High-performance, ink-jet printed 99% semiconducting carbon nanotube transistors with enhanced contact interfaces

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Carbon nanotube (CNT) network with the form of thin films have been shown to provide high mobility, thermal conductivity, mechanical flexibility, and chemical stability as semiconducting channels in field-effect, thin-film transistors (TFTs). A variety of CNT network-based TFTs has been demonstrated with record breaking performances [1]; however, there has still been limited effort toward improving overall CNT-TFT performances. In particular, due to the randomness of CNT network channel, it is difficult to control the performances of CNT TFTs, such as contact resistance (R_C), threshold voltage (V_T), and subthreshold swing (S). Especially, contact interfaces comprising of the overlap between CNTs and metal S/D electrodes play a particularly dominant role in determining the performances and degree of variability in the CNT-TFTs [2, 3].

The present work demonstrates the ink-jet printed CNT-TFTs with enhanced contact interfaces for better device performances. The CNT network as an active channel for each device was created from high purity semiconducting CNT solution produced by a density-gradient ultracentrifugation (DGU) method [4]. Highly purified, pre-separated 99% semiconducting CNTs were utilized as a formation of CNT network channel using simple drop-casting method from the solution; hence, the contact area between semiconducting CNTs and the metal S/D electrodes is very important to determine the properties of contact interfaces and overall performances of CNT-TFTs. For the enhanced contact interfaces, we carefully controlled the density of CNTs underneath the S/D electrodes during formation of CNT network and systematically investigated the contact resistances and overall performances of the fabricated CNT-TFTs. Through designing and optimizing the CNT densities, the enhancements of device performances were obtained, in terms of 92% increased on-state current, 4% increased on/off current ratio, and 77% decreased total R_C. We believe that our findings enable to guide further development of CNT-TFTs.

References

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Acknowledgments: This work was supported by NRF (2016R1A2B4011366 and 2016R1A5A1012966), and partially by the Future Semiconductor Device Technology Development Program (Grant 10067739) funded by MOTIE and KSRC.