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CHARGE TRANSPORT CHARACTERISTICS IN GRAPHENE OXIDE FILMS AS A TRANSPARENT CONDUCTING OXIDE

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ABSTRACT
The modified Hummer process was used to effectively create graphene oxide thin films. The spin coating procedure was used to prepare the material. The thickness of these decreased graphene composite films, as determined by profilometry, ranged from 0.03-0.12mm, demonstrating that the greater the number of layers, the greater the transparency. The carrier density, electrical conductivity, resistivity, sheet resistance, and mobility of graphene oxide as a transparent conducting material were also investigated using the Hall Effect measurement.

Keyword: Composite rGO Thin Films, charge transport, Sheet Resistance, bulk concentration, mobilty, conductivity, and resistivity.

INTRODUCTION
Electronics today are built on semiconductors. We must comprehend the characteristics of every semiconductor, and this is related to quantum physics, which describes how electrically charged particles move through solids when their atoms or molecules are grouped in a small pattern called a crystal lattice. Between a conductor and insulators like wood and plastic, semiconductor materials like copper and graphite may carry electrical charges (Bedi and Singh, 1998). In contrast to metals, semiconductor materials are known to have higher temperatures due to their electrical conductivity. Semiconductor devices contain important characteristics that cause them to pass current in a single direction, showing that they are sensitive to light, heat, and changes in resistance. By adding impurities to a semiconductor material to enhance its electrical characteristics, we may also influence how effective the material is. Doping is the process of introducing an impurity to a semiconductor. Consequently, these semiconductor-based materials are used in energy conversion and switching. When electrons and holes, generally referred to as "charge carriers," are in a state of free motion, a semiconductor can conduct current. Doping aids in boosting a semiconductor material's charge carrier density. A doped semiconductor is referred to be "n-type" if the majority of its electrons are free. To precisely manage the position and concentration of p- and n-type areas, the semiconductor materials used in electronic devices are doped. The p-n junctions between these regions are what provide the useful electronic behavior. Silicon, germanium, and compounds of gallium are the most common elements utilized in electronic devices, despite the fact that several pure elements and compounds exhibit semiconductor capabilities (Adachi S, 1994). This will further inspire scientists to develop new discoveries on the characterization of other semiconductor materials for usage in power electronics, including LED lights, photovoltaics, etc. To be able to identify the commonalities between these materials, scientists will need to modify several of the already used characterisation techniques (Baladin et al, 2008). The movement of electrons or (holes) in materials is the basis for electronic devices. Either an electric field or gradients in carrier concentration are present during this transport. Almost all electrical components, including diodes, field effect transistors, bipolar transistors, and optoelectronic components like lasers and detectors, rely on free or portable charges. Optoelectronic devices like light-emitting diodes, field-effect transistors, and organic solar cells now need a carefully regulated flow of charges in order to operate efficiently and effectively. It is essential to comprehend the mechanisms that govern charge transfer in order to create materials with superior molecular structure-property links.

EXPERIMENT

Production of Graphene Oxide

As a precursor for producing graphene, Graphene Oxide (GO) was produced from graphite powder using a modified Hummer's technique. In a nutshell, 0.5g of sodium nitrate and 3g of graphite were combined. Under continuous stirring, 23ml of strong sulfuric acid was added. To prevent overheating and explosion, we progressively added 18gm of $KMnO4$ to the already-mixed solution after an hour at a temperature of less than 30°C. 400 cc of ice was added to the mixture while it was being vigorously agitated and heated to 50 °C for 12 hours to dilute the resultant solution. It was then treated with 3 ml of $H2O2$ solution to guarantee that the reaction with the $KMnO4$ was completed. The resultant mixture was rinsed with 200ml of HCl and 200ml of water. We rinsed the mixture with 200ml of ethanol after 5 minutes. The solution was then filtered and dried. The graphene oxide was acquired at this point. The solution was allowed to settle for 24 hours in order to extract graphene.

