Structural effect on carrier doping in carbon nanotube thin-film transistors

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Owing to unusual structural and electronic properties, CNTs have been regarded as emerging materials in wide areas of modern technologies. It has been demonstrated that CNTs work as conducting channels in field effect transistors (FETs) and thermoelectronic devices. In usual CNT-based devices, the channels consist of mat films of CNTs, which intrinsically intersect or align with other CNTs. At the intersectional and aligned regions, the intertube interaction plays decisive roles to determine the device performance. In our previous work, we predicted that field inversion occurs at the intersectional region of two CNTs under a weak electric field. [1,2] Although the aligned CNTs can work as a conducting channel in real devices, the carrier distribution is still uncertain in densely aligned CNT thin films in the FET structure. Thus, in this work, to elucidate the carrier distribution in CNT thin films, we studied the electronic structures of CNT thin films under an external electric field using density functional theory combined with effective screening medium method (Fig.1).

Our calculations show that the distribution of accumulated carriers by the electric field slightly depends on the field strength, constituent CNT species, and intertube spacing. For the thin films consisting only of semiconducting CNTs under large gate voltage, the carriers are primarily distributed on the CNT layer at the electrode side with a small carrier penetration into the opposite CNT layer. In contrast, the carrier penetration in the CNT layer at the opposite side of electrode is enhanced under a low gate voltage. Unlike the cases of the semiconducting CNTs, for the thin films containing metallic CNTs, accumulated carrier distribution strongly depends on the metallic CNT arrangement with respect to the electrode. In addition, a large intertube spacing in the thin films enhances the carrier concentration on the CNT at the electrode side, except in the thin films containing metallic CNTs.

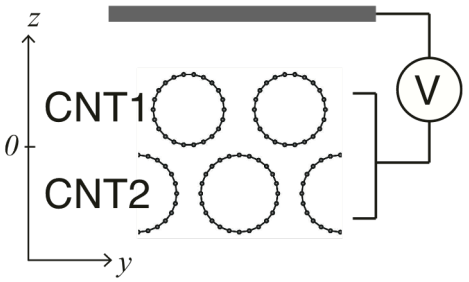

Fig. 1: Structural model of CNT thin film FET.

Reference

[1] Taketo Kochi and Susumu Okada, Appl. Phys. Express **9**, 085103 (2016)
[2] Taketo Kochi and Susumu Okada, Appl. Phys. Express **10**, 075101 (2017)