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DC Electrical Conductivity of Unfilled and CdS Filled PEO Nanocomposite Thin Films

ROSHANI N. BHAGAT
Asst. Prof., Department of Physics, Rajarshee Shahu Science College, Chandur Railway, Amravati, India
Author for correspondence [1](roshanibhagat04@gmail.com)

Abstract.
Thin film nanocomposites, consisting of CdS nanoparticles embedded in a PEO matrix, were synthesized using solution evaporation technique. The electrical conductivity of these composites was measured at various concentrations. Dark I-V relationship and also, I-V relationship of irradiated composite samples was studied. The radiation induced conductivity also studied which gives that, the irradiated sample radiation induced conductivity increases with temperature. The variation in activation energy values which are calculated from the Arrhenius relationships shows ionic conduction in composite samples

Keywords. Nanocomposite thin film; CdS; PEO; I-V relationship, Radiation induced conductivity

1. Introduction

The surface conduction is the excess electric conduction tangential to a charged surface and originates from the excess counter ions. The corresponding electrical conductivity is called the surface conductivity. The electrical properties of composites are closely related to the morphology of the embedded nanostructures, which are dependent upon both film thickness and filler concentration. I report here on the correlation between the electrical conductivity of unfilled PEO and CdS filled PEO at different weight percentage that is 1, 5, 10 and 15 by weight and their microstructures as a function of both temperature and filler loading

2. EXPERIMENTAL

2.1 *Synthesis of unfilled PEO and CdS filled PEO nanocomposite thin film*

In this work poly (ethylene oxide) (M W 4,000,000) is used obtained from CNR (Nopoli-Italy). Composite thin films of unfilled PEO and CdS filled PEO were prepared by solution evaporation technique. Before casting the mixture solution of PEO and CdS was stirred for two hours using magnetic stirrer so that the CdS Nano powder uniformly mixed with PEO solution. Then the mixture was cast on a leveled glass substrate and was allowed to evaporate the solvent at room temperature under normal atmospheric pressure. Then after completing evaporation, the film was detached from surface. Composite thin films of PEO with 1, 5 10 and 15 weight percentage of CdS were dried at room temperature for two days. In this way, the thin films of unfilled PEO and CdS filled PEO were prepared by solution evaporation technique. [1].

CdS nanoparticles are produced in gram scale.

3. Result & Discussion

3.1 Current-Voltage Characteristics of Composites

A current-voltage characteristics is a relationship, typically represented as graph between the electric current through a circuit, device or material and the corresponding voltage across it. While I-V curves are applicable to any electrical system, they find wide use in the field of biological electricity, particularly in the sub-field of electrophysiology. There are many workers who worked on I-V characteristics curve. (2, 3, 4]. On the whole, the above researchers mainly focused on the influence of the content and dispersion of CdS on the electrical properties of the composites.

In this part, an experimental investigation on the I-V characteristics of the epoxy matrix composites containing different concentration of CdS is presented. The influence of the exposure to an electrical field, which may cause the electrical breakdown of epoxy resin, on the composites containing different concentration of CdS has also

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been experimentally studied. An attempt has been made to assess the predominance of the Poole–Frenkel conduction mechanism in composite thin films at room temperature and higher ambient temperatures. A suitable optical arrangement was made to illuminate the sample uniformly, for illumination two types of light source are used in which first is ordinary light source and second is infra-red-light source. Irradiation effect is now used for several purposes like food irradiation, sterilization of surgical equipment's, polymerization. In present work ordinary light and infrared light have been used for irradiation purpose. High ambient temperatures were achieved by using a dimmer connected across a coil and temperatures were measured with the help of a temperature sensor. Photocurrent and dark currents were measured with the help of a nanoammeter. I-V characteristics has been studied for unfilled PEO and CdS filled PEO composite thin films and are as shown in Fig. 1

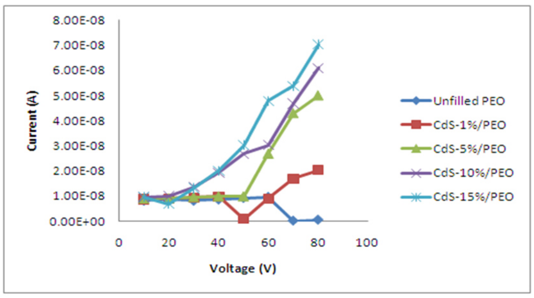

Fig 1: Dark I-V characteristic for unfilled PEO and CdS-1%/PEO, CdS-5%/PEO, CdS-10%/PEO, CdS-15%/PEO samples.

