Band-like hole transport in an ordered smectic phase of phenylterthiophene derivative

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Liquid-crystalline (LC) semiconductors exhibit high carrier mobility as well as solution-processability. LC oligothiophene derivatives have been applied to field-effect transistors.1 One of the remarkable features in electronic charge carrier transport in LC semiconductors is temperature-independent mobility. The origin of the temperature-independent carrier mobility is not clear. In order to understand the carrier transport mechanism in LC phases, the measurement of the carrier mobility over wide temperature range is necessary. We have already reported LC phenylterthiophene derivatives which exhibit an ordered smectic phases over wide temperature ranges including room temperature.2,3 In this study, we purified Phenylterthiophene derivative 1 (Scheme 1) with a train vacuum sublimation method, and hole mobility in the ordered smectic phase was measured between 470 K and 200 K by a time-of-flight method.

Scheme 1 Chemical structures of LC phenylterthiophene derivative 1

Non-dispersive transient photocurrent curves were obtained, as shown in Figure 1 (a). The hole mobility was 0.1 cm²/Vs and it was almost independent of the temperature and the electric field, as shown in Figure 1 (b). In Hoesterey-Letson model, negative temperature-dependence of the hole mobility cancels the thermally-activated detrapping from localized states. The carrier mobility μ has a relationship with temperature T, concentration of localized states Ne/N0, and the depth of the localized states ET as described in equation 1.

\[
\ln \left[ \frac{\mu T^{-n}}{\mu} - 1 \right] = \ln \left[ \frac{N_e}{N_0} \right] + \frac{E_T}{k_B T} 
\]

(1)

Figure 1 (a) Transient photocurrent curves for holes at room temperature. The sample thickness was 50 μm. (b) The hole mobility as a function of the temperature. The solid curve is calculated using eq. 1.

The temperature-independent hole mobility can be explained by the Hoesterey-Letson model as shown in Figure 1 (b). This result indicates that band-like conduction is possible in the smectic phase which is softer and more flexible than molecular crystals.4

References:

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