Abstract:

We have fabricated field effect transistors in order to study charge trapping in pentacene transistors and charge noise in a variety of organic field effect transistors.

Summary:

Pentacene is a leading candidate for its use in organic transistors, yet its performance is limited by a variety of factors, including charge trapping. In order to shed light on the mechanism of charge trapping, we have fabricated pentacene transistors and have subsequently studied these devices via scanned-probe atomic and electric force microscopy [1]. By measuring the rate of charge detrapping with varying wavelengths of light, we have obtained a chemical signature of the charge trap which can be used to positively identify the trap species [2]. In Figure 1 we show an electric force microscope image of surface potential in a pentacene transistor infused with a candidate trap species.

In another area of study we are using electric force microscopy to investigate charge noise above organic field-effect transistors. Electric force measurements of charge noise in these devices are still in progress. To fabricate the substrates for the pentacene transistors, we have grown 300 nm of SiO on top of a silicon wafer and have patterned interdigitated metal electrodes with a 5 µm spacing on top of the SiO.

References:


Nano-Scale Devices for Biosensor Applications

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Abstract:

Several nanowire devices of mono-crystalline silicon were fabricated using e-beam and optical lithography. The monocrystalline and polycrystalline device characterization was compared and demonstrated with gate and drain voltages. The electrochemical impedance spectroscopy was used to test device stability and sensitivity under various experimental conditions. The stable, selective and well aligned polycrystalline silicon nano-wire have been proposed as an economic alternative to other nano-wire devices. By controlling fabrication conditions results similar to those obtained from monocrystalline silicon and other semiconducting materials. These polysilicon nanowires showed excellent stability with several repeated current voltage test.

Summary of Research:

Nanowire based bio-sensing has been the focus of an intensive ongoing effort from various scientific programs to develop low-cost, ultra-sensitive devices, which perform detections in very little time. Currently, nano devices are becoming ever more sophisticated and reliable. These nanoscale devices can be widely applied in several potential fields including clinical diagnostics, environmental detection, food analysis, bio-agent detection and containment. However, the commercialization has been slow due to various technical difficulties that arise in the materials, surface chemistries, and fabrication processes of these devices. Carbon nanotubes and silicon nanowires have been demonstrated as single molecule biosensors [1,2], but the fabrication methods that have been used for creating these devices are typically not compatible with current process techniques and their integration is technically difficult [3].

The aim of our research is to review nanoscale device fabrication using doped polysilicon as the primary semiconductor. The nanowire was chosen for its easy fabrication and low fabrication cost. Researchers have also shown that polysilicon nanowire devices have superior electrical properties and have better gate controllability than other materials [4,5]. Our current work is a step forward towards addressing these issues. The resolution these issues will greatly benefit the fabrication, and large-scale production of these small sized devices. It will also have a great impact in the future market for polysilicon based nanowire devices.

The detailed fabrication method used in this work is published elsewhere [6]. A 50 nm low boron doped mono-crystalline silicon nano-wire device with $5 \times 5 \mu m$ hole in center shown in Figure 1 was fabricated for detection of shiga toxin. The I-V characterization curves (Figure 2) for this set of monocrystalline nanowire with an Au/Ti interface exhibit a Schottky type of interface. The Schottky nature of these devices especially with Au/Ti metal contact was in good agreement with simulated results. When a boron-doped nanowire is sandwiched between two Ti/Au metal contacts, two back-to-back Schottky diodes are formed. The nanowire has very high resistance, which can be changed using a voltage applied to the wafer substrate. On the other hand, Ohmic contact can be seen in the devices with an Au/Cr nanowire interface (Figure 3 right side). The polysilicon device functionality was tested under different concentration of bacterial samples, with the results compiled as a time vs. impedance plot (Figure 3). A 10 mV sine wave was used as device input. Repeatable results from these devices indicate excellent sensitivity. This will serve as a reference model for ongoing biosensing research.

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References:


Figure 1: A horn shaped image of a nanowire terminal to improve metal contact shown on this figure which is ~ 45 nm wide and ~ 175 nm thin lightly boron doped monocrystalline silicon nanowire separated with 20 µm between two Au/Ti metal contacts.

Figure 2: Most of these devices show repeatable I-V characteristics with the least variation in nanowire current, which is well under 50 nA. This set of devices also show Schottky behavior. Figure on right hand side shows gate voltage vs. drain current profile of these lightly doped devices showing ohmic profile but the main difference was bias voltage and Cr/Au contact for these devices.

Figure 3: A single frequency (1009 Hz) electrochemical impedance spectra of different concentration of bacterial sample solution. 15.0 mV AC was applied between drain to source electrode with 0.0V DC bias. Higher concentration (1E-6 Molar) shows high drop in impedance compare to lower concentration (1E-14 Molar) which indicates clear interaction of samples towards nanowire surface.
Characterization of Graphene Obtained by Chemical Vapor Deposition

CNF Project # 1486-06
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Abstract:

Following the increasing demand for graphene, chemical vapor deposition (CVD) has emerged as a viable method to obtain large-area graphene. CVD graphene shares many of the remarkable properties observed in exfoliated graphene. It still remains of paramount importance to fully characterize CVD graphene, as many of its properties can be altered by a smaller grain size. We studied the mechanical response of CVD graphene membranes, finding a decreased breaking strength. In addition, we fabricated devices to study the individual effect of grain boundaries on electronic transport.

Summary of Research:

We fabricated arrays of membranes by growing graphene by chemical vapor deposition (CVD) on copper foil [1]. Graphene was then transferred from the copper foil onto holey silicon nitride membranes by protecting graphene with a poly(methyl methacrylate) (PMMA) layer and then etching copper away in a ferric chloride solution. These holey silicon nitride membranes were fabricated by growing low pressure chemical vapor deposition (LPCVD) low stress silicon nitride on standard silicon wafers, and patterning them with standard photolithography and reactive ion etching. The PMMA layer was then removed by thermal decomposition in air, leaving graphene freely suspended across holes in the silicon nitride membrane, as shown in Figure 1.

We studied the resulting graphene membranes with atomic force microscopy (AFM). As can be seen in Figure 2, the CVD graphene membranes are wrinkled. By correlating observed features in phase AFM images with those obtained by transmission electron microscopy and scanning transmission electron microscopy, we have determined that grain boundaries are discernable in the AFM images lines [2,3]. This is the case because grain boundaries, which are more reactive than pristine graphene, are decorated with nanoparticles formed during the copper etching process, as well as amorphous carbon residues.

By performing indentation measurements, we have determined that wrinkles and grain boundaries have a measurable effect on graphene’s mechanical properties. First, wrinkles in graphene decrease its effective
elastic modulus, in comparison to exfoliated graphene, as determined by membrane indentation. We calculate an effective 2D elastic modulus of ~ 55 N/m, which is approximately a factor of 6 less than what had been reported in exfoliated graphene samples [4].

Second, graphene’s polycrystallinity weakens the membranes, as graphene is observed to unzip along grain boundaries (Figure 3).

By determining the location of grain boundaries with a dark field transmission electron microscopy (DF-TEM) method recently reported by our team, it will be possible to study the electrical properties within and in between different graphene grains, by individually contacting these domains (Figure 4).

References:


