

4-20-2015

Towards Molecular Modification of Carbon Nanotube Junctions in Thin Film Transistors

Noelia Caloca

A. Nicole Chang

Kari McLaughlin

David Estrada



Towards Molecular Modification of Carbon Nanotube Junctions in Thin Film Transistors

Noelia Caloca, A. Nicole Chang, Kari McLaughlin, David Estrada
Boise State University, Department of Material Science and Engineering

Background

Carbon nanotube thin film transistors (CNT TFT) have recently been used on flexible and transparent substrates for applications in integrated circuits and display drivers. Such networks are of interest due to their relatively high carrier mobilities and mechanical flexibility. [1] However, the I_{ON}/I_{OFF} ratio of these networks varies inversely with the carrier mobility and advances in reducing the electrical and thermal resistance of nanotube junctions are needed to improve the device performance and reliability. [2,3]

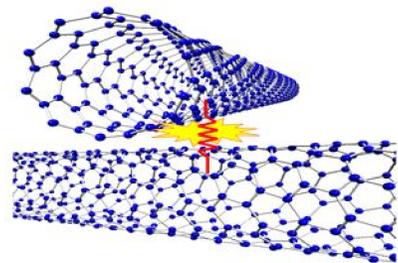


Fig. 1 Schematic of cylindrical nanostructure of a carbon nanotube and nanotube junction

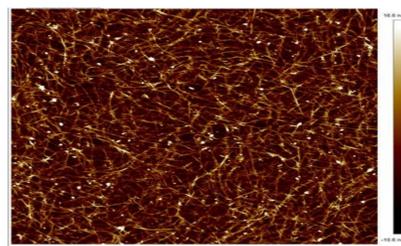


Fig. 2 AFM image of a carbon nanotube network

Objective

Our objective is to create a process to improve CNT TFT device performance by using zero-dimensional molecules to modify the physical properties of nanotube junctions.

Methods

1. Contacts and metal pads are placed on the substrate via photolithography, thermal evaporation, and lift off processes
2. Carbon nanotube (CNT) solution is vacuum filtered
3. A CNT film is then transferred on to the receiving substrate by dissolving the filter via an acetone vapor bath
4. Carbon nanotube network (CNN) channels are patterned via photolithography
5. Devices are characterized by running voltage sweep tests
6. Fullerene solution is deposited on to device
7. Devices are characterized to determine the effect of the fullerenes on device performance

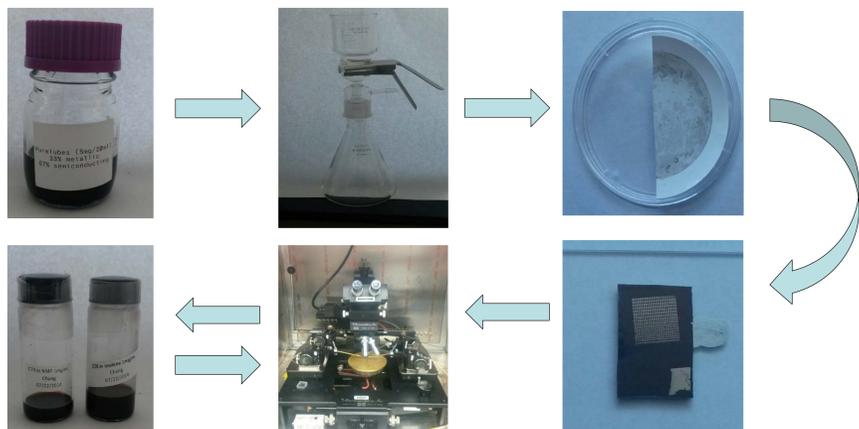


Fig. 3 Carbon nanotube device fabrication procedure

Device Structure & Experimental Setup

To characterize these devices:

- V_{GS} is swept across the device (-20V to 20V)
- V_{DS} is held constant (0.1 V)
- I_{DS} is obtained for each V_{GS}
- I_{ON}/I_{OFF} ratios, device resistance, and carrier mobility can be extracted

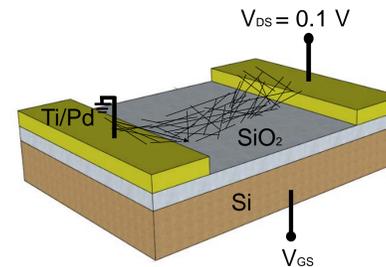


Fig. 4 Thin film transistor device structure utilizing a channel of CNTs

C_{ox} : Gate Capacitance per unit area
 V_{DS} : Drain voltage
 L : CNN channel length
 W : CNN channel width
 g_m : Peak Conductance