From Fig. 1, it is observed that for all composite samples, initially as voltage increases current become constant upto 20 V but for unfilled sample it is constant upto 60 V, after that current gradually decreases becomes negligible. For 1 weight percent of CdS filled PEO sample, as current increases voltage become nearly constant upto 20 volts after 40 volts current gradually decreases upto 50 volts and after 50 volts, it shows sharp increase. For 5 weight percent of CdS filled PEO sample, current remains constant upto 50 volts, and after that it increases gradually. For 10 and 15 weight percent of CdS filled PEO sample. Initially upto 20-volt current remains constant and then it slowly increases. Thus, from Figure 1 it is observed that in the absence of light, at room temperature voltage increases dark current also increases and current is found to be higher for higher concentration of CdS in PEO as compared to unfilled PEO sample. Unfilled and CdS filled PEO composite thin film exposed to an electric field. The distance between the positive and negative electrode was 2 cm. The current was measured by the nanoammeter at each voltage level. The Current-Voltage relation for the composite samples containing different concentration of CdS are shown in Fig. 2 (a) and (b) irradiated by ordinary light and infrared light respectively.

From Fig 2 (a), the I-V characteristics of the composite's samples are nonlinear. For unfilled PEO sample current increases gradually with increasing applied voltage. For 1 weight percent CdS filled PEO sample, as voltage increases current remains constant upto 40 volts, beyond 40 volts, it gradually increases. For 5 weight percent CdS filled PEO sample current becomes slowly increases upto 20 volt and then it increases rapidly. For 10 and 15 weight percent CdS filled PEO samples with the increase of applied voltage, current increase sharply that is for all samples current increases non-linearly with increasing voltage. As concentration of CdS in PEO composite sample increases current gradually increases with time having high current range in higher loaded {CdS} sample than lower loaded in PEO sample.

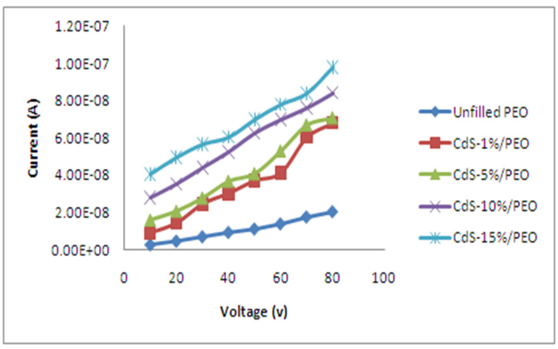

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Fig 2: I-V plots for unfilled PEO and CdS-1%/PEO, 5%/PEO, CdS-10%/PEO, CdS-15%/PEO samples irradiated by ordinary light.

In Fig. 2 (b) {all samples irradiated by infra-red light} the plots indicate at room temperature, current increases linearly as voltage increases. Only the rate of increase of current with applied voltage is slow in case of lower weight percent that is for 1 and 5 weight percent CdS filled PEO samples. The order of current in CdS/PEO sample is found to be greater than unfilled PEO sample. As we compare the plots 2 and 3, for all samples as voltage increases current increases. When infrared light source was used for irradiation, the rate of increase of current somewhat higher than ordinary light. All these results can be explained as follows.

According to [5] polymers and composite polymers are insulating or poorly conductive in the dark and more conductive when illuminated at room temperature. It is observed that as voltage increases, dark current also increases which is less conductive than irradiated composite samples {CdS/PEO}. The non-linear increase in current can be explained by the conduction mechanism of filled polymer semiconductor composites. In doping process, the insertion of CdS into the insulating polymer system takes place over the bulk volume of the material rather than just at the surface and as a result, a very large amount of charge carriers is produced per unit volume. Also, the conduction mechanism in polymers is very different compared to intrinsic semiconductors. Here the negative or positive charges initially added to the polymer chain upon doping do not simply begin to fill the rigid conduction or valence bands. In polymer there are no permanent dipoles. However, there exists random charge trapping in the sample. Under the influence of applied external field, a strong coupling between electrons and phonons hence charge trapping results into strong an effective electric dipole. As the applied field increases the formation of polarons and bipolarons increases with contributes to the rapid increase in current with respect to applied voltage and get non-linear I-V curve [6].

