NDnano Undergraduate Research Fellowship (NURF)
2011 Project Summary

Student name: Kevin Burke
Faculty mentors names: Michelle Kelly and Grace Xing
Project title: Chemical Vapor Deposition Growth of Bilayer Graphene

Problem/Problem Area

Recent years have experienced a significant increase in materials research surrounding the production of graphene following its first extraction from graphite via adhesive tape in 2004. Graphene, both single and multi-layer, exhibits favorable electrical applications and offers great promise for the production of future electronic devices. Its low resistivity offers exceptionally high electron mobility and thermal conductivity, and it also exhibits excellent mechanical strength. Additionally, bilayer graphene offers the potential for a tunable band gap, which is essential because that is what allows a semiconductor to be switched on and off. Methods of growing high-quality single-layer graphene using a CVD are well established, but growth of only one additional layer is not yet well established. This is primarily because the growth mechanism of the second layer is not clear. Thus far reports of bilayer growth have been made by several groups, but there is no reliable method to create high-quality bilayer graphene.

Activities and Results

By examining the methodology of several research groups who have achieved variable success, we have replicated their growth conditions using a CVD reactor. The first approach is similar to monolayer growth, which involves heating the sample to over 1000^{o}C, annealing the copper foil, a 10-15 minute growth step during which methane is flowed, and rapid cooling. But in this case the sample is cooled slowly, until 500^{o}C, when the reactor is opened to ambient pressure and cooled rapidly.[1] For the growths modeled after the first approach, we alternated the flow of C^{13} and C^{12} methane. The reason for this was to be able to monitor the growth pattern of the graphene, where ideally there would be a central region of one isotope and then a sequence of rings surrounding it alternating between C^{13} and C^{12}. In this regard it would be clear where different sites of nucleation were. The second approach uses two copper foils, where one clean piece catalyzes growth on top of a foil covered in monolayer graphene.[2] In addition to these trials, we also conducted several growths with slight modifications to compare the resulting graphene with that of the literature. Using a Raman spectroscopic microscope, 25 µm x 25 µm scans were taken of each sample. The Raman images show characteristic phonon vibrations of the samples by showing the "Raman shift" of the incident laser. By comparing the different peaks in the resulting spectra, it can be assessed as to whether or not the growths contain bilayer or monolayer, and how high the quality of the graphene is. All of the samples showed some degree of bilayer growth, but the most successful was one of the modified versions of the first approach. We found that in the sample where methane flow was continued during the cool down phase, coverage of bilayer was the greatest. Additional experiments are being planned based on this to provide further insight into the growth mechanism of the second layer.

Average Spectrum of Approach 1 – Sample C

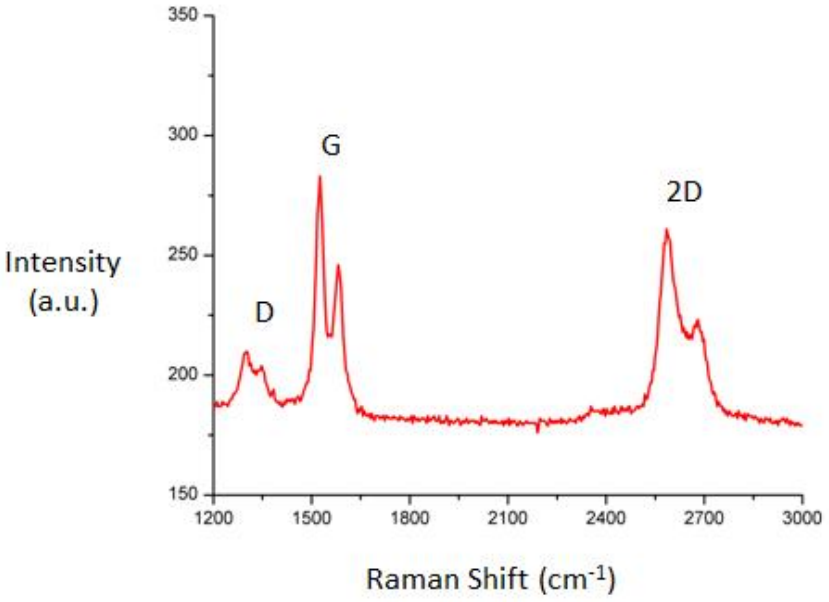

Figure 1.

This image shows the average spectrum for the entire scan of the successfully modified growth. By comparing regions where the G and 2D peaks are approximately "1:1," it can be determined where there is likely bilayer growth. The dual peak nature of all three peaks is due to the flow of $C^{13}$and C^{12} isotopes.

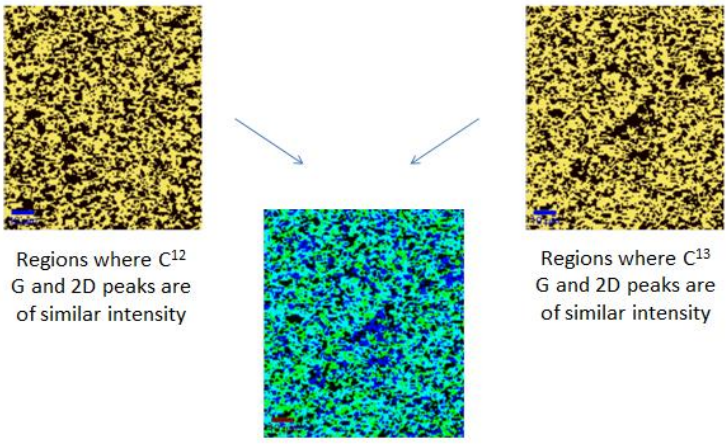

Figure 2.

This figure shows the total coverage of the successfully modified growth. All colored regions in the composite image show potential bilayer growth. The green areas are C^{13} isotopes and the blue regions are C^{12} isotopes. The teal represents areas with both isotopes.

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Poster Submissions

Title: Chemical vapor deposition growth of bilayer graphene
Authors: Kevin Burke, Phillip Cook, Subrina Rafique, Rusen Yan, Grace Xing, Michelle Kelly
Presented at:
Science and Engineering Summer Undergraduate Research Symposium – August 5, 2011
To be presented at:
Midwest Institute for Nanoelectronics Discovery Annual Review – August 17, 2011

Paper Submissions

Research will be continued into the fall semester, culminating in a paper to be submitted for publishing

References

1. Lee S, Lee K, Zhong Z. Wafer scale homogeneous bilayer graphene films by chemical vapor deposition. Nano Letters 2010; 10 (11): 4702–4707.
2. Yan K, Peng H, Zhou Y, Li H, Liu Z. Formation of bilayer bernal graphene: layer by layer epitaxy via chemical vapor deposition. Nano Letters 2011; 11 (3): 1106-1110.