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CHARGE-CARRIER MOBILITY MEASUREMENTS USING THE SURFACE-TYPE CELL FOR ORGANIC CRYSTALS

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The drift mobility measurement using the surface-type cell was presented, by which the charge-carrier mobility of the flake-like thin crystals and the evaporated thin films for the organic compounds was observed; the values for anthracene single crystal were about 1.2 $cm^2/V \cdot s$ for holes and 0.5 $cm^2/V \cdot s$ for electrons, those of tetrabenzoperylene evaporated film were 0.8 $cm^2/V \cdot s$ for holes and electrons at room temperature.

Introduction The mobility measurements for the organic molecular crystals have been carried out by several workers by means of the time of flight method with sandwich-type mobility cells[1]. In such measurements, single crystal should be more thick than a few tenth millimeter and have a considerable plane-size to obtain reliable experimental results. However, only a few organic materials, such as anthracene, naphthalene or pyrene, can form such a size of single crystal, and one could not determine the drift mobility for many other interesting organic substances of which crystals might not be thick enough.

To avoid this restriction, we present an alternative method for drift mobility measurement using the surface-type cell, by which one may measure the charge-carrier drift mobility in the thin crystals and also evaporated thin films.

Experimental The surface-type mobility cell was prepared on a Teflon disk, the detail of which was illustrated in Fig. 1. A Mylar sheet with 0.006 mm thick was used as a blocking spacer between the crystal and the electrodes. Aluminium electrodes were evaporated on one surface of the sheet with the gap having 3 - 4 mm distance and the crystalline sample was tightly sticked onto the other face under compression. When the evaporated film was used as the specimen in the place of a crystal, an organic material was evaporated on this Mylar sheet directly. The photocreation of charge carriers in one part of the organic crystal was caused by a pulsed light from a Xe-lamp* through a 0.3 mm slit properly set in front of the specimen (Fig. 1). The drift mobility measuring system was reported previously by Maruyama and Inokuchi[2]. The temperature of the cell was varied in the range of 293 - 353 K by an electric heater and the corresponding changes in the mobility pulse width were observed.

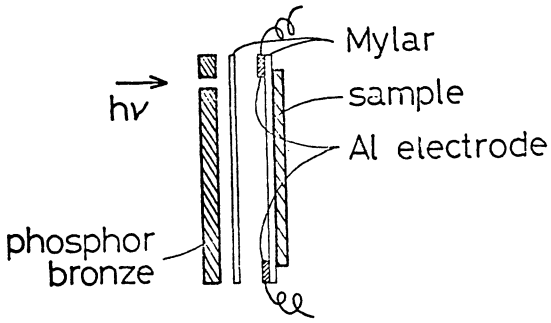

Fig. 1 Surface type drift mobility measurement cell.

Highly pure anthracene was synthesized from anthraquinone and purified by extraction and recrystallization, followed by 50 times zone refining. Tetrabenzo [a,cd,j,lm] perylene (TBP) was synthesized from benzanthrone and it was purified by repeated recrystallizations, sublimations and further by means of chromatography.

Results and Discussion An anthracene single crystal was cleaved parallel to the ab plane in the size of ~7 mm x ~7 mm, having about 1 mm in thickness. Figure 2 shows the typical photocurrent pulse curve for the anthracene single crystal under the specified condition,

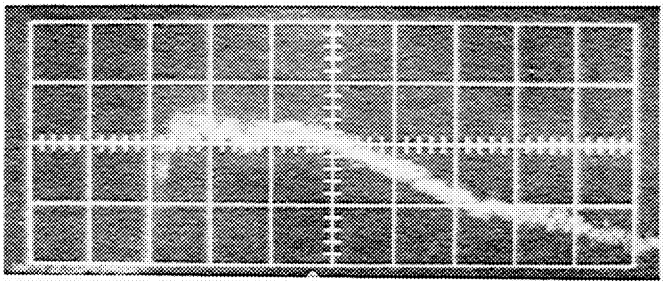

Fig. 2 The time of flight curve of hole in anthracene single crystal at 300 K: the axis of abscissa; 1 ms/division

