Carbon Nanotube Capture by AC Dielectrophoresis for the Fabrication of a Thin Film Transistor and Investigation of its Properties by Scanning Gate Microscopy

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Single walled carbon nanotubes (SWNTs) are one of many unique materials subject to recent attention due to their remarkable properties, including high electron mobility, flexibility, optical transparency, and chirality dependent electrical properties. Accordingly there has been interest in their application in thin film transistors (TFTs) in the form of random nanotube networks [1]. Considerations for the enhancement of the quality of such a device include the concentrations of metallic and semiconducting nanotubes in the network and the network layout. Deposition of aligned nanotubes has been demonstrated via AC dielectrophoresis (DEP) under certain conditions [2], so we have further investigated the effects of this fabrication technique, using atomic force microscopy (AFM) and scanning gate microscopy (SGM), among other conventional techniques. AC DEP has been shown to selectively capture semiconducting SWNTs from solution, exhibiting much weaker interaction with metallic SWNTs in our experiments. This behavior can be explained by the dependence of the DEP force on the complex dielectric constants of the SWNT and the solution. No significant alignment was achieved with our SWNT samples. Since the torque on SWNTs in an electric field increases with tube length, our average length of 1.6 μm might be too small for a substantial aligning torque. We also report on SGM observations and device characteristics of the SWNT network fabricated in this process.

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Introduction

Single Walled Carbon Nanotubes (SWNTs)
- Cylindrical molecules of sp\(^{2}\) bonded carbon
- Low dimensionality
- High electron mobility
- Structure dependent electrical properties
- Optical transparency
- Flexibility
- Mechanical strength

Thin Film Transistors (TFTs)
- Responses at M/S junctions desired [1]
- Metallic connections short device
- Current path is indirect

Motivations
- SWNT Layout Manipulation
- Enhance M/S junction density
- Reduce metallic shorts
- More direct current path

Method

AC Dielectrophoresis (DEP)
- Shown to align high density networks from solution [2]
- SWNTs applied to electrodes, bias applied for 30 seconds to 1 minute
- NanoIntegrins sSWNT and mSWNT 90% 1mg/100mL, with surfactant for dispersion
- Methanol treatment to remove surfactant
- Plasma etching to confine channel to 5μm

Scanning Gate Microscopy (SGM)
- Mobile point gate scans FET response
- Obtain Atomic Force Microscopy (AFM) and Scanning Gate Microscopy (SGM) images simultaneously
- Locate and characterize FET response [1]

Results and Analysis

AFM of DEP Network
High Density Alignment Nanotube capture
Semi-conducting Metallic
Lower density No alignment
No capture

SGM of Semiconducting Network
Before

AFM

After

FET Hysteresis
- Backgate Voltage Dependence
- Scan Speed Dependence
- Time evolution

Conclusions and Future Work

⇒ DEP selectively captures SWNTs, no alignment
⇒ FET response within SWNT network

More Investigation of:
⇒ Solution concentration, deposition parameters
⇒ Network Composition (Raman spectra, etc.)
⇒ Hysteresis: Avoidance or Exploitation

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