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SYNTHESIS AND ELECTROLUMINESCENCE STUDIES OF CDS/PVK NANOCOMPOSITES

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Abstract: CdS/PVK nanocomposites have been successfully prepared by chemical method. The size of the particle was varied with different CdS loading. The XRD pattern showed that the CdS nanoparticles has zinc blend structure and line broadening suggests the formation of amorphous compound. The AFM and SEM studies show the clusters of particles in the range of a few tens of nm. The results obtained from XRD, SEM and AFM studies show increase in particle size, by increasing the CdS concentration in PVK. The EL emission starts at higher threshold voltage for higher frequencies and lower threshold voltage for higher concentration of CdS in PVK. The EL intensity of the composites increases with increasing concentration of CdS in PVK. Beyond a particular concentration (30%) of CdS nanoparticles, saturation occurs in the EL intensity. The V-I studies show the linear relationship between current and voltage which indicates the ohmic nature that is there is ohmic contact between samples and electrodes. V-I property of the devices depends on the strength of the electric field. The slope indicates that, the impedance decreases as we increase the frequencies.
Keywords: Electroluminescence, nanocomposites, XRD, CdS, PVK.

1. Introduction

Semiconductor nanoclusters comprise a burgeoning area of materials science that has great potential for many optoelectronic applications and have attracted much attention in the past few years because of their size, shape and surface dependent unique physical and chemical properties [1-4], nonlinear optical behavior [5-6] and unusual fluorescence [7-8]. CdS is a well known inorganic semiconductor. Hybrids of CdS nanoclusters and PVK promise both the excellent carrier generation efficiency and mobility of the inorganic semiconductor and the processibility of the organic polymer [9-13]. The optical and electrical properties of nanomaterials can be controlled by their particle size and therefore attracted much interest for their fundamental and applied aspects [14-18].Poly N-vinyl carbazole (PVK) is a hole transport organic semiconducting polymer. It has been widely used as an electronic and optical material [19]. CdS is a well known inorganic and wide band semiconductor that has been a subject of considerable research due to its potential application in the areas of spin-electronics, opto-electronics, sensors, photocatalyst etc [20-23]. Previously, the nano composite of CdS/PVK was prepared simply by mixing PVK and CdS nano cluster or their precursors were prepared by simply mixing the synthesized nanoparticles with polymer. The effect of the inevitably introduced precursor molecules or the synthesized semiconductor nanoparticles is not clear to date, further more the conventionally synthesized semiconductor nanoparticles have a tendency to aggregate into larger clusters and their fine dispersion in the polymer is not very easy. Khanna et al [24] have reported that the careful preparation of CdS nanoparticles in DMF with metal rich surface can be considered responsible for stable light emission [25-27]. This desire has promoted us to extend the synthetic methodology to functionalized and non- functionalized polymers. Polymers are considered a good choice as matrix materials for such purpose due to their long time stability and because they possess flexible reprocessibility. Present studies have been undertaken to synthesize CdS/PVK nanocomposite with various loading of CdS and Study their electroluminescence properties and investigated their I-V characteristics.

2. Experimental

For the synthesis of nanocomposite CdS/PVK films, 400mg of poly N-vinyl carbazole (PVK) was dissolved in dimethylformaldehide (DMF) by constant stirring and heating at 80ºC temperature. Cadmium acetate was added to the solution as 10, 20, 30 40 and 50% weight of PVK, so that CdS loading in polymer equivalent weight. The resulting solution was stirred for 30 minutes. The solution was refluxed by applying nitrogen and then H_2S gases for a 30 second. The solution immediately turned turnip yellow. Now again the solution was stirred for a few seconds. The chemical reaction as follows:

$$PVK + Cd(CH_3COO)_2 + H_2S \rightarrow CdS/PVK + 2CH_3COOH$$

Then the solutions were caste over glass slides and conducting glass plates and were dried in an oven for several hours to obtain uniform film of CdS/PVK nanocomposite. For study of I-V characteristics and electroluminescence of nanocomposites of CdS/PVK thin film sandwiched between conducting glass plate and thin film of aluminium foil.

