Influence of channel morphology on CNTFET device performance

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Enhancement of carbon nanotube based field-effect transistor (CNTFETs) performance for high frequency analog electronics goes inevitable along with an increase in the density of semiconducting nanotubes [1, 2]. However, with increasing density device performance is more and more determined by shielding and bundeling issues [3]. In this paper we unfold the influences of channel morphology by a systematic study on two different sets of FET structures correlating morphologic and electrical characteristics as well as changes after thermal annealing. In addition, simulations have been performed to support the experimental findings. It revealed a diversified picture on FET performance under different structural situations.

In Fig. 1, transfer characteristics of CNTFET-d (debundled) and CNTFET-b (bundled) devices including the state before and after annealing are compared. As expected, on-conductance (G_{on}) increased after annealing due to the reduced Schottky barrier and improved current injection. While in the as-prepared state both FET configurations indicate gate control of devices, the transfer characteristics dramatically change after annealing indicating different environmental and structural situation. Since removal of contaminants along with rinsing is expected to be less efficient in bundled CNT assembles, assembly structure should be directly interrelated to interface configurations with respect to doping and proximity effects. In addition, measuring the device under atmosphere lead to a water-induced doping. It can be assumed that spacing in bundled as well as closely packed CNTs is reduced by the annealing which eventually reduces gate control in conjunction with the CNT doping. The strong shift of V_{th} seen for the bundled CNTs in the experiment, can be explained by an effective increase of the impact of doping due to the proximity of CNTs after annealing. This has been confirmed by the simulations as shown in the inset in Fig. 1b. Thus, a higher $+V_{GS}$ is required to deplete all injected charges and completely switch off the device, which results in a shift of the transfer characteristics curves more into the positive gate voltage. In conclusion, this study shows that contaminants and water-induced doping has a much larger impact on the device characteristics especially in the subthreshold region and for V_{th} in case of tube bundles. This emphasizes that especially in dense s-SWNT assembles bundling has to be suppressed to enable removal of all contaminants at interfaces in order to get reproducible and stable device characteristics.

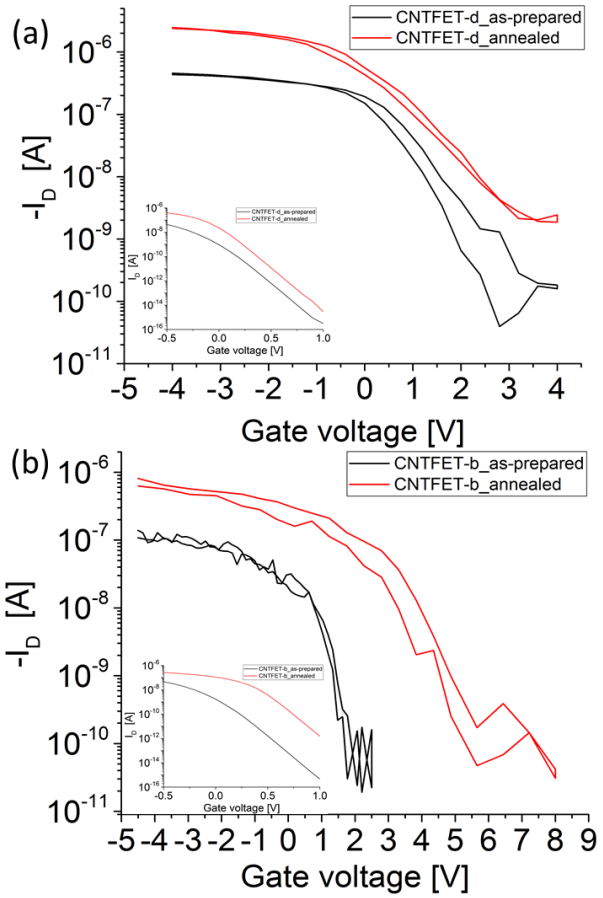

Fig. 1. Transfer characteristics of FETs comparing as-prepared and annealed state of FETs with (a) debundled and (b) bundled nanotubes. Figure inset show the results obtained from the simulation.

References

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