GROWTH, FABRICATION AND CHARACTERIZATION OF CARBON NANOTUBE BASED FIELD EFFECT TRANSISTORS

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With favorable electrical and optical properties, carbon nanotube (CNT) based field effect transistors (FETs) are a promising area of nano-scale research. Compared to conventional MOSFETs, CNT-FETs can be used to create smaller, higher speed devices. However, due to the lack of precise control over CNT growth and the CNT's sensitivity to adhesive materials on the surface, it has been a difficult task to fabricate CNT-FETs with uniform electrical properties. Our experimental project consists of two parts. The first is to learn the basic micro-fabrication techniques used to make CNT-FETs with single-walled CNT channels. To make these samples, we used p-type silicon wafers with layers of SiO_2. First, spin-coating was used to place two layers of resist on the substrate; the first to improve the bond between the substrate and the photo-resist and to prevent excess material from being deposited on the ends and then a layer of photo-resist. Through positive-type photolithography, the locations of the catalysts were patterned. Next, electron beam deposition was used to add the catalysts for CNT growth. Then, utilizing chemical vapor deposition, CNTs were grown. Following this, electron beam and thermal evaporation thin film deposition were used to place layers of Ti and Au on the substrate for use as electrodes. Finally, via atomic layer deposition, HfO_2 was deposited to add passivation and to decrease the hysteresis on the samples. For our measurement setup, we used a semiconductor parameter analyzer to measure current versus voltage and current versus ground voltage, for both source-drain and gate-drain applied voltages. In the second part of the project we will design CNT-FETs with suspended CNT channels. According to the design, electron beam lithography will be used to make the holes underneath the CNT channels and will be investigating appropriate conditions for the reactive ion etching process to make the hole. Electrical properties of the devices will be investigated in detail.

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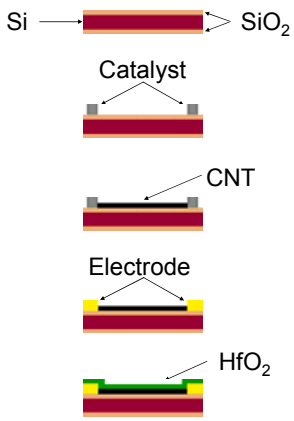
Introduction

With favorable electrical and optical properties and their application to smaller, higher speed devices and sensors, carbon nanotube (CNT) based field effect transistors (FETs) are a promising area of nano-scale research.

Our experimental project was to first learn the basic micro-fabrication techniques needed to fabricate and evaluate FETs with single-walled CNT channels and then to fabricate CNT-FETs with self-suspended CNT channels. These devices will offer a unique opportunity to investigate the electro-optical properties of CNT channels without the effects of the adhesive materials' interaction with the channel on the substrate.

Device Fabrication



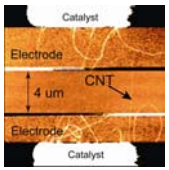
(1) Used Si wafers covered in SiO_2
Si thickness: 500μm
SiO_2 thickness: 300nm

(2) Deposited catalysts for CNT growth
Si(20nm) / Al(30nm) / Fe(2nm) / Mo(0.3nm)

(3) CNT growth via chemical vapor deposition
Growth temp: 900° C Growth time: 15 min
Gases: CH_4 (1000sccm) and H_2 (500sccm)

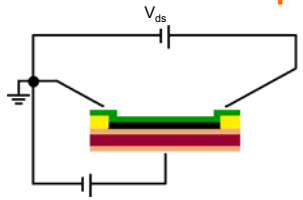
(4) Deposited electrodes
Ti(20nm) / Au(60nm)

(5) Deposited HfO_2 via atomic layer deposition
Thickness: 20nm

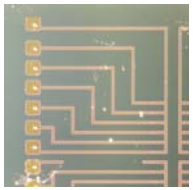


-Channel length: 4μm

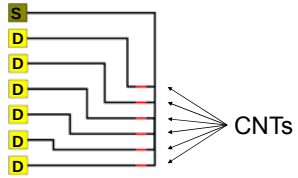
Measurement Setup



(a) Back gate setup

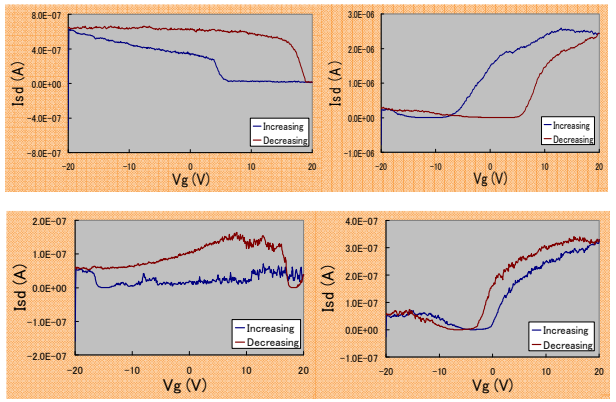


(b) Photo of sample



(c) CNT-FET circuit schematic

Results



Parameters:
V_{ds} = 1 V
V_g = -20 V ~ 20 V

(a) Depositing the Hf caused a changed from a N-type to a P-type FET.

(b) Hf deposition caused a noticeable decrease in the hysteresis.
Decrease: 33.3 V →2.7 V

Future Plans

In order to further study the electro-optical properties of the CNT-FETs, reactive ion etching will be used in combination with the above process to fabricate FETs with suspended CNTs as the channel. The appropriate conditions for the reactive ion etching process to make the hole and the electrical properties of the devices will de investigated in detail.

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