International Journal of Latest Research in Science and Technology **ISSN (Online):2278-5299**
Volume 3, Issue 5: Page No 145-147 September-October 2014
https://www.mnkpublication.com/journal/ijlrst/index.php

OPTIMUM CHARGE-CARRIER MOBILITY OF ORGANIC LIGHT-EMITTING DEVICES

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Abstract- ***The carrier mobility of organic light-emitting devices(OLED) is studied theoretically. Here, our numerical results demonstrate that relative small space charge density results in the more steady behavior ,which decreases near the interface ,then reaches a final certain value. Moreover, with the increase of characteristic length, the coefficient decreases. It has been demonstrated that the carrier mobility is constant for charge carrier densities typically <$10^{23}$$m^{-3}$ at low bias voltages and at room temperature.The hole or electron density has an effect on the carrier mobility and increases with a power law with the charge carrier density >$10^{23}$$m^{-3}$ at high bias voltages.and the carrier mobility increases with the temperature up.***

Keywords: charge-carrier mobility;organic light-emitting devices;transport

I. INTRODUCTION

Organic semiconductors hold great promise for a variety of optoelectronic devices: light-emitting diodes,[1]field-effect transistors [2] ,and photovoltaic cells [3,4] .Moreover,they show potential applicability to large area devices with a broad range of colors and easy processing compared to semiconductor technologies [1–5] .The mechanism for electro-luminescence devices made from inorganic semiconductors, in that photon production occurs through the radiative recombination of charged polaron excitons.

Electrons and holes, injected from the contacts into the polymer, form negatively and positively charged polarons in the polymer. Since the discovery of electroluminescence in organic semiconductors[6], it has been recognized that charge transport is a key ingredient for the efficiency of organic light-emitting diodes (OLEDS) [7,8] .

The mobility of charge carriers in the organic semiconductors is a very debatable parameter and plays a very crucial role in the performance in these devices.The electric current in the organic semiconductors is determined by the space charge and is known as the space charge limited current(SCLC).SCLC through organic semiconductors has been interpreted (i) either by the drift of charge carriers in extended states(known as the trap/band model,where mobility is assumed to be field and temperature independent)[9-11] or (ii)with a temperature and field dependent mobility (the so-called mobility model)[12-13].In the mobility model ,mobility has an exponential square root of electric field dependence.The field effect transistors are also used to measure the field effect mobilities in the accumulation mode of the organic semiconductors.But it is well know that the carrier mobility at the surface is some order of magnitude higher compared with that in the bulk[13].

Nowadays the research mainly focus on the development of high EL efficiency, stable electroluminescence material, and im-proving the structure. In the theory field, it is urgent to research and understand more into the process of the OLED operation and the microscope physics .Here,we discuss the carrier mobility and the device characteristics of the organic light-emitting diodes(OLEDs).

II. MEHTODS AND RESULTS

Carrier mobility is the average drift velocity under the unit electric field,which has an important effect on the electrical Ch-aracteristics of the semiconductor devices. First people research on the Current –Voltage of OLED with the constant carrier mobility at low bias voltages at room temperature. At high bias voltages the enhancement of the current has been attributd to a field-dependent mobility on the field of the Poole-Frenkel[7] form.

$$\mu(F) = \mu_0 \exp(\beta\sqrt{F}) = \mu_0 \exp\sqrt{\frac{F}{F_0}}$$

(1)

with μ_0 for mobility in zero field, β is the coefficient related to the field ,F for applied field, F_0 is the characteristic field. Recently, the dependence of the mobility on the charge carrier density has been obtained from the transfer characteristics of OC_1C_{10}-PPV based field-effect transistors.[8]Unification of the diode and field-effect measurements shows that the dependence of the hole mobility on charge carrier density is given by[14]

$$\mu_h(p,T) = \mu_h(0,T) + \frac{\sigma_0}{e}\left[\frac{\left(\frac{T_0}{T}\right)^4 \sin\left(\pi\frac{T}{T_0}\right)}{(2\alpha)^3 B_c}\right]^{T_0/T} p^{T_0/T-1}$$

