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A Simple Method for Extraction of Contact Resistance in Organic Thin Film Transistors

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1. Introduction

Recently, organic semiconductors come into the spotlight and are researched widely because of the advantages such as flexibility, low cost and low temperature process. The major deices are expected to be organic light emitting diode, organic solar cell and organic thin film transistor (OTFT). Especially, OTFTs are getting attention because of the applications of flexible display and RFID [1].

Usually, the contact resistance of OTFTs are very large with the range from several hundreds kΩ to even a few MΩ [2]. Although the contact resistance affected the performance, there are many unknown factors to determine electrical characteristics of contacts and it also has not sufficiently studied yet.

Typically, the contact resistance can be extracted from the plot of the inverse of drain current versus channel length by extrapolating the curve to a channel length of zero, and multiplying by drain-source voltage [3]. Although the method is useful, it requires the OTFTs with the various channel length and also good scaling behavior. Otherwise, it is difficult to extract contact resistance and the uncertainty is large.

In this paper, we propose a simple method to extract contact resistance between Au contact and pentacene active layer of OTFTs. This method can be applied to a single OTFT without the various channel lengths.

2. Method for contact resistance extraction

The source-drain voltage V_{DS} consists of a voltage drop across contact resistances $I_{DS}\cdot R_C$ and a channel resistance V_{ch} as shown in Fig. 1. Thus the current-voltage relationship can be expressed by

$$I_{DS} = \beta[(V_G - V_T)(V_{DS} - I_{DS}R_C) - \frac{(V_{DS} - I_{DS}R_C)^2}{2}]$$

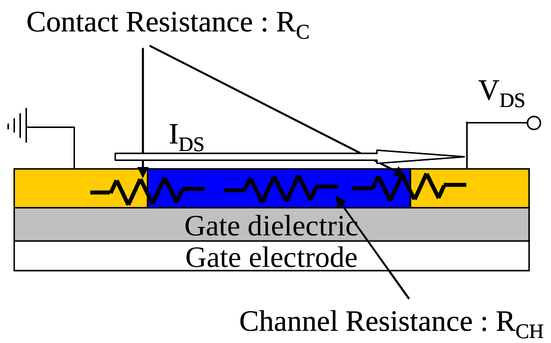

Fig. 1 The schematic of contact resistance and channel resistance produced from source to drain current path.

If we extract the contact resistance at around 0V of V_{DS}, the second term $(V_{DS} - I_{DS}R_C)^2/2$ can be ignored so that

$$I_{DS}\Big|_{lowV_{DD}} \approx \beta(V_G - V_T)(V_{DS} - I_{DS}R_C)$$

We can obtain the output conductance g_D by differentiating drain-source current with respect to drain-source voltage [4].

$$g_D = \frac{dI_{DS}}{dV_{DS}}\bigg|_{lowV_{DS}} \approx \beta(V_G - V_T)(1 - R_C\frac{dI_{DS}}{dV_{DS}})$$
$$= \beta(V_G - V_T)(1 - R_C g_D)$$

Therefore, the contact R_C can be extracted from the measured g_D by the equation of the following.

$$\therefore R_C = \frac{\beta(V_G - V_T) - g_D}{\beta(V_G - V_T)\cdot g_D} \tag{1}$$

The output conductance g_D can be found from slope at the drain-source voltage of near 0 V of output curve. Therefore, using this method, we can extract contact resistance easily from one OTFT.

3. Experiment and result

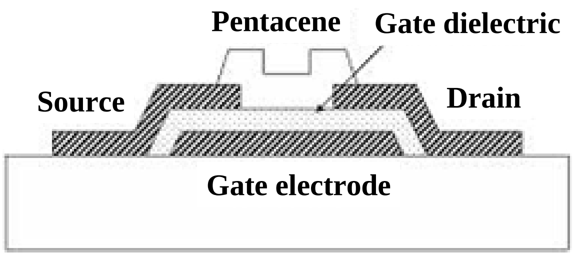

Fig. 2 The structure of OTFTs used for R_C extraction.

We used a heavily doped silicon substrate as bottom gate electrode and silicon oxide as gate dielectric. And we deposited Au as drain-source bottom contact. Finally, we deposited pentacene as active layer by Organic Molecular Beam Deposition (OMBD) as shown in Fig.2. We also prepared OTFTs with the various channel lengths from 10 μm to 60 μm to test the accuracy of this method by comparing the results with those of the previous method.

The squares in Fig. 3 show the obtained contact resistance by the proposed method at drain-source voltage of near 0 V. The contact resistance decreases with V_{GS} from 40 kΩ to 160 kΩ, likely due to the increase of carrier density in the channel and near the contacts [3].

By comparing with the results of the previous method presented by the circles in Fig.3, we found a discrepancy which was increased with V_{GS}. The discrepancy is caused by the carrier density in channel and near drain electrode, which is not correctly considered in Eq. 1. However, this method can be useful to estimate R_C in the first order without the various channel lengths, and also the accuracy will be enhanced by considering the second order effects such as the carrier density and depletion layer around the drain electrode.

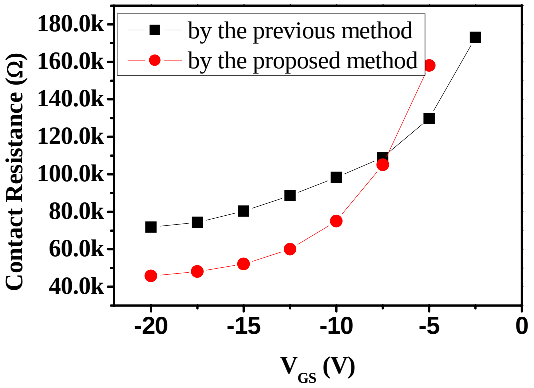

Fig. 3 Comparison of contact resistance extracted by the proposed method and the previous method.

4. Conclusion

We proposed a simple method to extract the contact resistance of OTFTs by considering the voltage drop across the source and drain contacts into the current-voltage relationship. The obtained R_C was compared with the results of the previous method. We found a discrepancy which was increased as V_{GS} increased because of the carrier concentration in channel. The method can be simply applied to estimate the first order of R_C without the OTFTs with the various channel lengths. The method can be improved if we consider the second order effects such as the carrier density as well as the space charge around the drain electrode.

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