CNT/metal hybrid electrodes with low contact resistance for organic thin film transistors

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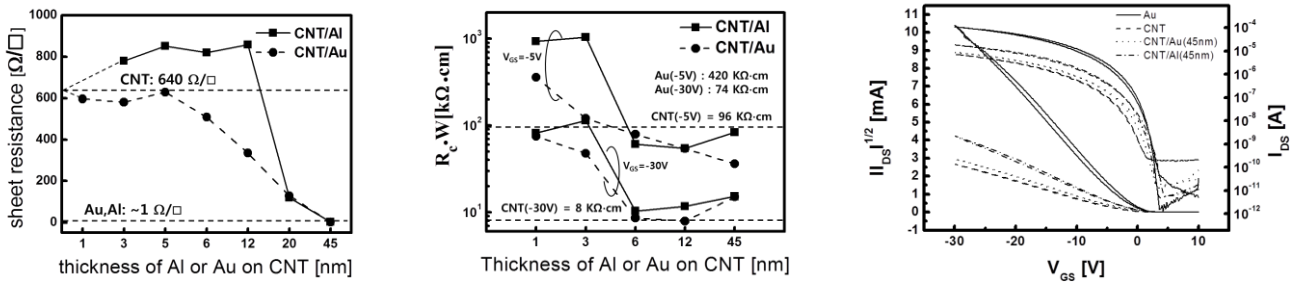
Technology of organic thin film transistors (OTFTs) has been matured able to be applied as a key device of large area and flexible electronics. However, the source and drain electrodes with low contact resistance have still a large room to be developed.

In this paper a metal hybrid electrode based on carbon nano tube (CNT) is proposed for S/D contact of OTFTs. The CNT/metal hybrid electrodes consisted of two layers; CNT base electrode and a metal layer on it. The CNT base electrode was fabricated by spraying a well-dispersed CNT ink, and then a metal was thermally evaporated above the CNT layer. In this study, gold (Au) and aluminum (Al) were used for the metal. The CNT/metal hybrid electrodes were applied to source and drain (S/D) contacts of OTFTs using bottom gate and bottom contact structure.

The sheet resistance of CNT/Au electrodes remained at 640 Ω/□of CNT electrodes until d_{Au} reached 5 nm, and reduced down to 2.4 Ω/□ at d_{Au} = 45 nm (CNT/Au(45nm)) (Fig.1a). The CNT/Al electrodes exhibited the different variation. It was slightly increased from 640 Ω/□ to 852 Ω/□ until d_{Al} increased to 12 nm, and abruptly decreased to 3 Ω/□ at d_{Al} = 45 nm (CNT/Al(45 nm)). The sheet resistance of CNT/Au(45nm) and CNT/Al(45nm) is comparable to 1 Ω/□of the bare Au(45nm) and 1.2Ω/□ of the bare Al(45nm) electrodes, respectively. The reason of the different variation according to the metal will be analyzed in detail. The R_C·W of CNT and Au electrodes was 96 kΩ·cm and 420 kΩ·cm at V_{GS} = -5V, respectively. As shown in Fig.1b) the R_C·W of CNT/Au gradually decreased as d_{Au} increased. In the region of d_{Au} < 5 nm it was between Au and CNT, but when d_{Au} > 5 nm, it became smaller than CNT and was about 40 kΩ·cm at d_{Au} = 45 nm, corresponding to about one half of CNT and one tenth of Au electrode. The CNT/Al electrodes show the different dependence of R_C·W on d_{Al}. It was larger than CNT as well as Au when d_{Al} < 5 nm, but became smaller than CNT in the region of d_{Al} > 5 nm and slightly increased back to CNT at d_{Al} = 45 nm. There are various factors to affect the contact resistance; Schottky barrier at interface between electrode and semiconductor, contact area and morphology of semiconductor on and near electrode, and enhancement of field emission in the case of CNT electrode. The reasons will also be discussed in presentation. The transfer curves of OTFTs using five different electrodes such as Au(45nm), CNT, CNT/Au(45nm), and CNT/Al(45nm) are presented in the Fig.1c). OTFTs using Al electrodes did not show transistor characteristics due to the energy level mismatch between the highly occupied molecular orbital (HOMO) of pentacene (5.1 eV) and the work function of Al (4.08 eV), and thus were discarded from the following discussion. The other OTFTs exhibited well-defined transistor characteristics. The performance will be evaluated by analyzing the important parameters such as contact resistance, mobility, and Schottky barrier height.



a) b) c)

Figure 1 a) The sheet resistance and b) the contact resistance of CNT/metal hybrid electrodes according to thickness of Au and Al layer on CNT, c) the transfer curves of pentacene OTFTs using the CNT/metal hybrid electrodes.

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