Publication History
Manuscript Received : 9 October 2014
Manuscript Accepted : 22 October 2014
Revision Received : 29 October 2014
Manuscript Published : 31 October 2014

where $\mu_h(0,T)$ is the hole mobility at low densities obtained from the quadratic SCL current, σ_0 is a prefactor for the conductivity, α^{-1} is the effective overlap parameter between localized states, T_0 is a measure of the width of the exponential density of states, and B_c is the critical number for the onset of percolation. And from the continuity and the research on modi-fied transport pro-perty by Nonlinear Optics Laboratory , the constant θ_0 is the value at x=0 of a function, $\theta_0\mu$ plays the role of an effective mobil-ity near the injecting electrode due to the non-uniformity of the polymer layer in this region.

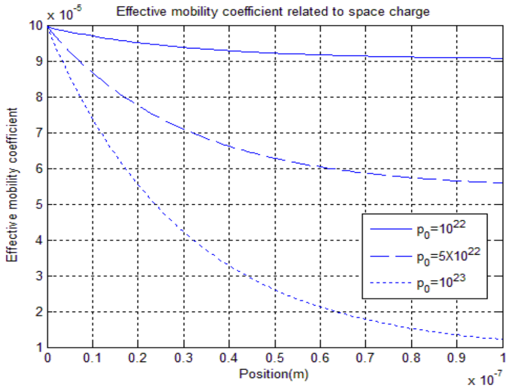

Fig 1 Effective mobility coefficient related to space charge

From the continuity and the research on modified transport property by Nonlinear Optics Laboratory, the constant θ_0 is the value at x=0 of a function defined by:

$$\theta_0 = \frac{j/\varepsilon_r\varepsilon_s}{F_0 dF/dx} \qquad (3)$$

$\theta_0\mu$

plays the role of an effective mobility near the injecting electrode due to the non-uniformity of the polymer layer(along x) in this region.

Fig1 shows how space charge limit affect the coefficient distribution, which depict the strongly dependence of carrier effective mobility coefficient on space charge. The relative small space charge density results in the more steady behavior.

It is clear in the Fig 2 that the carrier mobility coefficient is decreasing near the interface, and reach a final certain value. Moreover, with the increase of characteristic length, the coefficient decreases.And the carrier mobility coefficient increase with the voltage on the device from Fig 3.

Then we study the temperature affection carrier mobility with Formula(2). This experimentally determined mobility depend-ence on carrier density now enables us to solve the contrib-utions of the electric field and the carrier density to the enhanc ement of the SCL current at high bias. We can see from Fig4 and Fig5 apparently, at low temperature the field dependence of the mobility becomes important. Furthermore, it appears th-at at any temperature with the density lower than $10^{21}-10^{26}\text{m}^{-3}$, the mobility is not significant dependent on carrier density, when higher than 10^{23}m^{-3}, it starts increase.

In Fig 5 density and temperature determine the mobility. We can know here in low density, the temperature cannot significantly affect the mo-bility, but when the density large enough, the temperature is obvious one major factor decide the mobility.

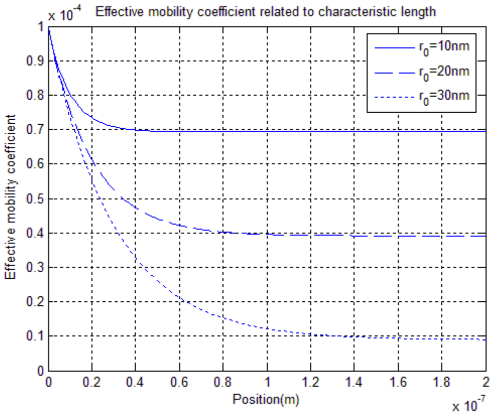

Fig 2 Effective mobility coefficient related to characteristic length

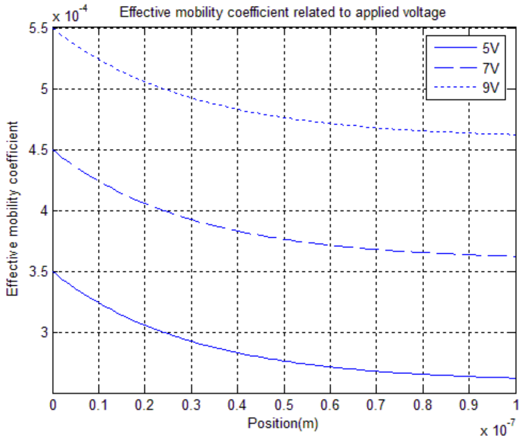

Fig 3 Effective mobility coefficient related to applied voltage

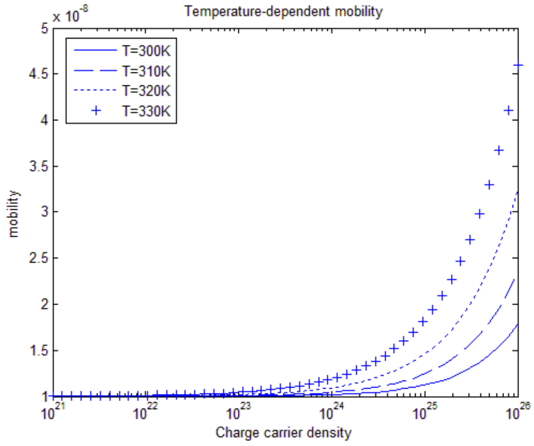

Fig 4 Temperature-dependent mobility for various carrier density

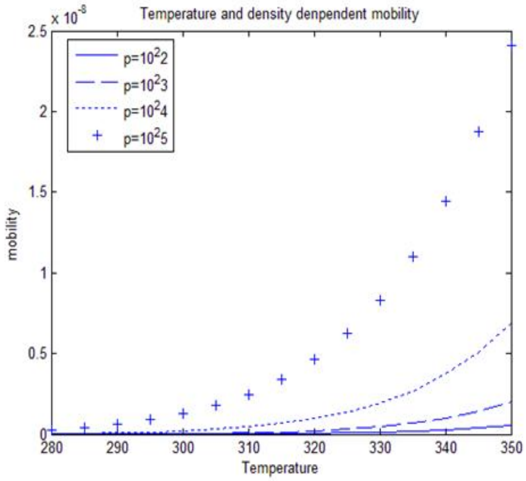

Fig 5 Temperature and density dependent mobility

Based on the assumption of carrier density decreasing exponentially from the electrode. Fig6 has shown that in the diverse condition of characteristic length of space charge distribution, the change of carrier density inside the device. With the increasing of r_0, the carrier density changing trend is towards slow, simultaneously it also increase correspondingly.

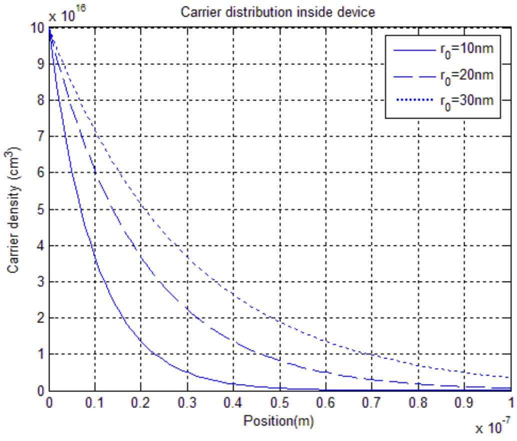

Fig 6 Carrier density for three characteristic lengths

III CONCLUSION

Since electroluminescence was reported more than one decade ago.The charge transport properties have been extensively studied in order to understand the fundamental phenomena that govern the operation of these dvices.[15-17] Carrier mobility is the important parameter to the research on the electrical characteristic of semiconductor devices.In this paper,we have studied the carrier mobility . The mobility could not be thought as constant at any voltage and at any temperature.The applied voltage 、temperature and carrier density have important effect on the carrier mobility. It has been demonstrated that the carrier mobility is constant for charge carrier densities typically $<10^{23}\text{m}^{-3}$ at low bias voltages and at room temperature.The hole or electron density has an effect on the carrier mobility and increases with a power law with the charge carrier density $>10^{23}\text{m}^{-3}$ at high bias voltages.and the carrier mobility increases with the temperature up.

This work is supported by“the Fundamental Research Funds for the Central Universities”.

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