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Charge Carrier Mobility in Tetracene Single Crystals

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The importance of charge carrier mobility measurements for the study of charge carrier transport mechanism in solids has been widely accepted.

The present note is concerned with systematic studies aimed at drift mobility measurements in a broad range of organic solids, both amorphous and crystalline.[1] In spite of the success which has been achieved in understanding charge carrier mobility in anthracene,[2] the situation in the case of its nearest homologue, tetracene, has not been clarified. Theoretical calculations have predicted mobility values around 1 $cm^2/V \cdot s$. The results of Frankevich and Balabanov[3] gave a value of 0.5 $cm^2/V \cdot s$ and those of Szymański and Labes 0.01 $cm^2/V \cdot s$[4] with a negative temperature coefficient.

The more extensive study undertaken in our laboratory has shown that electric field independent mobility is not a good approximation, at least in the case of tetracene. By using different samples and making numerous measurements it has been shown by Kondrasiuk and Lipiński[5] that the drift mobility in tetracene monocrystals at low fields is approximately 2 $cm^2/V \cdot s$ for holes and 1.2 $cm^2/V \cdot s$ for electrons, and that for holes it decreases approximately as E^{-1} over a wide range of fields.[6] The aim of the present note is to report on the temperature dependence of the mobility.

Experiments were performed on tetracene sublimation flakes. The thicknesses of the crystals were in the range of 0.1–0.3 mm. The technique of photoinjection of charge carriers was employed. The method adopted for these experiments and the apparatus have been described elsewhere.[1,5] The measurements were made in air in well shielded cells over the 100 V/cm to 1000 V/cm field range.

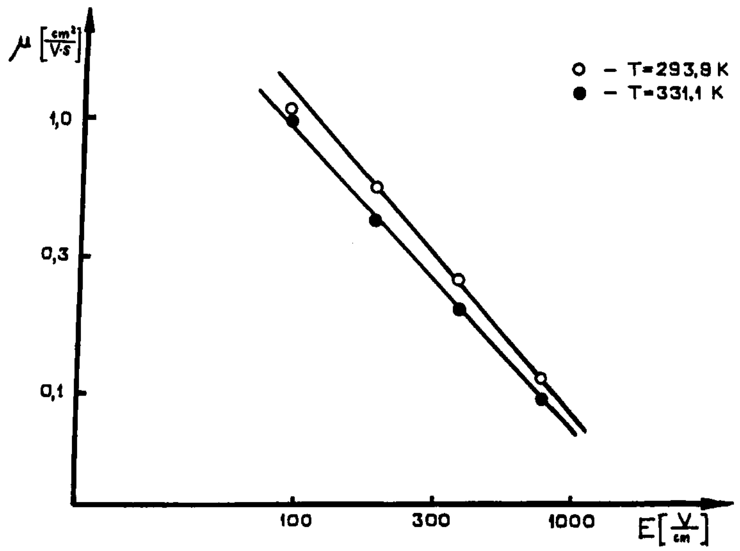

Figure 1. Mobility on electric field $\mu = f(E)$ dependence for two different temperature T values.

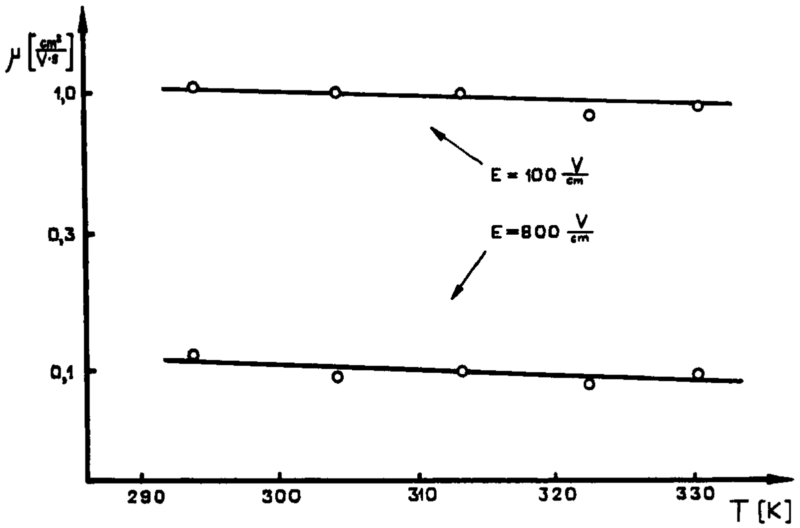

Figure 2. The temperature dependence of the mobility $\mu = f(T)$ on two different electric field values.

As can be seen from Fig. 1, hole mobility falls as E^{-1} starting from $1\ cm^2/V\cdot s$ at 100 V/cm to $0.1\ cm^2/V\cdot s$ at $E = 1000$ V/cm.

There is a minor influence of the temperature at low fields. In high fields the effect seems to be more pronounced, but still smaller than the limits of error. The temperature coefficient, if any, is negative (Fig. 2).

As shown in Fig. 1, the present results agree well with those of Szymański and Labes.[4] If the $\mu = a \cdot E^{-1}$ dependence is obeyed the mobility value at 10^4 V/cm would be exactly equal to $10^{-2}\ cm^2/V\cdot s$.

With reference to the results obtained, two groups of problems should be discussed. One of these problems is related to the validity of the method used in the presence of space charge effects and field distortion. Space charge limited current theory gives a correction factor of 1/0.79. This factor makes no essential contribution to the μ on E dependence. One can check if there is any physical process leading to the saturation of the drift mobility measurements in high electric fields. Mobility field effects have been theoretically studied by Silver, Dy and Huang.[7] As one can see from their results, the observed transit times are distorted at low electric fields. As pointed out by Silver, the spurious " transit time " may be generated by trapping at the illuminated electrode. Trapping should be temperature sensitive and that is not the case observed here.

The other set of problems concerns the possible explanation of the experimental results from the point of view of the mechanism of carrier transport in tetracene. For fields as low as 10^2 V/cm drift velocity seems well saturated and its value is 100 cm/s a fairly low value. From this point of view the negative temperature coefficient is extremely difficult to understand. Therefore the authors believe that more complex studies, both theoretical as well as experimental, are necessary.

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