3. Results And Discussion

Surface analysis: Surface analysis of CdS/PVK nanocomposites such as XRD, SEM and AFM pattern shows increase in particle size, by increasing the CdS loading in PVK [28].

Electroluminescence: Electroluminescence (EL) is an optical and electrical phenomenon in which a material emits light in response to an electric current passed through it, or to a strong electric field. Electroluminescence is the result of radiative recombination of electrons and holes in a material (usually a semiconductor). The excited electrons release their energy as photons i.e. light. Prior to recombination, electrons and holes are separated either as a result of doping of the material to form a p-n junction (in semiconductor electroluminescent device such as LEDs); or through excitation by impact of high energy electrons accelerated by strong electric field (as with the phosphors in electroluminescent displays) [29].

For electroluminescence studies, EL power supply with audio frequency generator was used to apply A.C. voltage of various frequencies at conducting glass plate and aluminium electrode which contain the sample in between them. The EL brightness as different voltage was measured by a photomultiplier tube connected to a pico-ammeter. Electroluminescence of CdS/PVK composite thin film with different CdS concentration in PVK has been recorded at various voltage and frequencies, and characteristics of the samples have been drawn. On the basis of recorded data following characteristics were studied:

Brightness-Voltage Characteristics

The voltage dependence of EL brightness of CdS/PVK films was studied at different concentrations for different frequencies. The voltages brightness characteristics of pure PVK and 50% CdS loading in PVK, for frequencies 600 Hz, 800 Hz and 1000 Hz are shown in Fig.(1). It is observed from the graphs that: The brightness increases with the applied voltage at a given concentration of CdS in PVK for different frequencies. At a particular frequency emission starts at a threshold voltage and then increase with increasing voltage. The EL emission starts at higher threshold voltage for higher frequencies as shown in Fig.(2).

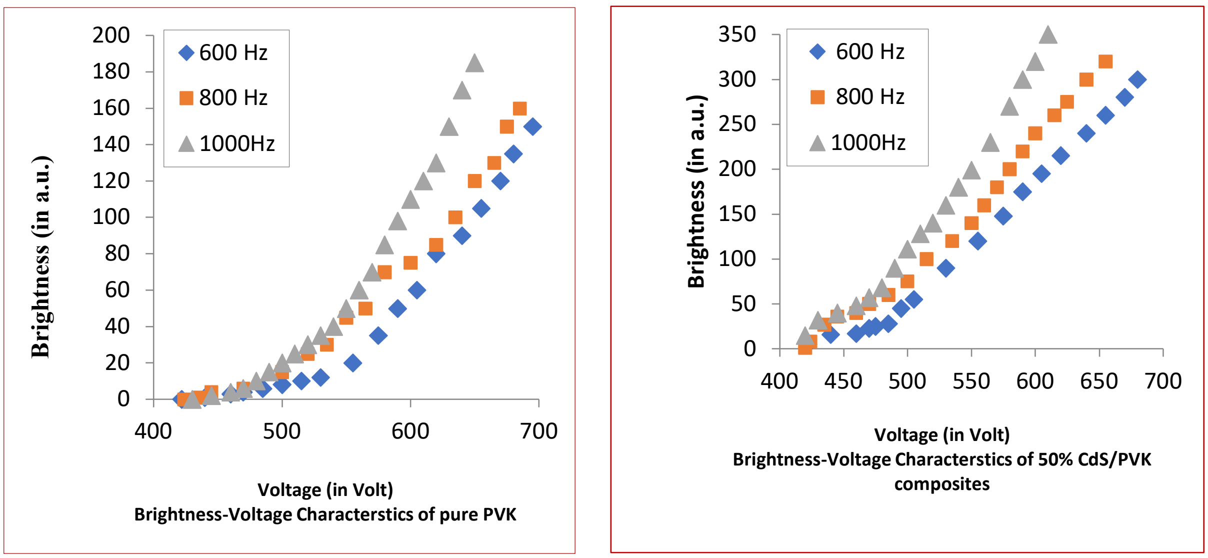


Fig. 1 Brightness-Voltage Characteristics of pure PVK and 50% CdS/PVK Composites at different frequency

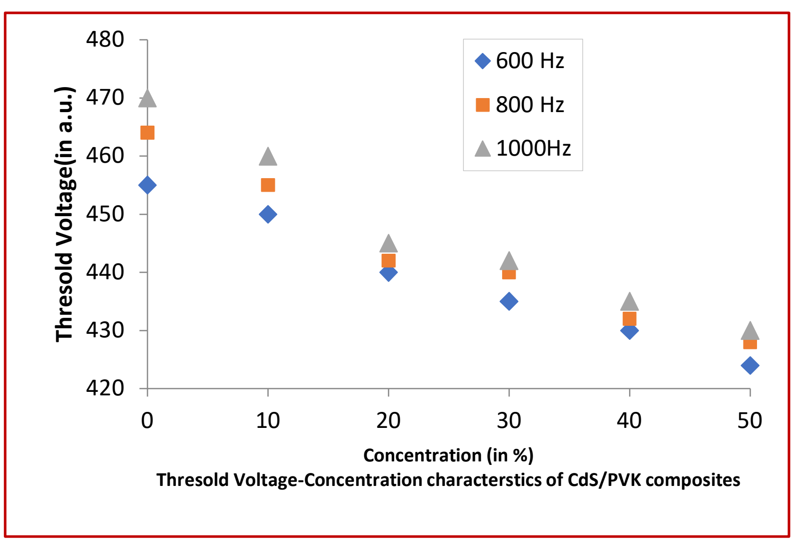


Fig. 2 Threshold Voltage with different CdS Concentration in PVK.

The fig.(3) shows that, brightness increase as we increase the concentration of CdS in PVK. EL emission starts at a lower threshold voltage for higher concentration of CdS in PVK and increases rapidly with increasing voltage. In the EL mechanism of semiconductor nano crystal, the electrons and holes injected from respective electrodes would recombine inside the semiconductor nanocrystals, and characteristics light would be emitted as a result. As voltage is increased, more electrons and holes are injected into the emission layer and their subsequent recombination increases the EL brightness. For higher concentration of CdS/PVK, which improve the electron-hole radiative recombination and enhance the electroluminescence.

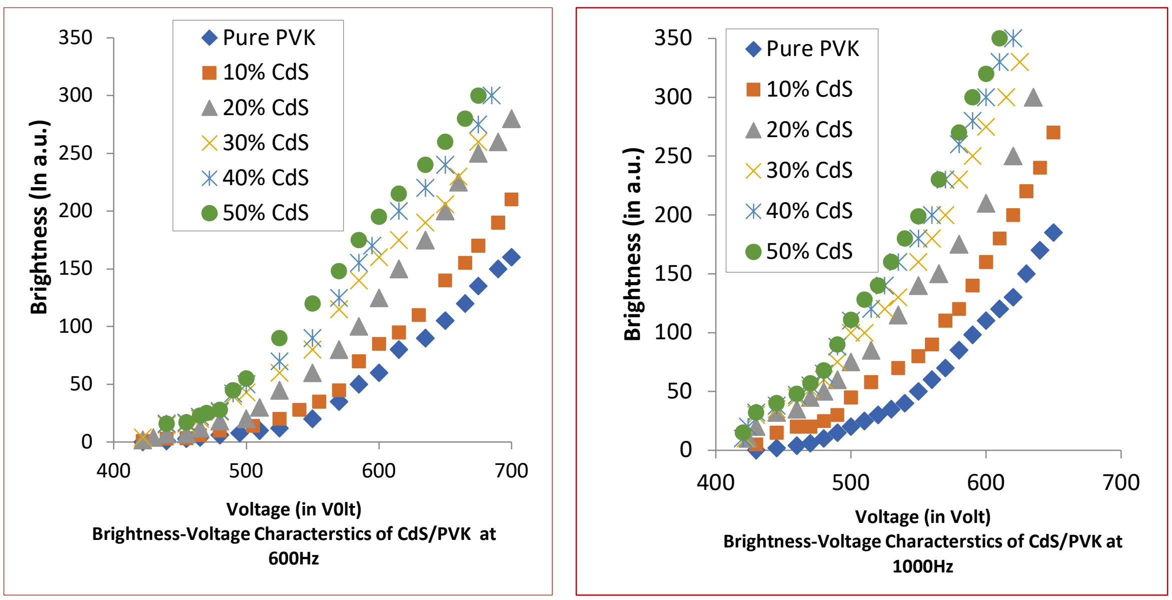


Fig. 3 Brightness-Voltage Characteristics of CdS/PVK Composites at particular frequency