* The pulse duration was about 1 ~ 2 μsec.

mentioned in its caption. Although this curve is a little different from the typical one, the knick point of an abrupt change in the slope after a flat on top could be recognized, at which the transit time of carriers was determined. A rather long tail of the pulse curve may be due to the defects of the crystal used and the traps on the surface of the crystal. As shown in Fig. 3, the drift velocity was proportional to the reciprocal of applied voltage. The obtained value of drift mobility in ab plane was 1.2_1 $cm^2/V \cdot s$ for holes at room temperature. On the other hand, in the case of electron current almost similar pulse shapes were observed; but they were not so definite as that of hole current. Electron may more easily be taken hold in the surface traps than holes. For electrons, the mean value of the drift mobility was estimated to be 0.5 $cm^2/V \cdot s$ at room temperature. The drift mobility increased with the temperature in the range of 293 - 353 K. Plots of the logarithm of the mobility versus T^{-1} give an almost straight line with an activation energy of 0.49 eV for holes and 0.23 eV for electrons, as indicated in Fig. 4. Kepler[3] reported the drift mobilities in ab plane in the anthracene crystal to be 1.3 $cm^2/V \cdot s$ for holes

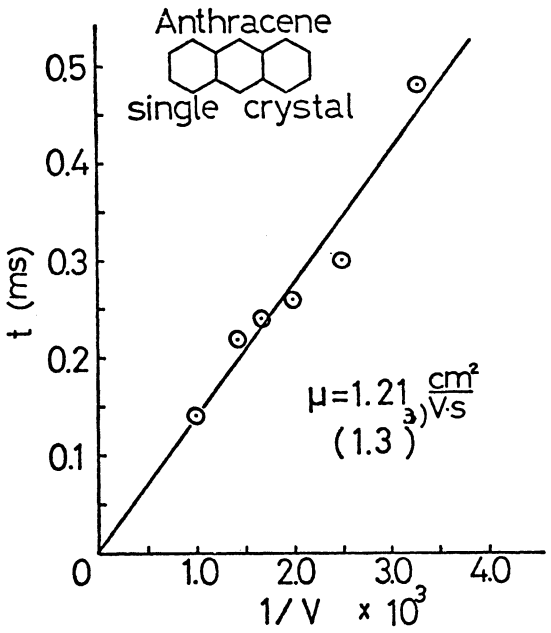

Fig. 3 The relation between the transit time and the reciprocal of applied voltage for the anthracene single crystal.

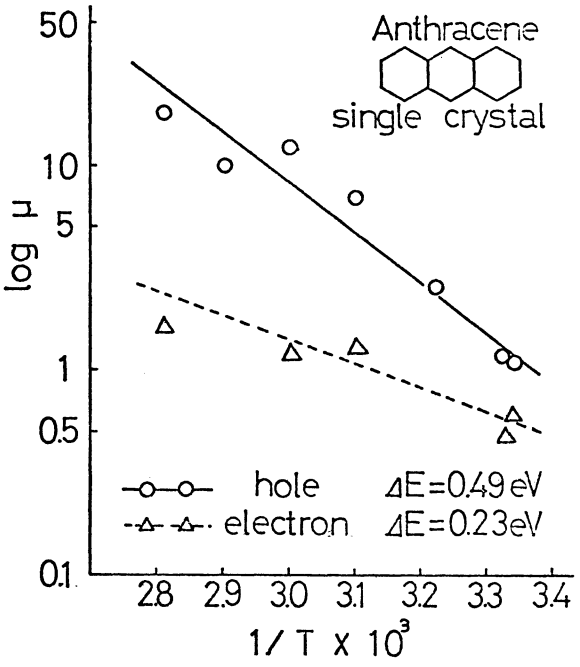

Fig. 4 The temperature dependence of hole and electron drift mobility for anthracene.

and 2.0 $cm^2/V \cdot s$ for electrons respectively, having some negative temperature coefficient in the range of 180 - 300 K. In regard to the mobility of holes at room temperature, our findings agree approximately with the value of Kepler's, but that of electrons is fairly different. Moreover, the temperature dependence shows the contrary character; that is, it involves a temperature activation process. These disagreements might be partly due to the differences of the crystal identity, the temperature range and the method of the measurement. Since the carrier transport parallel to the crystal surface was observed in our method, the effects due to surface traps should be much more important. Anyway, we have to try further studies before discussing the definite reasons for these differences.

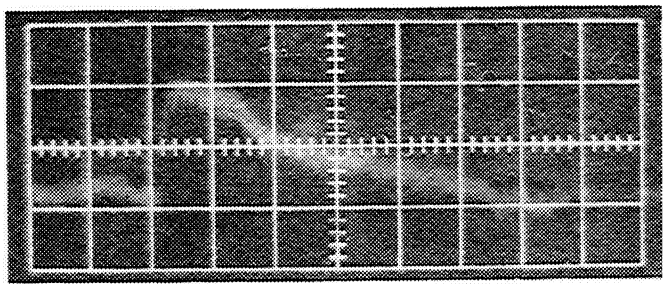

Fig. 5 The time of flight curve of hole in TBP film at 300 K; abscissa, 1 ms/division.

TBP is a so highly photoconductive material that we applied the surface-type mobility measurement to its evaporated films. In Fig. 5, the typical photocurrent pulse curve for the TBP evaporated film is shown on the specified conditions in its legend. The curve is also rather distorted compared with the ordinary one, but the mobility could be roughly estimated from the time of flight curve. The transit time was proportional to the reciprocal of applied voltage, as shown in Fig. 6. The values of the drift mobility were 0.8_4 $cm^2/V \cdot s$ for holes and 0.8_5 $cm^2/V \cdot s$ for electrons at room temperature.

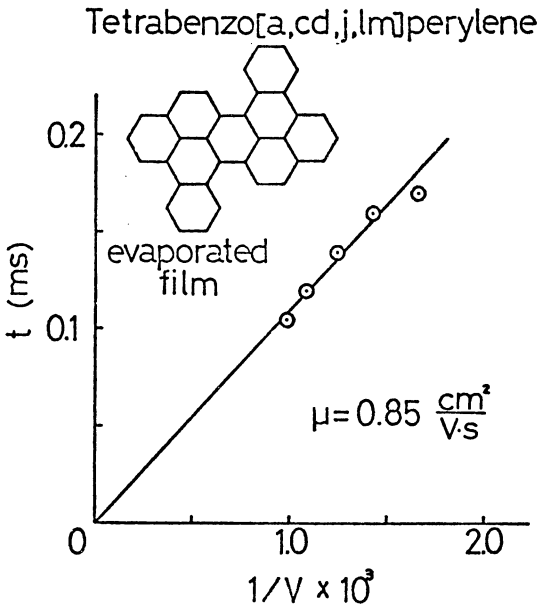

Fig. 6 The transit time as a function of the reciprocal of applied voltage for TBP evaporated film.

Thus, the drift mobility could be measured by using the surface type cell: This means that one can measure it for the flake-like thin crystals and even evaporated films which are easy to obtain for the organic compounds. Consequently, this method will become one of the powerful techniques for the drift mobility measurement for organic crystals. However, this method can be applied only to highly photoconductive materials, because a high electric potential does not applied to the specimen, and also it is not so easy to use a strong enough excitation light source with short time duration. Further, this method may be very sensitive to the surface conditions of the specimen, as mentioned above.

References

1) For example, O. H. LeBlanc, J. Chem. Phys., 35, 1275 (1961)

2) Y. Maruyama and H. Inokuchi, Bull Chem. Soc. Japan, 40, 2073 (1967)

3) R. G. Kepler, Phys. Rev., 119, 1226 (1960)

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