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Temperature effect on charge carrier mobility in SubPc and C_{60} organic semiconductors for photovoltaic applications

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Abstract—**Solar cells are considered as an important source of renewable energy to solve the shortage of energy today, and one of the most promising solar cells is organic solar cells. This type of cells have received much attention recently due to several potential applications, including compatibility with flexible substrates, low manufacturing cost, and roll-to-roll fabrication process. Carrier mobility is an important parameter in determining device performance in optoelectronics. In this work, we study the charge carrier's mobility of C_{60} and SubPc neat layers, for different temperature calculated in dark. the results show that temperature affects the disorder energy of organic semiconductor; when temperature is smaller than 289 K this parameter is around 0.03 eV and it is double when temperature is above this temperature. In these conditions the mobility of electron and hole are around 0.14 Cm2/Vs and 10-7 Cm2/Vs respectively.**

Keywords— **Organic Semi Conductor (C_{60}/SubPc), Effect of Temperature, Charge Carrier Mobility.**

I. INTRODUCTION

Organic photovoltaic devices have gained a broad interest in the last few years due to their potential for large-area low cost. One new photovoltaic technology, organic solar cell technology, is based on fullerene (C_{60}), boron subphthalocyanine chloride (SubPc) and molecules. In organic solar cells, it is essential to deduce and understand the laws that determine the charge transport and the parameters where affect the charge transport as carrier mobility, charge distribution and temperature. These parameters play a critical role in determining the fluency and efficiency of the organic solar cell. For that, the use of sophisticated modeling to simulate the charge transport is necessary. In contrast to the situation with crystalline and amorphous organic materials, the charge mobility in liquid crystals has been studied relatively little.

In this work, we initiated a study of mobility of charge carriers results obtained for different temperature of C_{60} or SubPc layers are calculated without illumination, it present nonlinear behavior. The structure of this solar cell is shown in figure 1. Starting from the bottom, there is the glass substrate, the indium tin oxide (ITO) layer, it is a transparent layer which serves as the hole contact, in the middle the active layer based on C_{60} or SubPc. C_{60} organic semiconductor used as the organic electron-acceptor for its high stability and high carrier mobility, SubPc organic semiconductor used as the organic hole-donor semiconductors [1]. Lastly, the aluminum layer is the electron contact.

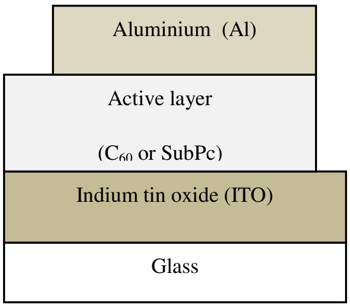


Fig 1: Organic (C60 or SubPc) Schottky diode structure.

II. THEORETICAL MODEL

The key factor to decide the efficiency is the process of carriers transport and collection by the electrodes. Therefore the carrier mobility is a critical factor to determine the efficiency. The mobility dependence of temperature as determined from the various electron-only or hole-only devices is given by Gaussian disorder model. It is governed by the width of a Gaussian density of states following as [2]:

$$\mu(E) = \mu_{\infty} exp\left[-\left(\frac{3\delta}{5K_BT}\right)^2 + 0.78\left(\left(\frac{\delta}{K_BT}\right)^{1.5} - 2\right)\sqrt{\frac{eaE}{\delta}}\right] \quad (1)$$

Where $\mu_\infty$the mobility as the temperature is going to infinity, δ is the Gaussian disorder, a is the inter-site spacing, Eelectric field and K_B is the Boltzmann constant.

The aim of our work is to investigate the effect of temperature on mobility for both C_{60} and SubPc schottky solar structure.

III. RESULTS AND DISCUSSIONS

In this work we investigated the effect of temperature on carrier’s mobility of neat electron layer (C_{60}) and neat hole layer (SubPc), each one sandwiched between a cathode and an anode as illustrated in figure 1.

Figures 2 and 3 show the electron mobility-only and hole mobility-only using equations 1, with the corresponding parameters for C_{60} and SubPc organic semi-conductor in the dark shown in table 1.

