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Field-Dependent Drift Mobility of Carriers in Polycrystalline Aromatic Hydrocarbon Layers

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S u m m a r y

It was found that the drift mobility of carriers in tetracene and p-quaterphenyl polycrystalline layers is dependent on electric field. A simple model to explain the dependence is presented in this paper.

1. I n t r o d u c t i o n

It was found by Mycielski, Lipiński and Kania that the drift mobility of carriers in polycrystalline tetracene and p-quaterphenyl layers is dependent on electric field (MYCIELSKI 1978, KANIA 1979). A simple qualitative model to explain this dependence is presented in this paper.

2. D e s c r i p t i o n o f t h e m o d e l

It has been pointed out that the predominant mechanism of carrier transport in polycrystalline simple aromatic hydrocarbon layers is hopping conduction between localized states at the Fermi level (BAK et al. 1979, BAK et al. 1980). The width of the "impurity band" at the Fermi level was found to be kT, which is in a good agreement with Mott's model of hopping processes at the Fermi level (MOTT and DAVIES 1971) It can be shown that without applying of the electric field there are some localized states between levels E_3 and E_4 (see Fig.2), which are not available for carriers at some defined time, despite of this that because of the Fermi distribution, the probability of occupying each of the states is larger than 0. Let us take two neighbouring states, energies of which differ from each other more than $h\nu_{ph}$, where

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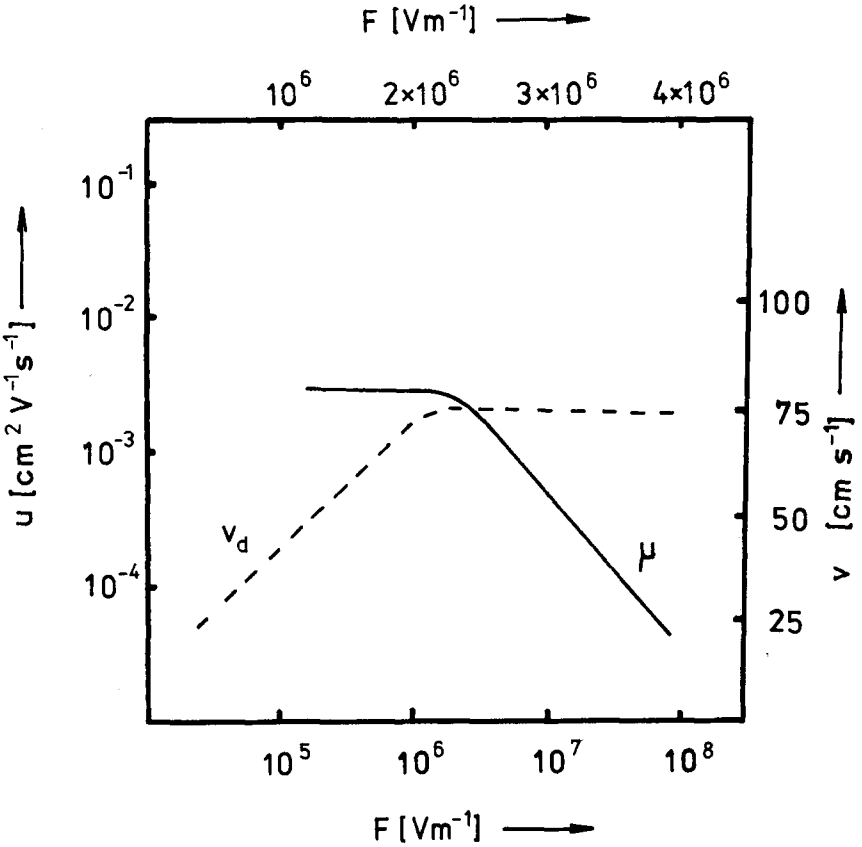

Fig.1. The field dependence of the hole drift mobility in tetracene: full curve-the hole mobility, dashed curve-the hole drift velocity

