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Towards Molecular Modification of Carbon Nanotube Junctions in Thin Film Transistors

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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 ION/IOFF 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]

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 filtrated
3. A CNT film is then transferred onto 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 onto device
7. Devices are characterized to determine the effect of the fullerenes on device performance

Device Structure & Experimental Setup

To characterize these devices:
• VGS is swept across the device (-20V to 20V)
• VDS is held constant (0.1 V)
• ION is obtained for each VGS
• ION/IOFF ratio, device resistance, and carrier mobility can be extracted

Carrier Mobility, \( \mu_{FE} \):
\[ \mu_{FE} = \frac{I_{max,at\ -20\ V}}{WC_{Gx}V_{DS}} \]

I\(_{ON}\)/I\(_{OFF}\) Ratio:
\[ \frac{I_{ON}}{I_{OFF}} = \frac{I_{max,at\ -20\ V}}{I_{min}} \]

Device Resistance \( R_{ON} \):
\[ R_{ON} = \frac{V_{DS}}{I_{ON}} \]

Results

<table>
<thead>
<tr>
<th>Device Pre Fullerene Deposition</th>
<th>Device Post Fullerene Deposition</th>
<th>Benchmark Devices [1]</th>
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<tbody>
<tr>
<td>Organic, a-Si, p-Bi [3]</td>
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Discussion & Conclusion

It was hypothesized that both carrier mobility and ION/IOFF ratio would increase with the deposition of fullerenes. When testing was done this was not the case. In fact, both mobility and ION/IOFF 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.

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

References


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