Carrier Mobility, μ_{FE} :

$$\mu_{FE} = \frac{Lg_m}{WC_{ox}V_{DS}}$$

I_{ON}/I_{OFF} Ratio:

$$\frac{I_{ON}}{I_{OFF}} = \frac{I_{max,at -20V}}{I_{min}}$$

Device Resistance R_{ON} :

$$R_{on} = \frac{V_{DS}}{I_{ON}}$$

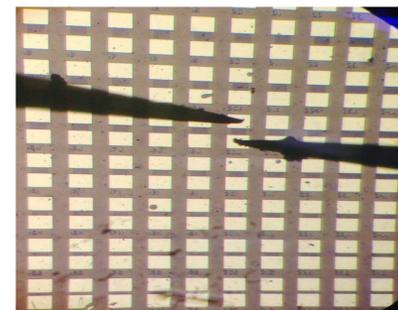


Fig. 5 Devices through microscope lens during characterization

Results

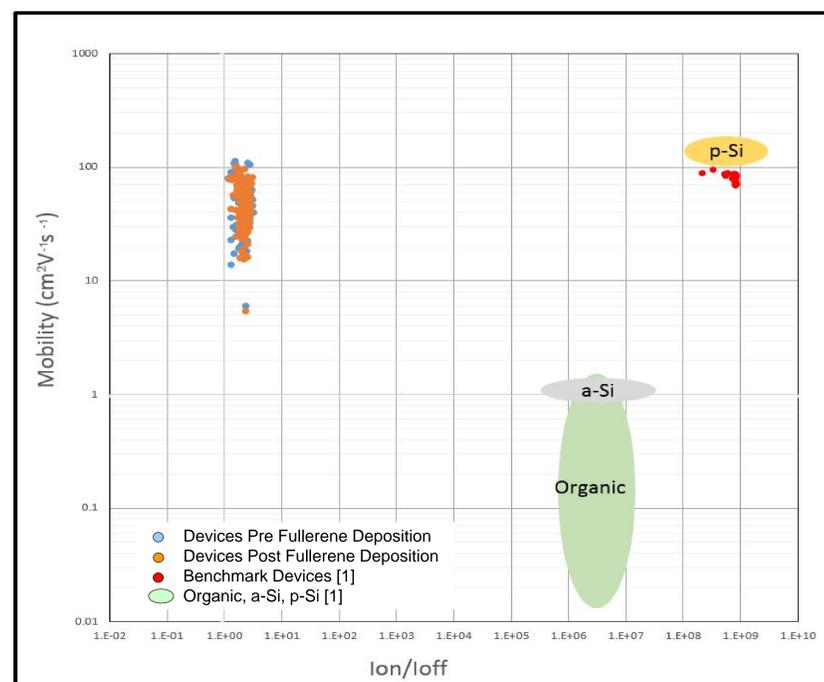


Fig. 6 Plot comparison between current study devices and other devices

Discussion & Conclusion

It was hypothesized that both carrier mobility and I_{ON}/I_{OFF} ratio would increase with the deposition of fullerenes. When testing was done this was not the case. In fact, both mobility and I_{ON}/I_{OFF} ratio decreased. This is believed to be because the fullerenes dope the devices as n-type, leading to increased p-n junctions in the otherwise p-type network.



Fig. 7 Keithly characterization system used to perform voltage sweep test on devices

The next steps in the project are as follows:

- Use different concentrations of metallic and semiconductor CNT solutions to decrease overall device resistance
- 99% Semiconducting
- 99% Metallic
- Deposit C70 via thermal evaporation



Fig. 8 Thermal evaporation station that will be used in future fullerene deposition techniques

References

- [1] D. Sun et al., Nat. Nanotechnol. 6, 156 (2011)
- [2] P. Nirmalraj et al., Nano Lett. 9, 3890 (2009)
- [3] M. Stadermann et al., Phys. Rev. B: Condens. Matter Mater. Phys. 69, 201402 (2004)

Acknowledgements

A special thanks to the Nation Science Foundation and Idaho Science Talent Expansion Program and to Dr. Paul Davis and the Boise State University Surface Science Lab for their assistance with AFM imaging.

Funded by:

