PROJECT 1
DEVIATION IN CHEMICAL VAPOR DEPOSITION FLOW RATE FOR GRAPHENE GROWTH

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Abstract

Since its discovery in 2004, graphene has been of high interest to condensed matter physicists and material engineers. The ability to produce graphene at commercial scale could revolutionize the electronics industry. This experiment studies a popular technique to grow graphene, chemical vapor deposition (CVD). The quality of graphene produced is highly dependent on the performance of the CVD process. In this experiment, the effects of flow rate differences was explored. We conclude that, in agreement with our hypothesis, as the difference in flow rate of the two gases changes, the stability and consistency of the flow is negatively impacted, thus affecting the quality of our graphene.

I. INTRODUCTION

Graphene is a 2D material first studied in 2004 by Andre Geim and Konstantin Novoselov. They won the Nobel Prize in 2010 for this discovery. It is made of a single layer of carbon atoms that are in a hexagonal lattice structure. The most exciting properties are high electrical conductivity, large mechanical strength, and high thermal conductivity. This allows to be broadly applicable in electronics, energy storage, and other devices. [1]

Due to these exciting properties, growing graphene at scale is high desired. A common technique, and the one used in this experiment, is called chemical vapor deposition (CVD). It is a tool that can be used to manufacture and produce everyday products, especially electronics. This method uses gas to create the vapor to deposit. In our CVD graphene production we use hydrogen and methane gas. To vaporize the gases, they can to be heated or have pressure reduced. The environment is kept consistent in a vacuum chamber, which minimizes outside forces like gravity and provides constant pressure. [2]

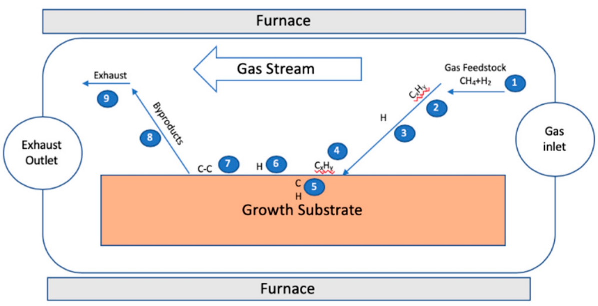

Figure 1: Example of our CVD system. [1]

This experiment explores the quality and consistency of our CVD process by examining the effect of different flow rates on the quality of our graphene produced. This will help us improve our system and determine uncertainty parameters.

II. ALGORITHM ANALYSIS

The first Python program simulates an experiment that uses random data produced via a probability distribution function. [3] The simulated data comes from a normal distribution with a mean of zero because the experiment is simulating a measured deviation from normal, which is zero in this experiment. The flow rate of the gases are the configurable parameters of the program. Once the parameters are chosen, the experiment is simulated. Each parameter is looped through the probability distribution to generate random data corresponding to the given parameter. The amount of loops it runs can be configured. To simulate the gases and their flow rate, 100 loops (minutes) of data was needed to find enough significant difference between parameter changes at smaller magnitudes. [4] If a more precise outcome is desired, the amount of data can be increased. These random data values are written to two text files and stored, one text file per gas simulated.

The second program is meant to analyze the random data that was stored in the text files during the first program's execution. [5] It is assumed (because…?) that the text files contain numbers, floating point values. After reading the files, the program plots the output of the simulated experiment. The flow rate measured versus time is plotted for both gases on one plot, making it easy to compare the two. [6] [7]

III. OUTPUT INTERPRETATION

By plotting the data sets on top of one another, we can see a clear difference in the experimental results for each hypothesis. Our hypothesis is that deviation from flow rate in the vacuum chamber is more prevalent when the difference in flow rates between the two gases is larger. We want to see if that is the case or if one of the two gases is more problematic than the other. We want to minimize flow rate deviation as much as possible to create viable samples for transfer. This experiment measures change in flow rate over time in our

CVD chamber with two gases flowing. The flow rate of each is adjusted and the output of every adjustment can be view on a plot. This helps to show what parameters are best, and which gas seems to be the most prone to fluctuations in flow rate. This knowledge will help us continue to evolve and advance our experiment for consistent, repeatable results.