Brightness-Concentration Characteristics: It is clearly observed from Fig. 4 that, at different frequencies and at constant voltage the EL intensity of the composite increased with increasing concentration of CdS in PVK and attains saturation at CdS concentrations more than 30%.

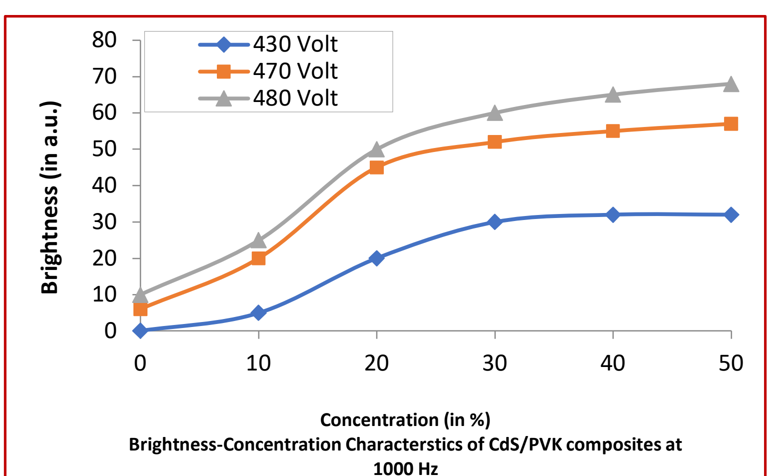
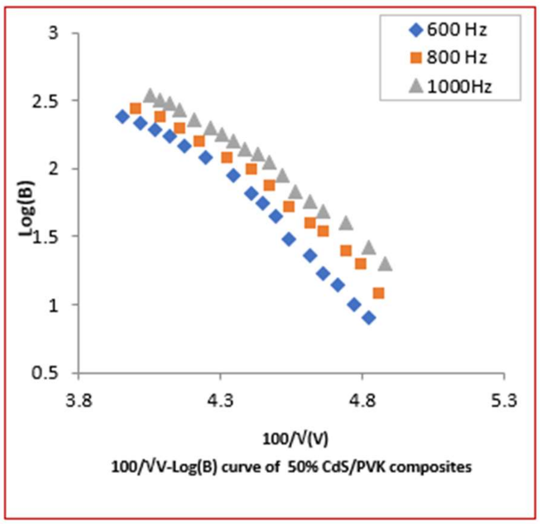


Fig. 4 Brightness-Concentration Characteristics of CdS/PVK at particular frequencies

Mechanism of Electroluminescence: Electroluminescence (EL) of nanocrystals is the radiative recombination of electron and hole pairs. The most suited relation for the voltage dependence of EL brightness may be given by [29-33]. $B = B_o \exp^{-b/\sqrt{V}}$ ------ (1)

where B_o and b are parameters, which depends on temperature, frequency of the alternative voltage and the material. Fig.(5) show the graph between logarithm of EL brightness and $100/\sqrt{V}$ for different frequencies for a particular concentration of CdS. It is clear that the plot is a straight line with negative slopes. For CdS/PVK nanocomposites, equation (1) successfully explains the voltage-brightness characteristics. The presence of square root of voltage is generally explained on the basis of acceleration collision mechanism [34]. Fig. (6) shows the graph between logarithm of EL brightness and $100/\sqrt{V}$ for different concentration of CdS in PVK at 1000Hz frequency. The slope of curve increases as we increasing the concentration of CdS in PVK that indicates the value of constant 'b' increases. Similar results are obtained for various frequencies.



