Optical and electrical properties of carbazole thin film

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Carbazole and its derivatives constitute a large family of aromatic amines, which receives much more attention due to their high photoconductive and photorefractive properties [1, 2]. Polymers based on Carbazole such as poly(vinyl carbazole) (PVK) and poly(N-vinyl carbazole) are widely used as an emitting layer in organic light emitting diodes (OLED) and also in xerographic industry [3]. Devices in which the emitting layer is formed by PVK blended with other polymeric systems have shown remarkable increase in luminescence efficiency as compared to those in which PVK is not incorporated [4–6]. It is found that the performance of OLEDs can be improved by using multilayers of Carbazole and PVK.

In this work we investigate the optical and electrical properties of vacuum deposited Carbazole thin films. Use of this monomer avoids shortening effect of polymer chain length during evaporation and provides comparable electroluminescence and rectification properties as that of its polymer unit [7].

Natural Carbazole is originally procured from Aldrich Chemical Company (U.S.A.). Highly polished and thoroughly cleaned micro glass slides are used as substrates. The evaporation is carried on a molybdenum boat using Hind Hivac12A4 vacuum coating machine, under a base pressure of 5×10^{-5} mbar. Thicknesses of the films are accurately determined by Tolansky's multiple beam interference technique [8]. UV-Visible absorption spectrum is recorded using a Shimadzu 160A spectrophotometer. The electrical conductivity study in the range 300–273 K is done using a programmable Keithley electrometer (Model No. 617). Carbazole thin film is mounted on the sample holder of the conductivity cell and it is cooled using ice blocks. The temperature in the conductivity cell is measured using a calibrated Cr-Al thermocouple. As Carbazole is a photosensitive material, conductivity study is made in darkness and in a rough vacuum of the order 10^{-3} mbar to avoid any possible contamination of the films.

The absorption spectrum of Carbazole thin film deposited at room temperature is shown in Fig. 1. There is a principal absorption peak around 340 nm with additional peaks around 369, 390 and 530 nm. The principal absorption peak around 340 nm originates from π to π^* transitions of partially conjugated double bonds due to nitrogen atom [8]. The absorbance (α) is greater than 10^3, which shows the existence of direct band gap. The absorption edge is analyzed using one electron theory of Bardeen *et al.* [9]. The coefficient α is related to band gap energy E_g under the equation

$$(\alpha h\nu) = B(h\nu - E_g)^n$$

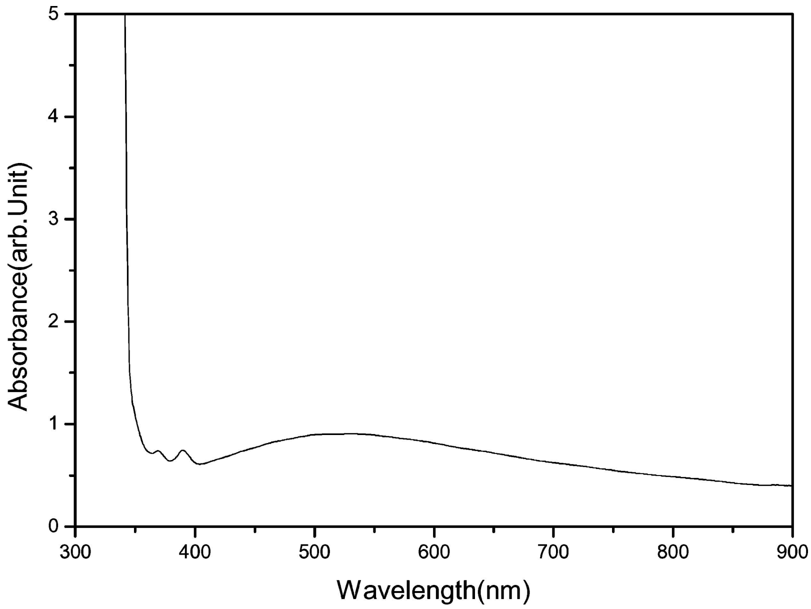

Figure 1 Absorption spectrum of Carbazole thin film of thickness 2500 Å.

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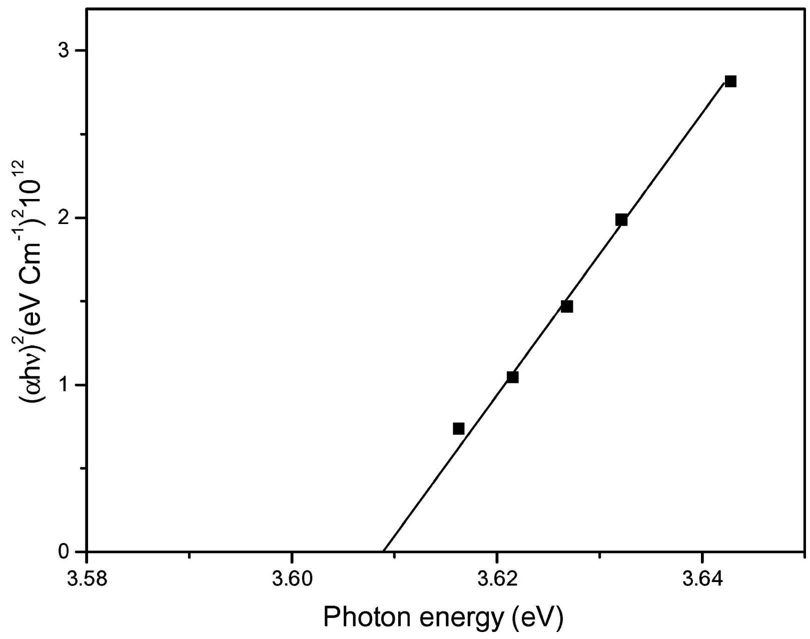