TABLE 1

MATERIAL PROPERTIES OF C_{60} AND SUBPC.

	a (10^{-8}cm)	μ_∞(cm²/Vs)	δ(eV)	
			T ≤ 289K	T > 300K
C_{60}	**14.17 [3]**	**0.3**	**0.03 [4]**	**0.06 [5]**
SubPc	**12 [6]**	**1.5×10-7**	**0.03**	**0.06**

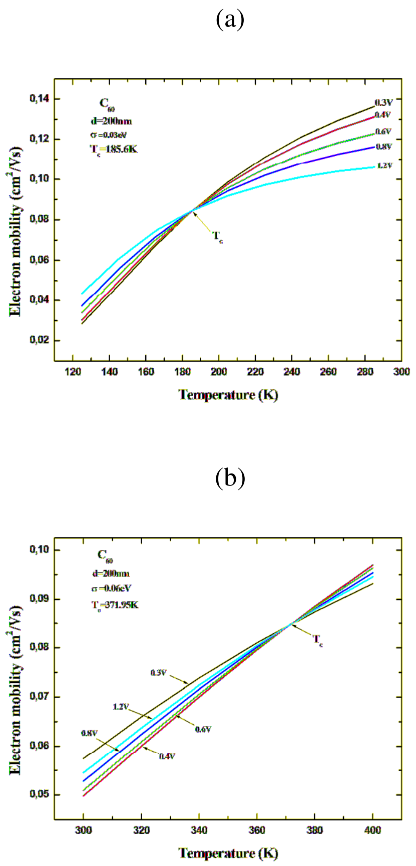
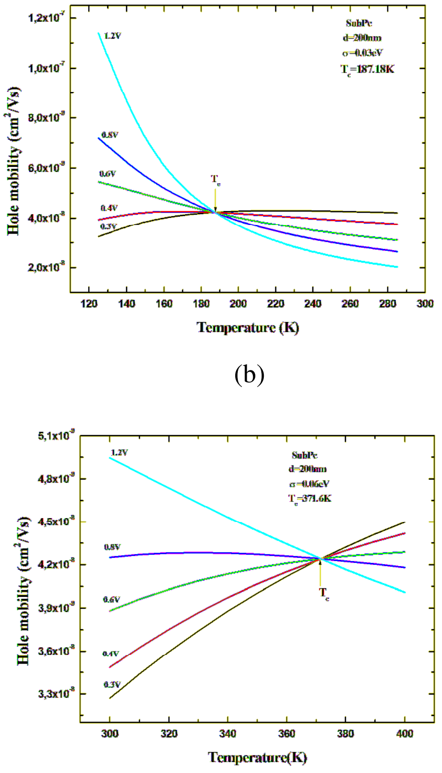


Fig 2: Electron mobility dependence of temperature in neat C_{60} for various values of voltage; of two case of Gaussian disorder (a) 0.03eV and (b) 0.06eV.

We can see that our results in figure 2 (a) exhibit tow regions for range of voltage (0.3, 0.4, 0.6, 0.8 and 1.2V) with various values of temperature: the first one is from 120K to Tc =185K (The critical temperature) the electron mobility increase with increasing of temperature and voltage. In contrast, when the temperature is above Tc (the second region) we observe that the electron mobility increase with increasing of temperature and the decreasing of voltage.

As a result, in figure 2 (b) the electron mobility increase with increasing of temperature from 300K to Tc=371.98K and decreasing of voltage, but after Tc the electron mobility increase with increasing of temperature and voltage.


(a)

(b)

Fig 3: Hole mobility as a function of Temperature in neat SubPc for various values of voltage; of two case of Gaussian disorder (a) 0.03eV and (b) 0.06eV.

Figure 3 (a) shows that contain two regions for range of voltage (0.3, 0.4, 0.6, 0.8 and 1.2V) with various values of temperature. In figure4 (3), the first one is from 120K to Tc =187K (The critical temperature), we can see when the bias is between 0.3V and 0.4V the hole mobility increase with increasing of temperature. In contrast, when the bias is above than 0.4V the mobility decreases. In the second region we observe that the hole mobility decrease with increasing of temperature and voltage.

As a result, in figure3 (b) when voltage is above 0.08V the hole mobility increase with increasing of temperature exceptionally for 1.2V. But in the second region after Tc the hole mobility decrease with increasing of temperature and decreasing of voltage. The effect of voltage has a main influence on the carrier mobility of SubPc neither of fullerene.

IV. CONCLUSION

In this paper, we have investigated the electron mobility in neat fullerene C60 n-type schottky diode and neat hole mobility in the boron subphthlocyanine chloride p-type schottky diode by using a recent analytical model assuming a Gaussian density-of states distribution. Also the temperature has influence dramatically on the ability of carrier transportation in device. For each characteristic there are two distinct critical temperature regions.

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