Flexible electronics using carbon-nanotube transistors

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Introduction

Carbon Nanotube Technology

- Carbon nanotube: an allotrope of carbon with a cylindrical nanostructure
- Field-effect transistor (FET): a transistor that uses an electric field to control the electrical behavior of the device
- Carbon nanotube field-effect transistor (CNTFET): a FET that utilizes carbon nanotubes as the channel material instead of traditional silicon
- Properties of carbon nanotubes (strength, flexibility, high conductivity), make it a very promising material for flexible electronics.

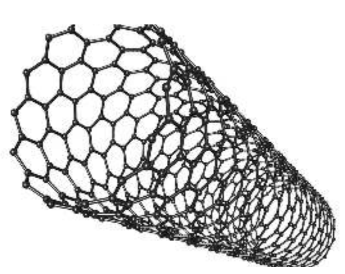


Figure 1. Structural model of a carbon nanotube. PC: AJC on Flickr

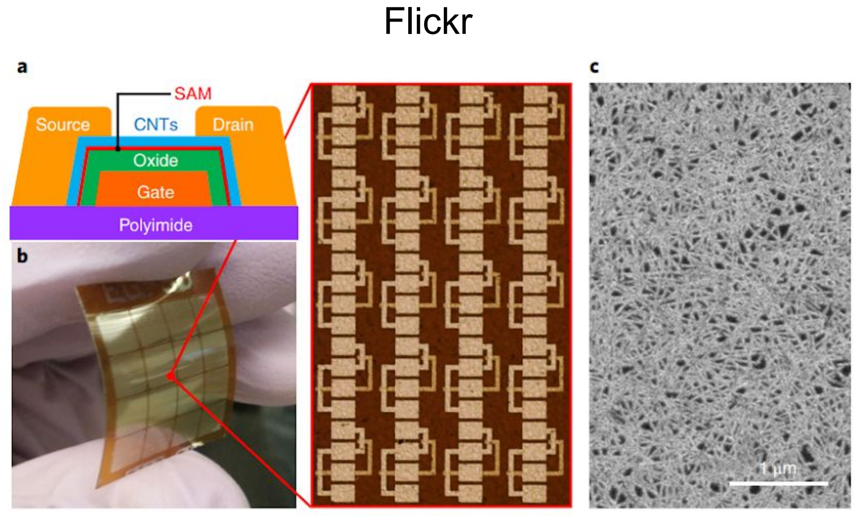


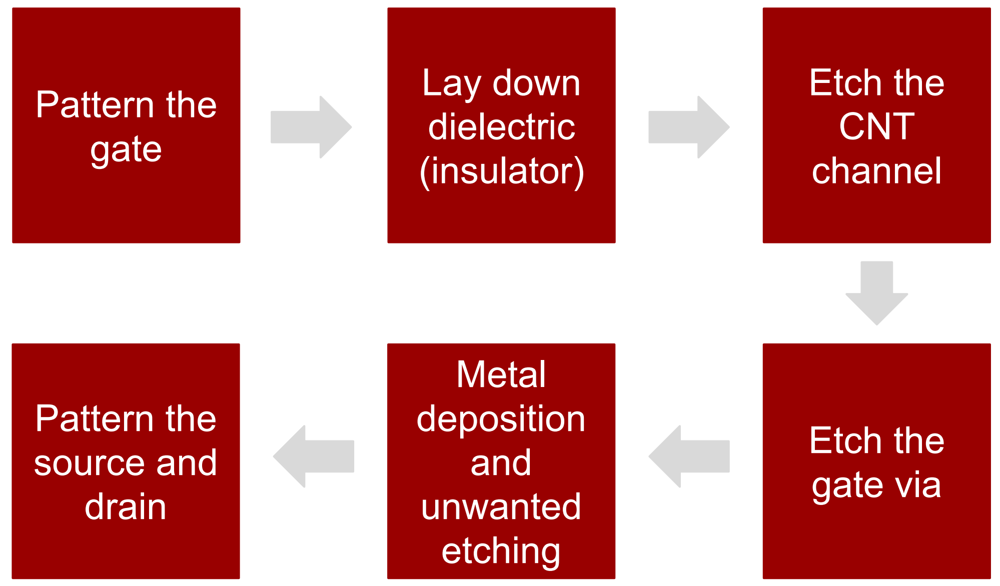
Figure 2. (a) Cut view of the structure of a back-gate device. (b) Photo of CNT devices fabricated on a flexible substrate. Inset: microscopic image of CNT arrays. (c) SEM image of the high-density network of deposited CNTs. PC: Jianshi Tang from *Nature*.

The goal of the research is to design devices and measure and model their electrical behavior, so that CNT technology can be utilized in circuits and, potentially, flexible electronics.