Figure 2 A plot of $(\alpha h\nu)^2$ vs. $h\nu$ for as deposited Carbazole thin film of thickness 2500 Å.

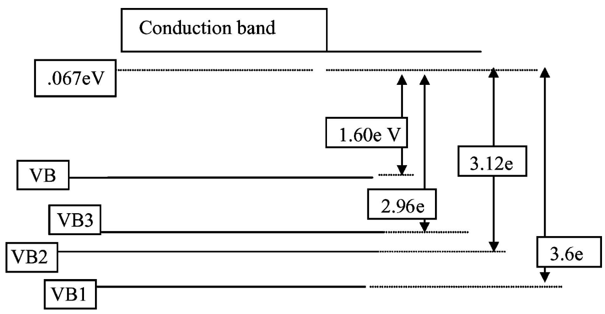

Figure 3 Energy level diagram for Carbazole.

where E_g is the band gap energy, B is a constant nearly independent of the photon energy and known as a disorder parameter. The value of $n = \frac{1}{2}$ for direct allowed transition and $h\nu$ is the photon energy. The band gap energy was determined by plotting $(\alpha h\nu)^2$ as a function of $h\nu$ as given in Fig. 2. A satisfactory fit is obtained and it shows the existence of direct band gap. The band gap corresponding to different absorption peak is listed in Table I.

The absorption spectrum shows three peaks in addition to the fundamental peak indicating the existence of three sublevels within the energy gap. A possible energy level diagram for the Carbazole thin film is shown in Fig. 3.

The electrical conductivity σ can be expressed in the form,

$$\sigma = \sigma_0 \exp\left(\frac{-E}{kT}\right)$$

where σ is the conductivity at a temperature T, E the thermal activation energy k the Boltzmann constant

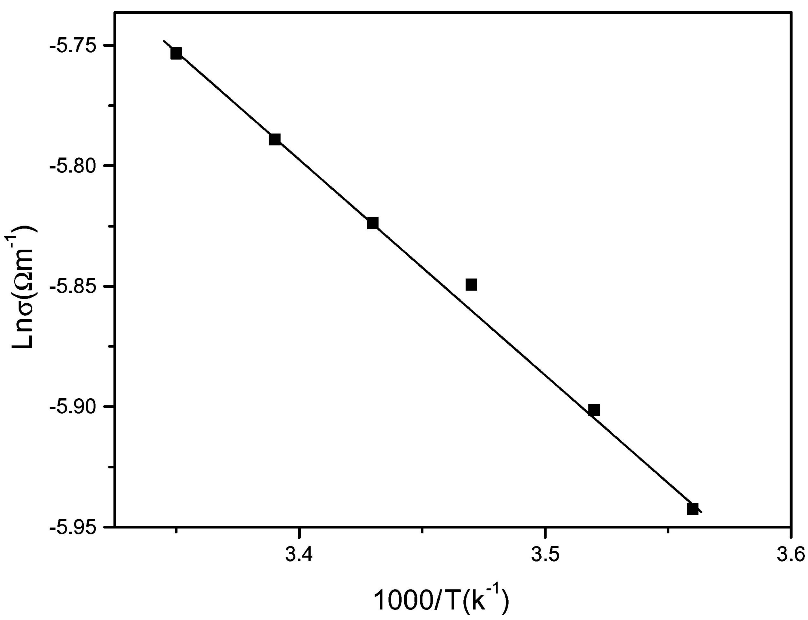

Figure 4 A plot of ln(σ) vs. 1000/T for as-deposited thin film of thickness 2500 Å.

TABLE I The band gap energy corresponding to different absorption peak

Absorption peak (nm)	Band gap energy (eV)
340	3.60
369	3.12
390	2.29
530	1.60

and σ_0 is the pre-exponential factor is given by $\sigma = \frac{l}{Rbt}$ where l is the length b the breadth, t the thickness of the film and R the resistance of the film. $\ln(\sigma)$ is plotted as a function of $1000/T$ and the slope of the graph yields activation energy. Fig. 4 shows a typical plot of as-deposited Carbazole thin film and activation energy is calculated to be 0.07 eV. From the mobility measurements, activation energy of the order 0.022 eV was reported by Morita *et al*. for multi layered electroluminescent devices of PVK doped with Carbazole [10].

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