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High-yield fabrication of n-type carbon nanotube thin-film transistors on flexible plastic film

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Carbon nanotube thin-film transistors (CNT TFTs) are envisioned to enable high-performance flexible electronic devices due to its highly desirable electrical and mechanical properties [1,2]. As-fabricated CNT TFT devices are normally p-type, due to the adsorption of oxygen molecules in the ambient air. However, n-type TFTs are also required for constructing complementary metal-oxide-semiconductor (CMOS)-based circuits with low power consumption and good noise margins. In this work, a relatively high-yield of 95.3 % for more than 800 n-type CNT TFTs on a flexible substrate was achieved.

Bottom-gate type TFTs were fabricated on a flexible and transparent poly(ethylene naphthalate) (PEN) substrate as shown in Fig. 1. Semiconductor-enriched CNTs were used for the channel material. Prior to n-type doping, we confirmed that all devices (831 devices) showed p-type behavior with on/off ratio of ~10^4 and rather uniform characteristics. Then, polyethyleneimine (PEI) (Sigma Aldrich, MW = 800) was used for n-type doping. An Al_2O_3 passivation layer was formed by atomic layer deposition [3].

Figure 2 shows the transfer characteristics of 827 operational devices after PEI doping with Al_2O_3 passivation. 99.5 % of 831 devices were converted to n-type behavior by the n-type doping method without significant degradation of on current and mobility. The other devices (four devices) did not work after doping due to gate leakage current or damage during measurement. A majority of the TFTs maintained on/off ratio of ~10^4, with an average hysteresis width of 0.25 V. However, low on/off ratio and threshold voltage shift toward the normally-on condition were observed by a few percentages of devices. This is probably due to non-uniformity in doping levels caused by the spin coating method.

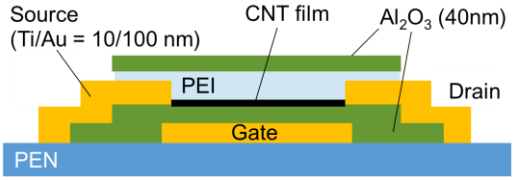

Fig.1 Schematic structure of a typical n-type device.

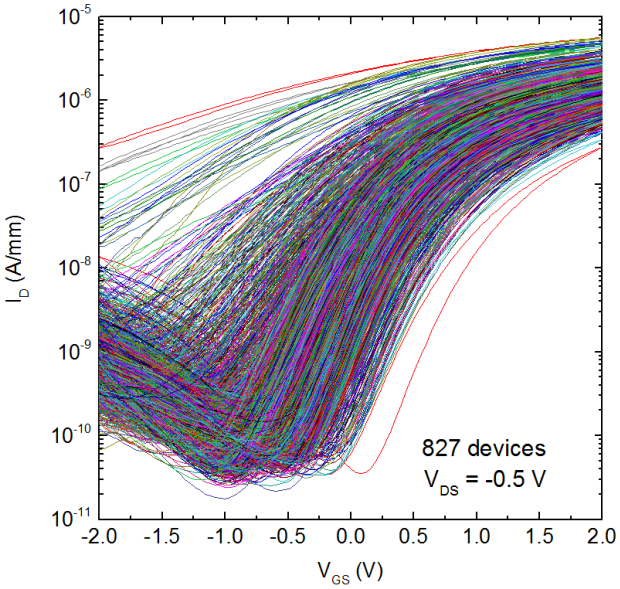

Fig. 2 I_D-V_{GS} characteristics at V_{DS} = 0.5 V of 827 CNT TFTs after PEI doping.

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References

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