Growth and Characterization of Graphene for Use in Nanoelectronics

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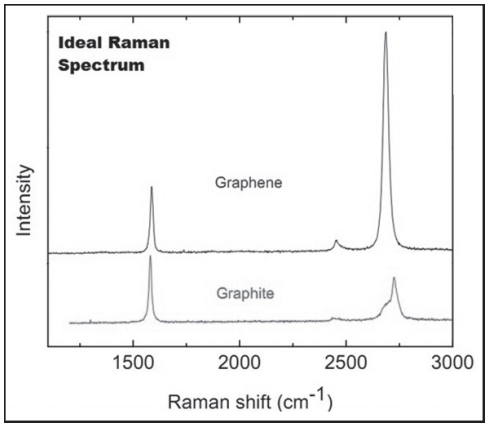
Introduction:

Graphene, an atomic layer allotrope of sp^2-bonded carbon, has gained the attention of the researchers in electronics and materials science. This is due to graphene's unique potential to enable high speed in future nanoelectronics, such as graphene field effect transistors (GFETs).



The current challenge with moving forward in the creation of these devices is the inability to create large-area graphene with low-defect density. The focus of this work was to investigate a reliable protocol to produce large area high-quality graphene for device application. Chemical vapor deposition (CVD) was employed to synthesize graphene on copper substrates. Certain parameters of the CVD were varied in an effort to find an optimized, more efficient protocol for graphene synthesis.

Methods:

The synthesis of graphene is performed in an Aixtron® Black Magic, a commercially produced CVD apparatus. Our state-of-the-art Black Magic CVD allows computer-based control (a standard set of commands referred to as recipe) of key parameters, including temperature, pressure, gas flow and time, for the synthesis of carbon nanomaterials in a vertical cold-wall chamber. The carbon source for CVD graphene is hydrocarbon gas which is decomposed on a 25 μm thick copper foil substrate that was cleaned by ultra-sonication in an acetone bath for 10 minutes.

The samples were loaded into the CVD chamber on a graphite stage, which served as the substrate heater to heat the samples together with a showerhead heater about 2-3 inches above. Using a heat ramp up to 1000°C, annealing was done for five minutes in hydrogen (H_2) at a flow rate of 1000 sccm. After annealing, graphene synthesis occurred. Pure methane (CH_4) was used as the processing gas for graphene synthesis and kept on at a flow rate of 10 standard cubic centimeters per minute (sccm) for five minutes. After cooling down to 180°C, the sample was pulled from the chamber and stored in a dessicator, until characterized using Raman spectroscopy.

For this project, certain variables of the CVD parameters were manipulated to see if the recipe for obtaining graphene film could be optimized. Specifically, the amount time in which the substrate was exposed to methane was varied to 3, 4, 6, 7, and 9 minutes. The amount of annealing time in conjunction with the flow rate of the annealing gas, hydrogen, was also varied to times of 3, 5, 7, and 10 minutes and the flow rate was varied to 10 sccm, 500 sccm, and 1000 sccm.

Results and Conclusions:

Raman spectroscopy was used to analyze the synthesized graphene. There are several characteristics in a Raman spectrum that help determine the quality and thickness of the graphene [1]: full width at half maximum (FWHM) of 2D peak (2D Peak occurs between 2720 and 2750 cm^{-1}), ratio of 2D peak to G peak (G Peak occurs around 1600 cm^{-1}), and D peak (represents defect in sample, D Peak occurs around 1400 cm^{-1}).

Our goal was to get monolayer graphene with the least or no defects, which required a 2D width of 25-30 cm^{-1}, 2D/G > 3 and the absence of a D peak. According to the data obtained from the Raman spectroscopy, there appeared to be a trend in the graphs showing the variation of growth time in methane. There was a direct correlation between time exposed to the growth gas and the quality of the graphene that was synthesized. The longer the copper substrate was exposed to the methane, the lower the defects in the graphene. In the runs where the annealing time and

the flow rate of the annealing gas were varied, it appeared that the higher the flow rate of the annealing gas, the better the quality of the graphene. This could be attributed to the adsorption of hydrogen on the copper catalyst, which could help decompose methane for the growth of graphene.

In a brief summary, we found that high annealing flow rates and longer times for both annealing and growth would yield the best results. The underlying scientific explanation of this optimized recipe needs further investigation, which in future studies will be in the scope of this project.

Using the results obtained from these syntheses, it can be concluded that each of the variables that were changed and tested in this project had a significant impact on the outcome of the graphene. The ability to create good graphene is a crucial step in the fabrication of graphene field effect transistors (GFETs) in a large scale.

Acknowledgements:

I would like to thank the National Science Foundation, the NNIN REU Program, and the Microelectronics Research Center at the University of Texas at Austin for the opportunity to participate in this program. I would also like to thank my Principal Investigator, Dr. Deji Akinwande, for the opportunity to work with his group, and my mentor, Dr. Li Tao, for his assistance throughout my project.

References:

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