Nanoelectromechanical Systems from Carbon Nanotubes and Graphene

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Abstract

Carbon nanotubes and graphene have many interesting properties. To exploit the properties in applications their synthesis and incorporation in devices has to be understood and controlled. This thesis is based on experimental studies on synthesis of carbon nanotubes and fabrication of nanoelectromechanical systems from carbon nanotubes and graphene.

Vertically aligned nanotube arrays with heights over 800 μm have been grown using acetylene with iron as catalyst on alumina support using thermal chemical vapor deposition. By varying the partial pressure of acetylene it was found that the addition-rate of carbon was proportional to the coverage of acetylene molecules on the catalyst nanoparticle.

In certain conditions the macroscopic pattern of the catalyst areas influenced the microscopic properties of the carbon nanotubes. It was shown that the initial carbon-precursor flow conditions could determine the number of walls produced. The amount of carbon incorporated into nanotubes was constant but regions that experienced less carbon precursor gas flow due e.g. to depletion, produced longer but fewer-walled nanotubes.

Arrays of vertically aligned nanotubes were shown to deflect as a single unit under electrostatic actuation, making possible the fabrication of varactors. Measurements of deflection were used to determine an effective Young's modulus of 6 ± 4 MPa. The capacitance of such a device could be reproducibly changed by more than 20 %.

Devices based on the nanoelectromechanical properties of few-layer graphene were fabricated and characterized. Electrostatic actuation of buckled beams and membranes led to a "snap-through" switching at a critical applied voltage. By characterizing this behavior for different sizes and geometries of membranes, it was possible to extract the bending rigidity of bilayered graphene, yielding a value of 35^{+20}_{-15} eV.

CNTFETs with suspended graphene gates were fabricated. It was shown that a moveable graphene gate could control the conductance of the carbon nanotube and improve the switching characteristics. Inverse sub-threshold slope down to 53 mV per decade were measured at 100 K. The experimental data were compared with theoretical simulations and it was inferred that the subthreshold slope could be improved beyond the thermal limit by improving the design of the device.

Keywords: Carbon nanotubes, Synthesis, Chemical vapor deposition, Graphene, Bending Rigidity, Nanoelectromechanical systems