Simultaneous Measurements of Drain-to-Source Current and Carrier Injection Properties of Organic Thin-Film Transistors

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Keywords: Organic thin-film transistor, Displacement current, Drain-to-source current, Charge injection, and Field effect mobility

Abstract

Displacement current (I_{dis}) and drain-to-source current (I_{DS}) are evaluated using the simultaneous measurements of source (I_S) and drain (I_D) currents during the application of a constant drain voltage and a triangular-wave gate voltage (V_{GS}) to top-contact pentacene thin-film transistors.

1. Introduction

For the practical use of organic thin-film transistors (OTFTs), the study of carrier injection properties at organic semiconductor-source/drain electrodes under the device operation is one of the most important issues. This is because the drain-to-source current (I_{DS}) tends to depend on carrier injection properties. Carrier injection properties have been investigated by Kelvin probe microscopy, four-terminal measurement, and displacement current measurement. Since displacement current measurement is a direct method with a high sensitivity for detecting charge motion in semiconductors, molecular thin films, and nanoparticles, various displacement current measurement methods have been developed.

Here we demonstrate simultaneous measurements of displacement current and drain-to-source current which are evaluated from source (I_S) and drain (I_D) currents during the application of a constant drain voltage and a triangular-wave gate voltage (V_{GS}) to top-contact pentacene thin-film transistors. The carrier mobility, threshold voltages and mean potential drops at the source/channel and channel/drain interface are simultaneously obtained from I_{DS}–V_{GS} and I_{dis}–V_{GS} relationships. Carrier injection properties, namely, the carrier injection voltage at the source electrode and the mean potential drop–V_{GS} relationship are discussed on the basis of results of the simultaneous measurements of I_{DS} and I_{dis}.

2. Experimental

Figure 1 shows schematic diagram of simultaneous measurement system of displacement current and drain-to-source current I_{DS} in top contact OTFTs. Source (I_S) and drain (I_D) currents have been measured during the application of a constant drain voltage (V_{DS}) and a triangular-wave gate voltage (V_{GS}) to top-contact pentacene thin-film transistors. Displacement current and drain-to-source current are evaluated using equations of

$$I_{dis}=I_S+I_D \qquad (1)$$

and

$$I_{DS}=(I_D-I_S)/2_{.,} \qquad (2)$$

respectively.

3. Results and discussion

Figures 2 show experimental drain-to-source current $I_{DS}^{1/2}=\sqrt{(I_D-I_S)/2}$ -V_{GS} dependence and displacement current (I_S+I_D)-V_{GS} dependence of pentacene thin-film transistor under V_{DS} = -19.6 V. Carrier mobility and threshold voltage are evaluated from $I_{DS}^{1/2}$-V_{GS} dependence as 0.33 cm^2/(Vs) and -3.6 V, respectively. Carrier injection voltage at the source electrode is also evaluated from I_{dis}–V_{GS} dependence as 2.5 V. Carrier injection properties and carrier transport properties are discussed based on the simultaneous measurements of I_{DS} -V_{GS} and I_{dis}-V_{GS} dependence.

4. Summary

Simultaneous measurement of displacement current and drain-to-source current is significant for the study of both carrier injection properties at metal electrode-organic semiconductors interface and carrier transport properties under the device operation of OTFTs.

Acknowledgements

This work was partially supported by Japan Lab., LG. Philips LCD.

5. References

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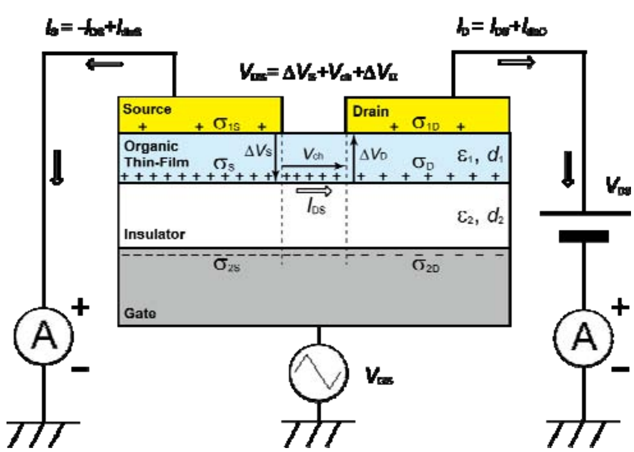
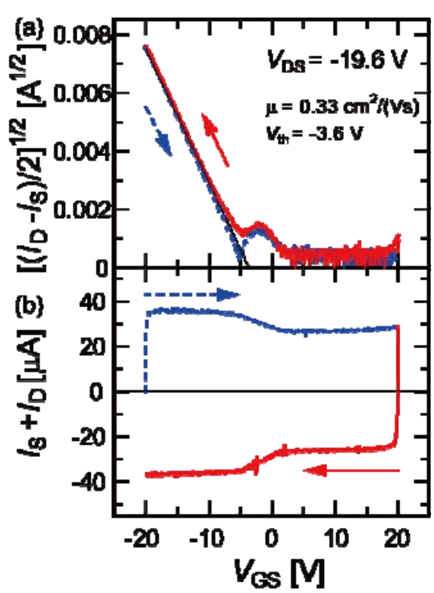


Fig. 1. Schematic diagram of simultaneous measurement system of displacement current at source I_{disS} and at drain I_{disD} and drain-to-source current I_{DS} in OTFTs. Source current I_S and drain current I_D are measured under the application of a triangular wave gate voltage V_{GS} and constant drain voltage V_{DS}.



Figs. 2. (a) Experimental channel current $\sqrt{(I_D - I_S)/2}$ -V_{GS} dependence and (b) displacement current (I_S+I_D)-V_{GS} dependence under V_{DS} = -19.6 V.