Stimulating Growth of Graphene Using Carbon Dioxide Laser Ablation on Silicon Carbide Wafers

1. Abstract

This study intends to stimulate growth of graphene using carbon dioxide laser ablation in varying environments. Silicon carbide wafers will provide the medium for graphene production. Wafers will be ablated in three different environments: a near vacuum, at atmospheric pressure in the presence of argon gas, and at atmospheric pressure in the presence of helium, noting that all circumstances keep oxidation of the wafer to a minimum. The beam will be focused on the wafer and pulsed for varying time intervals to test the effects of different infrared radiation exposures and power flux rates on growth patterns. The graphene may exhibit different characteristics, particularly the number of monolayers of carbon that share similar features of this allotrope. Ideally, an appropriate radiation flux bombardment time and synthesis environment yielding monolayer graphene will be extrapolated from this research.

2. Introduction

Graphene has been successfully produced and identified using carbon dioxide (CO_2) laser ablation at atmospheric pressure in the presence of argon gas on a silicon carbide (SiC) wafer (see Reference 1.) Graphene is an allotrope of the element carbon, particularly, an atomically thin single layer of this allotrope. Graphene is of specific interest because of its high electrical conductivity, strength, flexibility, capacitive abilities, and possesses high potential for nanotechnology especially within the electronics industry. The interest of this project is to test these results under varying infrared (IR) radiation pulsing times and beam power densities in three other ablation environments. Ablation in an argon environment inhibits oxidation of the sublimated silicon from the silicon carbide wafer. As a result the sublimating silicon draws with it carbon in atomically thin sheets. This is the formation of graphene. The project intends to test whether helium, another noble gas that will prevent oxidation, will provide similar circumstances and allow the stimulated growth to occur. Helium has less mass than argon and will likely transfer heat more quickly from the wafer potentially reducing the effective power density during the ablation process. We believe that under a high flow rate using relatively long IR radiation pulsing times that the growth may take place in a preferential manner. The second environment tested will be ablation of a wafer fixed in a vacuum cell. A vacuum negates oxidation as well but is more difficult to perform as a sealed cell is required. This environment will also be subjected to varying IR exposure times and beam widths. Finally, a third environment consisting of a sealed vacuum cell full of helium will be tested in a similar manner. The combination of surrounding helium in sealed vacuum cell will ensure an oxygen free environment. A collaborative project to this study will provide consistent characterization of any graphene samples using the Scanning Electron Microscope (SEM) throughout the duration of testing the three environments. In this way, we aim to compare growth patterns resulting from the different methods and to identify the most efficient and effective ablation process for stimulated graphene growth.

References

1. Spyros N. Yannopoulos, Angeliki Siokou, Nektarios K. Nasikas, Vassilios Dracopoulos, Fotini Ravani and George N. Papatheodorou, 2012, “CO2 Laser-Induced Growth of Epitaxial Graphene on 6H-SiC(0001)”, *Adv. Funct. Mater,*, p. 113-120.
2. Jamie H. Warner, Franziska Schaffel, Mark Rummeli, Alicja Bachmatiuk, 2013, *Graphene: Fundamentals and emergent applications,* Elsevier Inc., Waltham, MA, p. 209-214.

3. Description of Research

Successful completion of this project relies on implementation of the following procedures.

I. Optimization of the Carbon Dioxide Laser at 10.6 Microns

CO_2 lasers rely on a mixture of three gases: nitrogen, helium, and carbon dioxide. The gas purity, as well as flow rate, pressure, and proportions of the gases, optical cavity setup, and the current density of the ionized gases within the laser system are essential and must be dialed in precisely through experimentation. Through manipulation of these parameters the laser will lase allowing various power levels to be obtained and used for ablation.

II. Outfitting the Vacuum Cell

A Pyrex gas spectrophotometer will be outfitted to hold a SiC wafer suspended from the sides of the cell and allow gas flow. The cell will be retrofitted with a window fixed to one end that will provide an entrance for the beam and a zinc selenide (ZnSe) focusing lens will provide a means to focus the beam through the window and onto the wafer. The wafer holding apparatus will be constructed in a manner allowing for adjustments of its distance to the focus of the beam.

III. Testing for Stimulated Growth of Graphene

The first tests of laser ablation will be conducted in a helium environment with a calculated beam width and temperature. The ablation conditions will evolve with each test to include variances of all three primary environments. For the additional environmental scenarios, a Welch fore pump has been obtained and confirmed capable of 1 millitorr.

IV. Submit Sample for Characterization and Examination

Wafers will be transferred to the collaborative characterization researcher for testing. Results of graphene presence will be analyzed in relation to ablation temperature and beam power using the SEM. Following adjustments of beam power and IR radiation exposure time for the proceeding test environment will be based on this analysis.

V. Repeat Testing with Adjustments to Experimental Variables

Steps III and IV will be repeated for variations of all three ablation environments.

The completion of this research project will provide further insight into stimulated graphene growth using CO_2 laser ablation, conceivably opening the range of conditional possibilities under which this process can occur, and ideally, identifying an optimal beam width and exposure time for production of uniform graphene samples.

References

3. C. Kumar N. Patel, 1969, "High Power *Carbon Dioxide Lasers*", *Scientific American*, Vol. 219.
4. David R. Whitehouse, Understanding CO_2 Lasers, http://www.laserk.com/newsletters/whiteCO.html (August 2013).
5. Samuel M. Goldwasser, 2013, Home-Build Carbon Dioxide (CO2) Laser, *Sam's Laser FAQ*, http://www.repairfaq.org/sam/lasercc2.htm#cc2guide (August 2013).

4. Time Period

The research will take place from August 2013 through Spring 2014. The first weeks will consist of optimizing the laser and constructing the wafer chamber. The project will then pursue stimulated growth of graphene beginning with a wafer in the presence of helium, continuing on to the vacuum cell and a combination of the two.

5. Budget with Justification

The research team requests the following materials in reference to this project.

Material	Quantity	Price	Vendor
6H SiC wafers	7	$434.00	Precision Micro-Optics
ZnSe focusing lens	1	$60.00	Lightobject
Total		$494.00	

6. Seeking Additional Funding from Other Sources?

Currently no additional funding is being sought for this particular experiment, however, the collaborative experiment "Characterization of Graphene from the Ablation of Silicon Carbide with a Carbon Dioxide Laser" is also requesting funding from the UNC-Asheville Undergraduate Research Program during Fall 2013. My colleague Ashlyn Rickard will be performing the in depth analysis and characterization of the synthesized graphene to provide an integral feedback circuit such that the optimal ablation parameters can be identified and implemented.

7. Publication Outlet

Results will be published in the UNC-Asheville Journal of Undergraduate Research and presented at the Fall and Spring Symposia. In addition, significant findings will be submitted to the appropriate academic research journals as well as to the Proceedings of the National Conference on Undergraduate Research.