Electrolytic Gating of a Graphene Field Effect Transistor

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Abstract

Graphene is a 2-dimensional structure of carbon atoms arranged in a hexagonal lattice that exhibits many properties that make it a promising candidate for various fields. One such property is its electrical conductivity which surpasses that of many materials used today. It is possible to create a functioning field effect transistor using graphene and an evaporated transition metal, such as copper or gold. This is done by drawing graphene on copper using chemical vapor deposition using methane (CH4) as the carbon source, then transferring it onto a silicon oxide wafer. The graphene is then placed into an evaporator and the evaporated metal is allowed to deposit onto the graphene through a shadow mask. It is now possible to measure the current through the graphene by attaching wires to the metal on either side.

Introduction

Graphene exhibits many properties that make it a promising field of study, such as its strength, flexibility, and conductivity, among others [1]. Its conductivity makes it very useful for electronic applications, such as flexible electronics and high-frequency transistors [2]. This research provides valuable information about the electrical properties of graphene and its sensing capabilities, and is an important step towards widespread implementation of graphene in electronics. Further research needs to be done to optimize the yield and quality of graphene transistors.

Methods

In order to create a graphene field effect transistor, we grew graphene on copper through the process of Chemical Vapor Deposition using a ratio of 7 scm of H2 to 28 scm of CH4. After the process was complete, the graphene was transferred over to a SiO2 wafer by first cleaning the copper with O2 plasma, then applying PIMMA to the copper to act as a support layer for the graphene. The copper was then etched, placed into DI H2O air-dried, and then placed into a PMMA removal solution. At this point, it was necessary to create the transistor. We did this by placing the graphene into an evaporator and letting the evaporated metal deposit onto the graphene through a shadow mask. The metal used was gold, with a supportive layer of chromium underneath. Next, we ran a current through the transistor using the setup shown in Fig. 1. It was then possible to modulate the electron carrier density in the graphene transistor, thereby varying its conductance. This was done by making a “well” around the graphene while using a silicon adhesive, and then placing drops of 0.1M KCl into the well (see Fig. 2). The silicon adhesive was necessary to prevent the solution and the gold from interfacing. A third gate electrode was placed into the 0.1M KCl. By applying a voltage to the solution, it was possible to change the conductance of the graphene. We measured the current that ran through the graphene using every gate voltage from -500 mV to 500 mV, with increments of 100 mV. The voltage applied to the transistor (Vsd) was swept from -100 mV to 100 mV and the current was measured continuously throughout the sweep. Then, we measured the conductance of the graphene by fixing the Vsd at 50 mV and sweeping the Vg from -200 mV to 200 mV. In addition, we also measured a source drain in which there was no gate electrode attached, and a leakage current to measure any minimal loss of energy.

Results

We measured the current that ran through the graphene for different gate voltages, as shown in Fig. 4. In this current, the gate voltage was swept and the current was measured. The conductance of the graphene, measured with a fixed Vsd and a swept Vg, is plotted in Fig. 4. In addition, a leakage current was measured. In this current, the gate voltage was swept and the current was measured. The leakage current was not significantly large and is not reported due to space constraints.

Conclusions

Graphene electronics can be used to create various devices, such as flexible electronics. Graphene-based FETs, created through CVD and evaporated metal deposition, can be used to create more efficient electronics and sensors. In this study, we found that Graphene FETs have a lower effective resistance when the gate voltage is increased, and respond to negative gate voltages to a greater extent than positive gate voltages of the same magnitude. Further research should be done to improve the quality and yield of graphene transistors.

References

[4] All research belongs to the Bunch research group.

Acknowledgements

This research was done as part of the RISE summer program for high school students at Boston University. All research belongs to the Bunch research group.