Methods

Fabrication Process

- We first design the mask that is used to create the devices using photolithography, a process that uses light to transfer a pattern from a photomask to a light-sensitive chemical (photoresist) on the substrate.



- The back-gate design of the devices requires a complex fabrication process that takes weeks to complete.
- Each device on the wafer is varied; some have a different channel length or width, some are PMOS or NMOS devices.
  - PMOS device: holes (missing electrons) are charge carriers
  - NMOS devices: electrons are the charge carriers and require an extra step (passivation) that involves coating the channel with Al_2O_3.

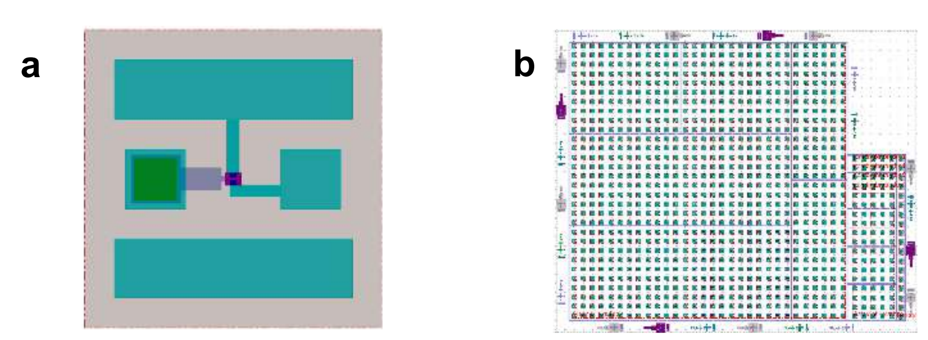


Figure 3. Design of a photomask for a back-gate device. (a) Design of one device. (b) 1000 devices on one wafer. PC: Hongyu Fu

Measurement

- After fabrication, I used a probe station to measure the current output of the devices.

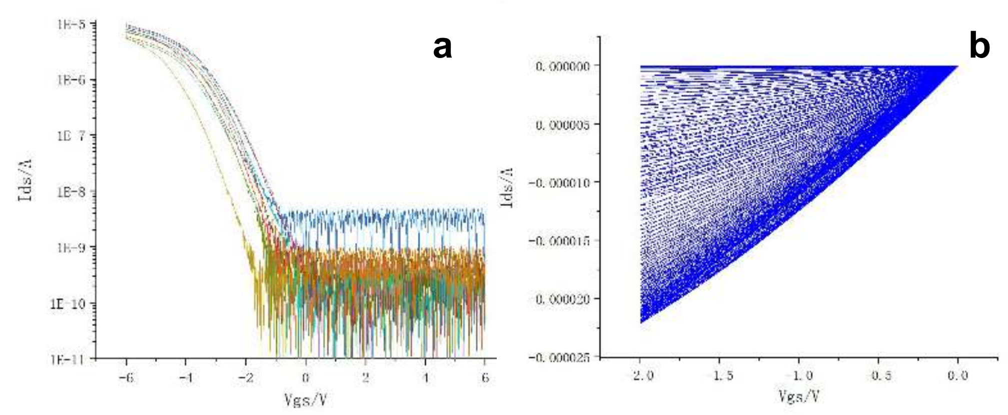


Figure 4. (a) Current output vs Vgs, transfer curve. (b) Current output vs Vds, family curve. PC: Hongyu Fu

- Vgs: voltage between the gate and source
- Vds: voltage between the drain and source

Modeling

- Finally, using the data gathered from the measurements, I created a model of a circuit using the devices to simulate its behavior in a program called Cadence.

Results

- These results are significant because they show that the simulated behavior of the devices is the same as the measured behavior.

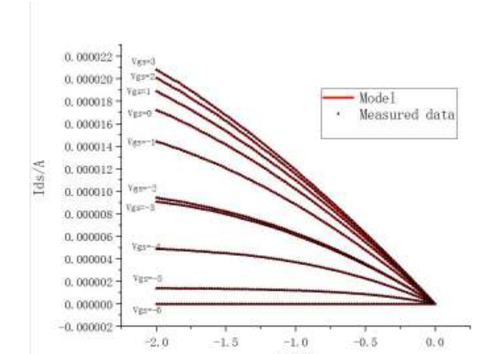


Figure 5. Data modeled in the simulation and data measured from the fabricated devices plotted on the same graph for comparison. PC: Hongyu Fu

Skills Learned

- Photomask design
- Measuring devices with a probe station
- Electro and device physics concepts
- Using Cadence and Verilog A to simulate circuits

Figure 6. Probe station used for measuring devices. PC: Jessica Chao

Impact of Research

- New MOSFET device technology that has many potential benefits over traditional devices
- Measuring behavior of fabricated devices allows simulation of new circuits and circuit design

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