS

From experimental studies, it has been concluded that in Polyaniline and Cadmium Sulphide junction the conduction of charge across the junction is typically a mixture of an electron from the n-CdS side a polaron and bipolaron from the p-Pani side. In addition to observing a thermionic emission, Schottky I-V characteristics are also observed, a pool frankly and trap-assisted field emission, a non-linear behavior. The junction characteristics of Pani/CdS thin film are complex of many conduction mechanisms and cannot be explained by simple theory. The n-CdS and p-Pani heterojunction also hold the promises of being studied and converted into an active device. The low value of fill factor and conversion efficiency can be attributed to the polycrystallinity of the CdS thin film and vacuum deposited Pani thin film, as they do not make an extremely sharp perfect heterojunction. The reported characteristics make it suitable for optoelectronic applications.

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