As observed in SEM images [1] Fig. 3 for all samples, can easily form global agglomerations and disperse in the polymer matrix uniformly. The increase of filler content will increase the number of CdS nanoparticles. The increase of number of CdS nanoparticles will decrease the thickness of epoxy resin gaps between CdS agglomerations and this will increase the conductivity of composite sample [7]. Therefore, the conductivity of composites increases slowly with the increase of content of CdS shows in fig. 1, 2 (a) and (b) resp. When the content of synthesized CdS [8] is less than the distance between two CdS agglomerations decrease with the increasing of content of CdS. Then the conductive channels are formed and this led to the sharp increases of the conductivity. When the content of CdS is more than the thickness of epoxy resin gaps between CdS agglomerations will not decrease further more. So, the conductivity of the composite increases slowly with the increasing of CdS content.

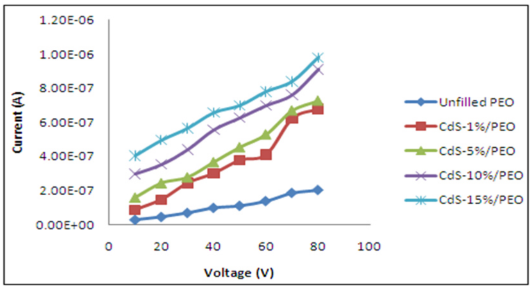

Fig. 3: I-V plots for unfilled and CdS filled CdS-1%/PEO, CdS-5%/PEO, CdS-10%/PEO and CdS-15%/PEO samples irradiated by infra-red light.

For irradiated composite samples, electron hole pairs are generated as soon as voltage is applied. Because sample is an electron transporting material hence photo generated electrons can readily flow into the surface. As a result, a net increase in the output current is recorded with increasing voltage [9]. Excitation of radiation creates equal numbers of holes and electrons. The electrons are pumped into conduction band and gets trapped in a shallow trap or lost by falling into a ground state and eventual recombination. The inverse process occurs with the holes. This excitation of free electrons in conduction band and free holes in valence band are under the action of electric field and gives rise to a conduction current [10].

From observations it is concluded that, in the case of dark, I-V relationship at room temperature, voltage increases, dark current also increases which is less conductive than irradiated composite thin films. And in case of I-V relationship of irradiated composite samples, a composite containing CdS has thinner epoxy resin gap and easy to form catenulate CdS agglomerations. If this CdS composite is under an electric field, some thin epoxy resin gaps that are broken down will change into conductors, the conductivity of the CdS composite will be irrecoverably and dramatically increased by the electric field treatment. The conductivity of composites containing conductive CdS increases gradually with the increasing of content of CdS. From this all the irradiated composite thin films increase in current is observed for increase in voltage. Increase in current is also observed increasing concentration of CdS in PEO. And current range of irradiated composite thin films by infra-red light greater than ordinary light.

4. Conclusion

From dark I-V characteristic curves for unfilled PEO CdS/PEO composite thin films and for all concentration of CdS, it is found that I-V relationship is not linear for unfilled polymer (PEO) and low weight ratio composite while above threshold voltage it is turn towards linear relationship. The range of dc current for CdS/PEO nanocomposite is $\approx 10^{-8}$ $(\text{ohm/cm})^{-1}$. Also, the conductivity of composite for polymer composites increases slowly with the increase of content of CdS. When the content of CdS reaches the threshold voltage, the distance between two CdS agglomerations decreases with the increased of content of CdS. Then the conductive channels are formed and this led to the sharp increases of the dc conductivity. When the content of CdS is more than percolation threshold, the thickness of epoxy resin gaps between CdS agglomeration will not decrease further more. So, the conductivity of the composite increases slowly with the increase of CdS content. For CdS/PEO nanocomposite thin films irradiated by ordinary and Infra-red light at room temperature. I-V curves are non-linear and linear respectively. That is for all composite samples irradiated by ordinary radiations, current increases gradually with increasing applied voltage only; the rate of increase of current with applied voltage is slow in case of lower weight percent of CdS. The range of current CdS/PEO nanocomposite sample irradiated by ordinary light is in the order of 10^{-7} (ohm/cm$)^{-1}$. Thus CdS/PEO nanocomposites gave better results when irradiated by infrared radiations.

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