Developing Thin Film of Graphene oxide

1. Prepare 2 samples of the masked glass substrate.
2. Mix 7ml of Acetone and 3ml of water to make a solvent.
3. Make 2 ml of graphene and 1 ml of the solvent.
4. Make sure the graphene and solvent are well dispersed.
5. Deposit (spin coating) the dispersed mixture on each glass substrate sample and spin dry for 30secs using the centrifuge machine. The advantage of spin coating is to have uniform layers of deposition of the graphene oxide on the films.
6. For more than 1 layer, spin dry for every drop of graphene oxide and anneal for 15mins after the last drop on each substrate sample.
7. For the 2 samples of glass substrates, drop 1, 5, and 9 drops of the graphene oxides on each of the substrates to get the different layers of our graphene oxide thin film.
8. The samples are labelled as thus: G7(1 layer), G12(5 layers), and G15(9 layers)

RESULTS AND DISCUSSION

Measurement of the Thickness of Graphene Oxide (GO)

The thickness of the reduced graphene oxide (rGO) films was determined using a proilometer. The thickness of the sample G7 was found to be 1,200Angstrom and was converted to micrometer (0.12µm), sample G12 was found to be 300Angstrom and was converted to micrometer (0.03µm), and sample G15 was found to be 600Angstrom and was converted to micrometer (0.06µm) as seen in the figure 1, figure 2 and figure 3 below. The thickness of the samples ranges from 0.03-0.12mm, which shows that the more the layers, the better transparency it produces. Below are the graphical representations of the profiliometry results:

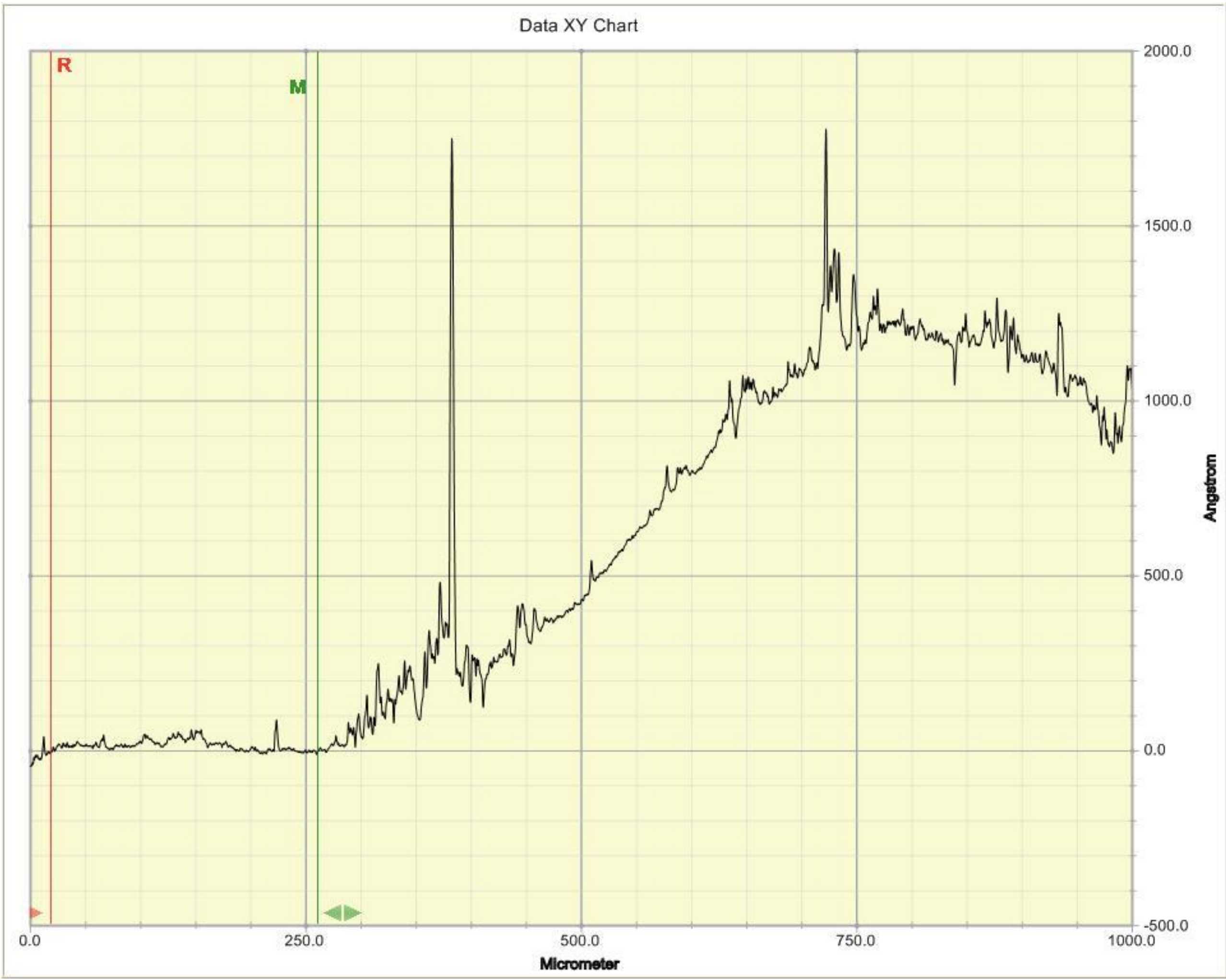

Figure 1: Profilometry image of Sample G7 1 layer

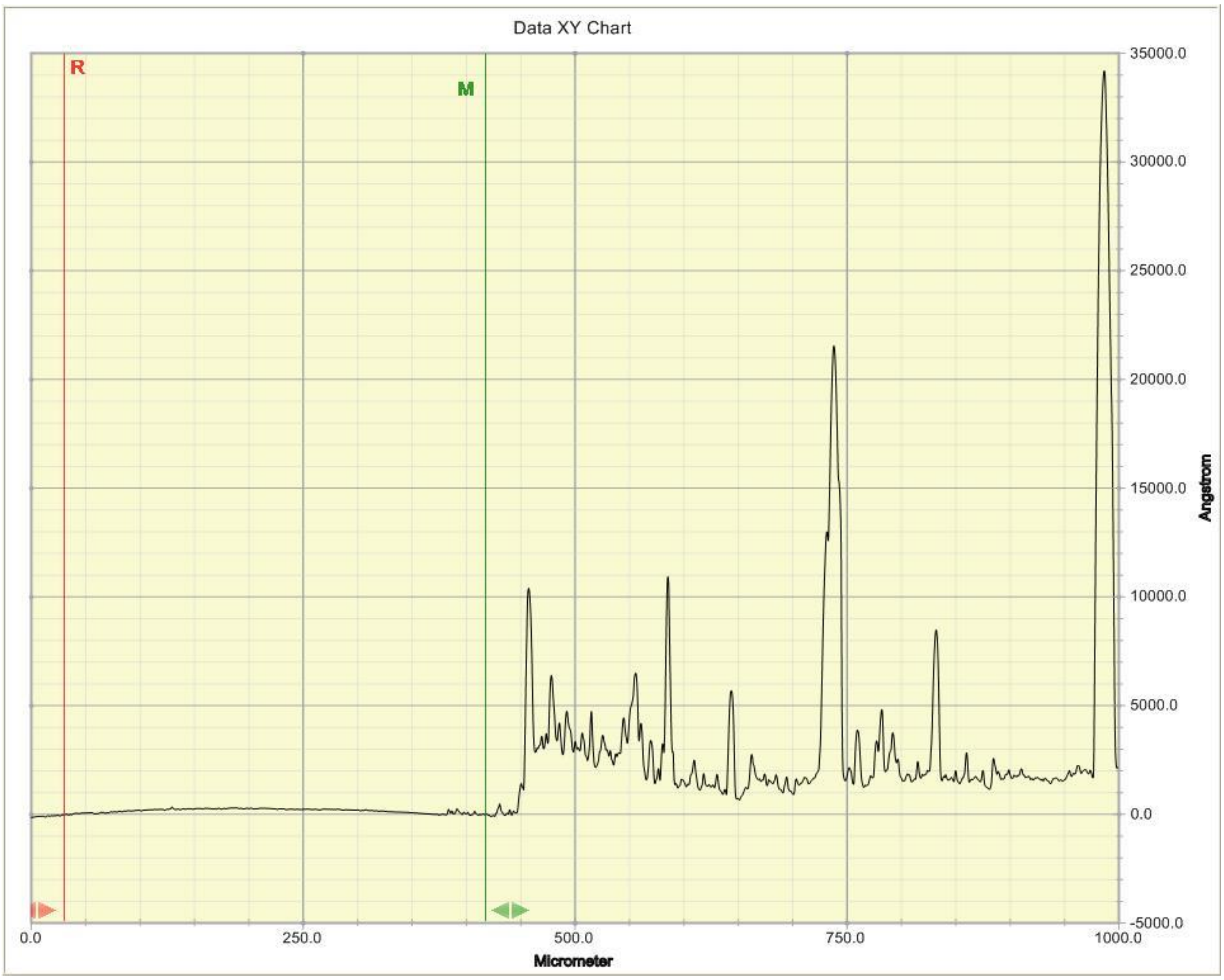

Figure 2: Profilometry image of Sample G12 - 5 layers

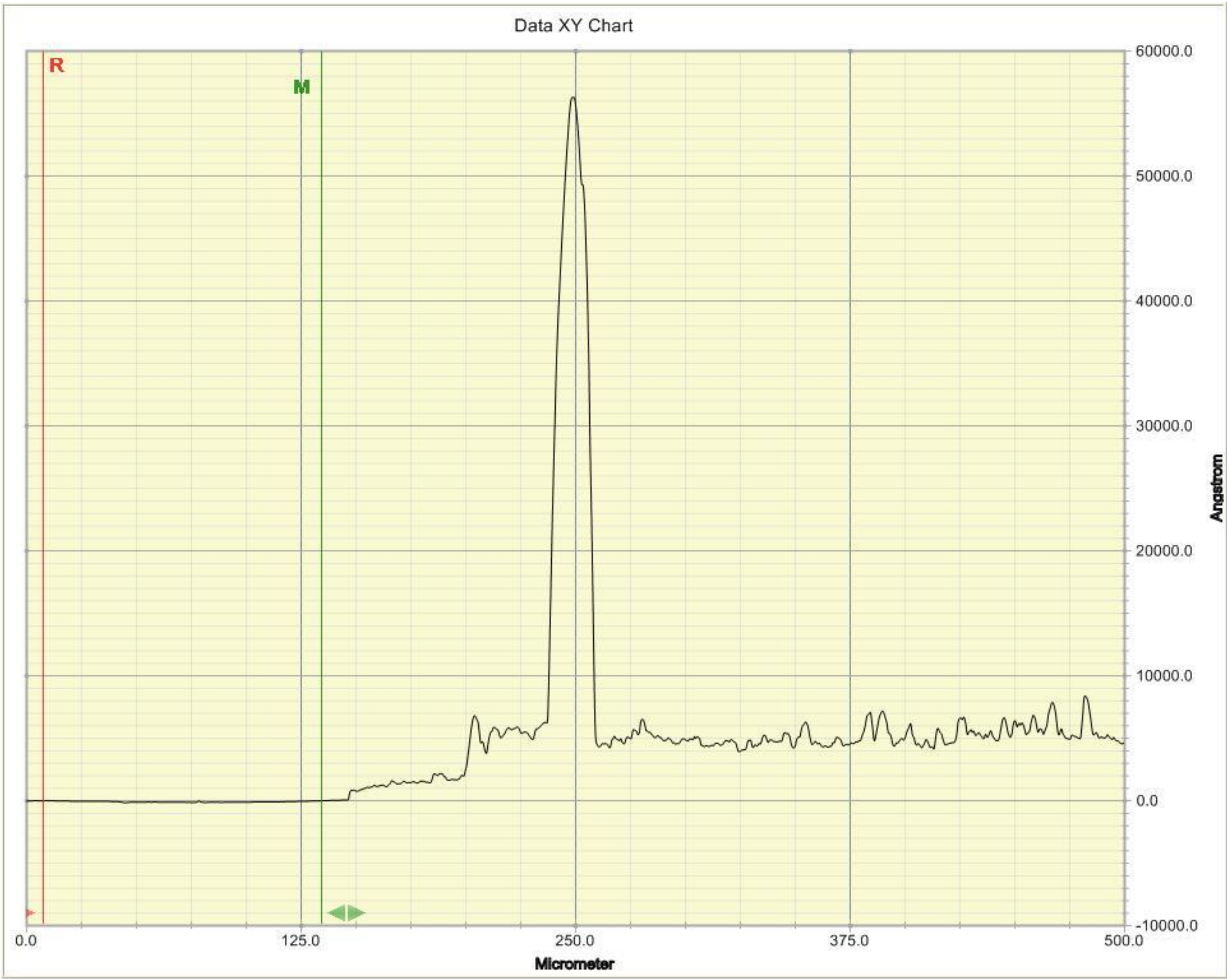

Figure 3: Profilometry image of Sample G15 - 9 layers

Electrical properties of the grapheme oxide (rGO) thin films

The electrical properties of the grapheme oxide (rGO) thin films were characterized using the Hall Effect measurement system. The electrical properties of the samples reveal the charge transport characteristics of the rGO thin films. According to the Hall Effect results, sample G7's rGO thin film has a very high resistivity and a low conductivity, whereas samples G12, and G15 have poor resistivity and thus have comparatively high conductivities. As a result, we may state that rGO multilayers have strong connection features

Table 1: Result for electrical analysis of the rGO thin films at Temperature 300k.

	Bulk concentration (/cm^3)	Mobility (cm^2/V$_5$)	Sheet Resistance (Ω)	Resistivity (Ωcm)	Sheet concentration (/cm^2)	Conductivity (1/ Ωcm)	Average Hall coefficient (cm^3/C)	B-D cross hall coefficient (cm^3/C)	Ratio of vertical/horizontal
Sample G7	**-4.53E+11**	**2.02E+02**	**6.20E+09**	**6.82E+04**	**-4.98E+06**	**1.47E-05**	**-1.38E+07**	**-1.27E+07**	**1.03E-01**
Sample G12	**2.48E+10**	**2.35E+03**	**3.06E+09**	**1.07E+05**	**8.68E+05**	**9.35E-06**	**2.52E+08**	**5.53E+07**	**4.48E-01**
Sample G15	**-4.01E+13**	**4.05E+04**	**8.55E+04**	**3.85E+00**	**-1.80E+09**	**2.60E-01**	**-1.56E+05**	**2.20E+04**	**8.54E-01**

CONCLUSION

Graphene has, luckily, had a significant influence on science and will soon be a widespread material in the electronics industry. Graphene sheets should be made in large quantities with attention paid to the material's band gap, conductivity, resistivity, and transmittance qualities in order to achieve effective manufacturing. Environmentally friendly reductants are increasingly being used to create graphene materials. The modified Hummer process has been used to effectively create graphene oxide thin films. Additionally, samples need to be annealed in order to produce reduced graphene oxide. The effective preparation of the films was demonstrated by the film's deposition, profilometry, and electrical characterization revealing the charge transport properties of the films.

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