Abstract: Graphene is a 2D crystalline sheet of carbon bonded together in a hexagonal lattice. Its unique structure gives it valuable optical and electrical properties that could be used in nanoelectronics or other fields. Current methods for graphene production do not reliably yield high quality graphene crystals on a large scale. A current method for graphene production is chemical vapor deposition (CVD), which involves dissociating carbon-based gas (such as methane) at high temperatures (>800 °C), and nucleating graphene on certain metal substrates (e.g. polycrystalline Cu). This project aims to create large scale and high quality graphene at less stringent conditions (e.g. lower temperature) and/or on other substrates (such as silicon), by putting methane in a plasma state before initiating growth.

Incorporation of Remote Plasma into CVD Graphene Growth

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Introduction:

CVD graphene growth has recently become a popular method for graphene production. In the CVD growth process, a carbon-based gas is flowed across a metallic substrate at high temperatures. The heat helps the C atoms to be adsorbed onto the surface of the metal, where crystals can start to form. The diagram below shows a simple model of the growth of graphene.

Fig 1. graphene growth model. Blue dots are C atoms, red are H atoms.
The setup for CVD graphene growth is basic and the materials required are very accessible: methane gas and polycrystalline Cu are commonly used. To incorporate a remote plasma source, a voltage difference is applied across two diodes, which are placed around the gas flow upstream of the substrate. The subsequent field partially ionizes the gas. To create the voltage difference, a radio frequency (rf) power source is used, with input powers from 0 – 300 W, creating what is known as a rf plasma. This ionized methane is what is used to grow graphene.

Objectives:

- to incorporate a rf plasma source into the CVD setup
- to lower the temperature required for graphene growth to occur on polycrystalline metallic substrates
- to possibly grow graphene on non-metallic substrates

Setup:

The mass flow controller (MFC) on the left controls the flow of methane and hydrogen gas into the system. The gases then flow to the right through metal piping into a glass section, where the two diodes of the rf plasma source are placed. After being ionized, the gases flow into our oven chamber, a 60 cm quartz tube in which the substrate is contained. This chamber can be heated up to 1000 degrees Celsius to allow for graphene growth. The pressure in the system is kept at a low vacuum through the use of a pump at the end of the quartz tube.

Results:

The graphene grown on the metallic substrate is then transferred onto a SiO2/Si substrate for analysis. This process entails coating the graphene in a polymer layer (PMMA), dissolving the Cu substrate in ferric chloride, and placing the graphene onto the new substrate. Then the PMMA is dissolved in turn, and the graphene is secured onto the new substrate by vacuum baking at 150 degrees Celsius.

Future Work:

When using the established CVD process, our system was able to produce high quality graphene. However, incorporation of the remote rf plasma source did not yield favorable results. We hypothesize that two changes could be made to hopefully improve upon the quality of the PCVD samples. First, experimentation with Ni substrates may be fruitful, as other research groups have had success with Ni substrates. Also, increasing the input power to the rf plasma source could yield graphene nucleation, due to an increased portion of the methane becoming ionized.

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