ν_{ph} is the phonon frequency, and let us assume that one of them is occupied and the other one is unoccupied. The carrier trapped by one of the states cannot be excited to the other one by any single phonon, so the state can be believed to be not available for the carrier at the time. It is more difficult to consider the transport of carriers taking into account the changing probability of occupying of localized states, so let us assume that all states below E_F are occupied (T=0). Such a simplified picture of the "impurity band" is shown in Fig.2. The whole width of the "band" is assumed to be kT=0.026eV, $h\nu_{ph}$=0.004eV (BAK et al.1980).These localized states, which are between the energy levels E_2=E_F

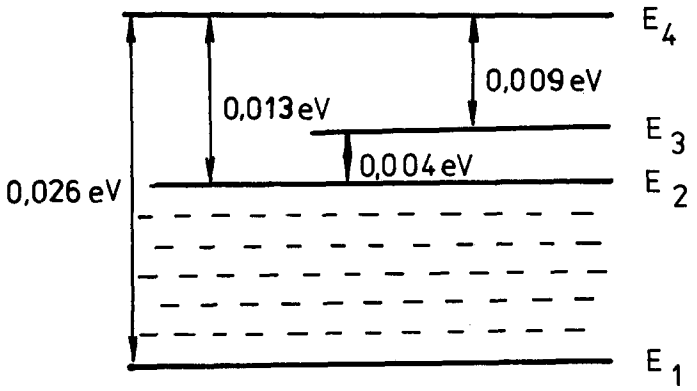

Fig.2. The picture of the "impurity band" at the Fermi level simplified

and E_3 are available for carriers at the intensity of the electric field F=0 V, forming the "available band" of states. When the field F is applied, the number of the available states increases, because the width of the "available band" increases as well and is given by:

$$\Delta W = h\nu_{ph} + FeR \qquad (1)$$

where R is the average distance between two localized states and e is the electron charge. When ΔW=0.013 eV, it means that all states are available for carriers, what amounts to this, that the structure of "hopping paths" becomes independent of the intensity of the electric field.
The average probability of a single jump between two localized states in the case of hopping conduction at the Fermi level is given by:

$$p = \nu_{ph} \exp\left[-2\alpha R\right] \exp\left[\frac{-W}{kT}\right] \qquad (2)$$

where α is the exponential decay parameter of the localized state wave function and W is the average activation energy of jumps. It may be assumed that $W=0.5(h\nu_{ph} + FeR)$, but when ΔW = 0.013 eV, W becomes independent of electric field as well. It amounts to this, that the hopping prob-

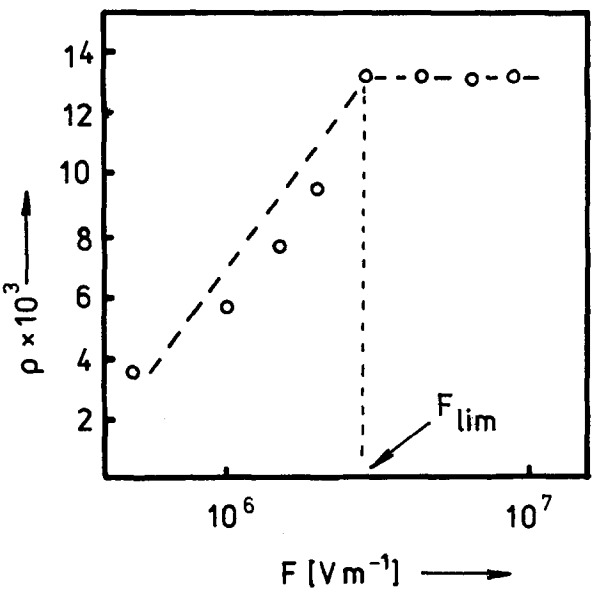

Fig.3. The probability of a single jump between two localized states as a function of electric field (compare with the drift velocity in Fig.1)

ability is independent of electric field at fields higher than F_{lim}, defined as follows:

$$0.013 = h\nu_{ph} + F_{lim}eR \qquad (3)$$

Assuming that R = 30Å (MYCIELSKI 1980), we obtain $F_{lim}=3\times10^6 Vm^{-1}$, which is in a good agreement with the value of the field found in tetracene layers see Fig.1 .
Fig.3 shows the probability of jumps as a function of field, calculated by using the formula (2). It can be seen that the shape of the probability curve is similar to the shape of the hole drift velocity curve, shown in Fig.1.

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