Prediction of Five-fold Increase in Current Gain of Optimally Aligned CNT Network over Random Networks

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Nanobundle thin film transistors (NB-TFT) based on *random* networks of Single wall carbon nanotube (SWCNT) are possible higher performance alternative to a-Si technology for macroelectronics applications[1]. Here, we use stick percolation model[2] to study the effect of alignment on the performance of NB-TFTs. In this paper for *the first time*, we (i) use a recently developed alignment technique[3] to fabricate NB-TFT devices with multiple densities (D), alignment (θ), channel length (Lc) and tube length (Ls), (ii) interpret the experimental data with a stick-percolation model to develop a comprehensive theory of NB-TFT for arbitrary (D, θ, Ls, Lc), and (iii) our simulations predict that a five fold increase in current gain (over existing designs) is possible with optimized transistor structure.

Although the alignment improves the drain current (Ion) by decreasing average path length, it also reduces the number of available paths for a long channel (Lc > Ls) transistor. This can lead to a decrease in Ion due to lesser number of tubes intersecting to form percolating networks. The above trade-off gives a point of optimal alignment for CNT networks and aligned NB-TFT requires a more careful design than previously anticipated[4].

The experimental two-terminal drive current (Ion) vs. θ is characterized by the three counter-intuitive features: (a) Ion is maximized by an optimum distribution in between random and aligned network, (b) Ion of the optimally aligned network is approximately 20-40% higher compared to Ion of the random NB-TFT, and (c) Finally, Ion degrades rapidly as perfect alignment is achieved.

Remarkably, our stick-percolation model, (i) quantitatively reproduces all the three experimental features discussed above and predicts 20-40% gain in optimally aligned network over the random network for Lc>>Ls, (ii) the simulations suggest that more alignment is needed to optimize the performance and % improvement increases with decreasing Lc and (iii) for Lc << Ls, the improvement could be as high as 100% over the completely random networks which is a five fold increase over the existing designs

In summary, we have used novel fabrication, characterization, and modeling to consistently interpret, for *the first time* experiments involving NB-TFTs with partially/fully aligned nanotubes networks. We have also demonstrated the possibility of simulation-guided optimization of transistor performance as a function of density, alignment and length of CNTs.

References

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