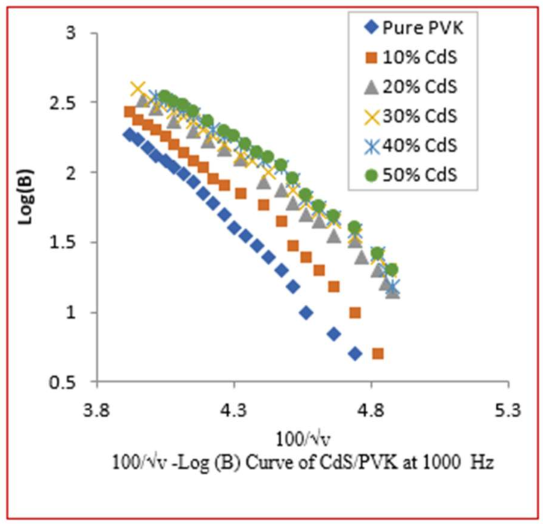


Fig.(5) Fig.(6)

Current Voltage Characterization

The voltage-current characteristics of CdS/PVK composite films 0, 10, 20, 30, 40 and 50% CdS loading in PVK for 1000 Hz frequencies are shown in Fig.(7) It is clear the graphs that: There is a linear relation between current and voltage which, indicates the ohmic nature that is there is ohmic contact between samples and electrodes. V-I property of the devices depends on the strength of the electric field. In this model, carriers have to tunnel through barrier at the nanoparticle and electrode interface under the influence of an electric field. Under the influence of applied field holes reach across an energy barrier into the valance band and electrons reaches across the conduction band of nanoparticle. These carriers are transported through a series of field associated ionization steps. The slope indicates that, the impedance decreases as we increase the frequencies. Ding et al. (2008) have also reported the linear relation between current and voltage [35] for CdS/PVK nanocomposites.

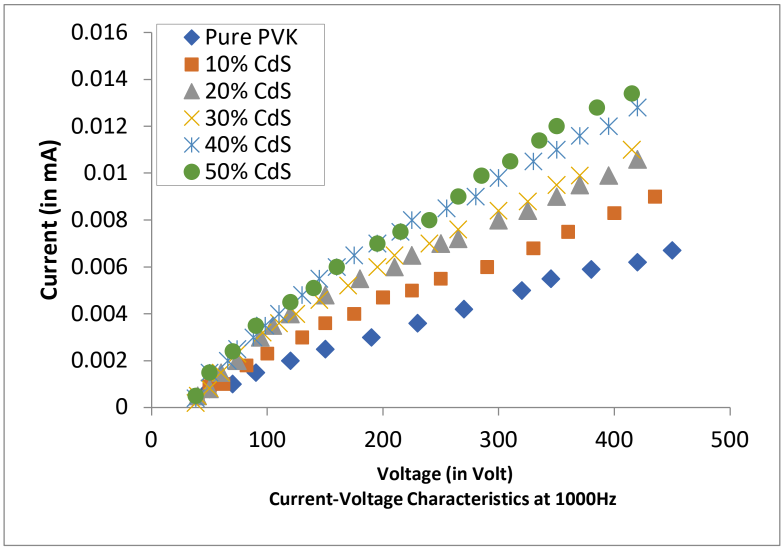


Fig.(7) the current voltage characteristics of CdS/PVK nanocomposites for different concentration of CdS at frequency 1000 Hz.

4. Conclusions:

The CdS/PVK nanocomposites were prepared using chemical technique for different concentrations such as 10, 20, 30, 40 and 50% of CdS loading in PVK. Study their electroluminescence and electrical properties. The size of the nanoparticle is found to increase with increasing concentration of CdS in PVK.

The EL studies show that the brightness increases with the applied voltage at a given frequency. The EL emission starts at lower threshold voltage for higher concentration of CdS in PVK. The brightness increases with the applied voltage at a given concentration of CdS in PVK for different frequencies. The EL emission starts at higher threshold voltage for higher frequencies. Initially, the EL intensity of the composites increases with increasing concentration of CdS in PVK. Beyond a particular concentration (30%) of CdS nanoparticles, saturation occurs in the EL intensity. There is a linear relation between current and voltage which indicates the ohmic nature that is there is ohmic contact between samples and electrodes. The impedance decrease as we increase frequency of applied voltage.

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