Graphene Growth by Chemical Vapor Deposition

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Abstract:

Graphene is a single layer of carbon atoms that is extremely strong, electrically conductive, transparent, and flexible. These properties lead it to have a variety of applications depending on how it is produced. Chemical vapor deposition (CVD) is the preferred method of production to implement in touch screens, smart windows and solar cells. The focus of this project was to determine the ideal conditions in which to grow graphene via CVD. Based on success in previous graphene experiments, the two materials chosen to use in this project were copper (Cu) and nickel (Ni). The samples were heated to 1000°C and both methane and hydrogen gasses were pumped through the system. Raman spectroscopy was used to characterize the samples, and it showed single-layer graphene on both Ni and Cu. Through this, a range of conditions has been deduced where it is most probable that graphene will grow.

Introduction:

CVD uses high process temperature to produce the high quality graphene needed in solar cells, however, CVD has a high production cost and only moderate sustainability. The goal of this project was to create a controlled environment where graphene could be efficiently reproduced. In order to achieve this goal, growth conditions had to be narrowed down to a specific range of conditions and ratio of gases. Once this was achieved, future work could shift to exploring graphene growth on other substances such as silicon and silicon dioxide.

Experimental Procedure:

The two main materials used were Cu foil and Ni evaporated onto silicon dioxide (SiO_2) wafers. These materials were pretreated by allowing them to soak in trichloroethylene, acetone, and methanol for three minutes each. The Cu was further treated by allowing it to sit in a warm acetic acid bath for five minutes. Ni was evaporated onto the SiO_2 wafers at varying thicknesses ranging from 150 to 3000 Å. The evaporated Ni was later switched out for annealed Ni foil.

Once the materials were placed inside the CVD system, they were annealed with hydrogen at 1000°C for 60 minutes. The methane gas was added to the hydrogen for the next 40 minutes during the growth phase. The furnace was then allowed to slowly cool to room temperature while still flowing the methane and hydrogen gases. Finally, the system was purged with argon for 15 minutes, so that the materials could be removed from the system.

Results and Conclusions:

The substrates were characterized by Raman spectroscopy, and this confirmed successful graphene growth on both Cu and Ni. The results ranged from no growth to multi-layer graphene to graphite. This allowed the conditions to be narrowed down until a range was found where graphene would consistently grow. Graphene was determined to have optimal growth when hydrogen gas flow was 1-2% of the methane gas flow. A range for Ni was unable to be narrowed to a specific ratio.

The lack of consistent growth on Ni most likely was caused by the amount of Ni evaporated on the SiO_2 substrate. When there was a larger amount of evaporated Ni, it was found to form into beads during the growth process, which inhibited graphene formation. Future research would find the optimum thickness of evaporated Ni and would move on to attempt growth on other materials such as silicon.

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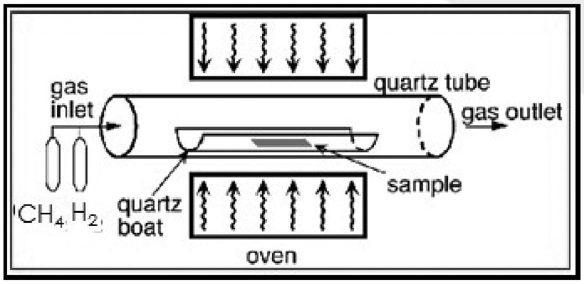

Figure 1: Diagram of simple CVD system.

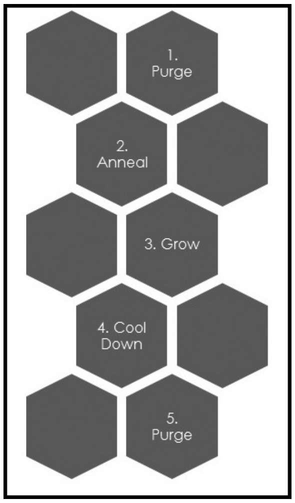

Figure 2: Diagram of CVD growth process.

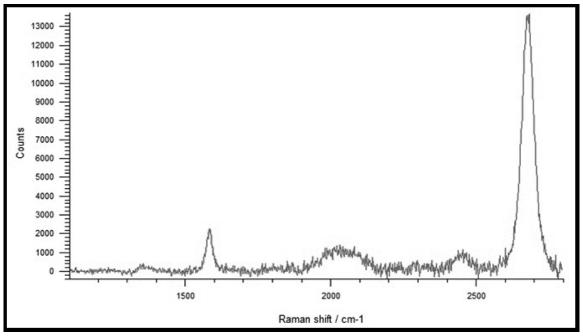

Figure 3: Raman spectroscopy results showing single-layer graphene growth on copper foil.

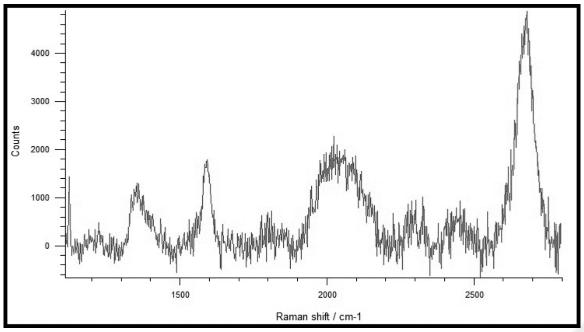

Figure 4: Raman spectroscopy results showing single-layer graphene growth on evaporated nickel.

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