Our first study looked at a 1 sccm hydrogen gas flow rate and a low flow of methane gas at 0.3 sccm. The outcome is plotted. The data clearly shows that flow rate of hydrogen varies much more than its counterpart of lesser rate. This

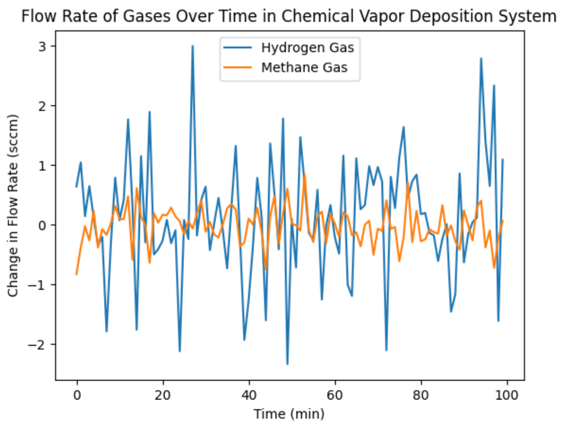

Figure 2: First study, 100 minute run using high hydrogen flow rate and low methane flow rate.

result shows that a large flow rate of hydrogen and low rate methane gas can cause the hydrogen gas to deviate from zero much more than the methane gas. This deviation and mismatch in process causes holes and defects in our graphene.

Our second study set a 1 sccm flow rate for methane gas. and low flow rate for hydrogen gas of 0.2 sccm. The outcome is plotted. This result shows that a large flow rate of methane

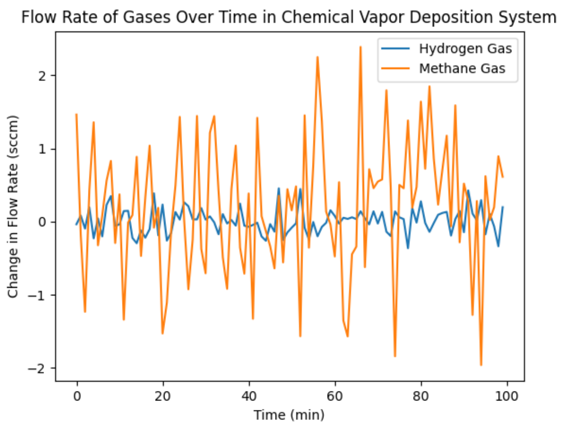

Figure 3: Second study, 100 minute run using high methane flow rate and low hydrogen flow rate.

and low rate of hydrogen gas can cause the same outcome. This deviation and mismatch in process also causes holes and defects in our graphene. Meaning, the flow rate, not the gas, is our issue.

Our third and final study set the flow rates to be very similar, to have as a control to rule out that one gas is causing the problem. This plot shows hydrogen flow rate of 0.1 sccm

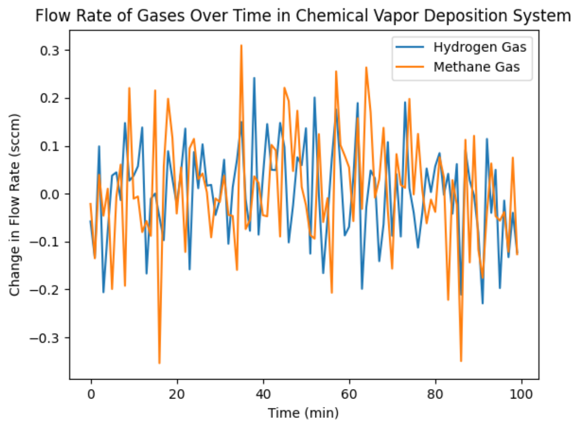

Figure 4: Third study, 100 minute run using similar methane and hydrogen flow rates.

and methane rate of 0.12 sccm. The gases interact in a way that results in a more consistent environment for the graphene to grow.

VI.CONCLUSION

In agreement with our hypothesis that a larger difference in flow rates between our two gases results in larger deviation from zero for the high flow gas. This results in negative graphene properties. Flow rates near each other allow the graphene to be formed with less defects. Since we know flow rate can greatly affect the quality of graphene produced by a CVD system, further investigations will be done to determine a stabilizing technique for flow rates of much different value.

V. REFERENCES

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[4] https://www.pythontutorial.net/python-basics/python-write-text-file/

[5] https://www3.ntu.edu.sg/home/ehchua/programming/webprogrammi

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[7] https://www.geeksforgeeks.org/how-to-plot-data-from-a-text-file-using-matplotlib/