Development of Graphene Oxide/Carbon Nanofiber Hybrid Structure

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Abstract

Graphene oxide (GO) and carbon nanofibers have unique individual properties that could be combined complimentarily to be utilized in a variety of fields. Combining these two materials together into self-standing structures would enable them to maximize their high surface area and electrically conductive properties into applications from lithium batteries to biosensors. This thesis aims to develop these structures through the involvement of the electroless deposition method and the chemical vapor deposition method. Results of this research included creating a self-supporting carbon nanofiber/GO structure that demonstrated improved electrical conductivity characteristics. The successful development of this hierarchal system through this cost-effective procedure can increase the applications that graphene oxide could be involved in.

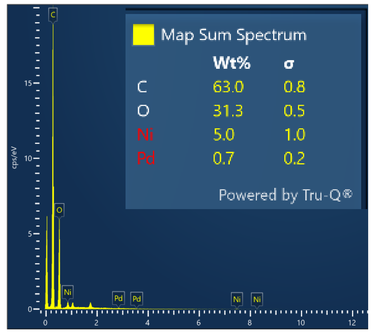
Methods

Upon completion of reviewing past literature on the electroless deposition and chemical vapor deposition methods in growing carbon nanotubes, development of the graphene oxide and carbon nanotube system first needed a metallic coating of nickel on the surface of the graphene oxide. The electroless deposition was implemented to first functionalize the surface with APTMS and then activate the surface by $PdCl_2$. Once an energy dispersive spectroscopy scan displayed that the desired metal was coated on the graphene oxide surface, the chemical vapor was implemented. The thermal chemical vapor deposition was performed on the nickel covered substrate. The gases implemented in the deposition were nitrogen, ethylene, and a hydrogen with argon mixture. After keeping the substrate at 800 °C for one hour under the gas flow, the substrate was cooled and stored for characterization later. Under the scanning electron microscope, it showed that the graphene oxide substrate contained dense carbon nanofiber growth on the top and bottom surfaces of the graphene oxide sheets. The carbon growth interaction was strong enough to physically lift the sample. Additionally, an electrical conductivity test demonstrated that the implementation of carbon nanofibers to the graphene oxide greatly decreased the electrical resistance of the system.

Future Work

- Adjustments to the electroless deposition method with temperature and time parameters during the metal deposition
- Adjustments to the chemical vapor deposition process with using a plasma enhanced chemical vapor deposition method
- Changes to the time, gas flow rates, and temperature parameters within the plasma enhanced chemical vapor deposition method
- Improved characterization tools for quantifiably determining the grown of carbon nanofibers on the graphene oxide surface

Figure 1: Electroless Deposition Results of Nickel.



a. Map Spectrum oof Nickel 8 min Deposition

Map Sum Spectrum

Element	Signal	Atomic %	σ
C	71.93		
O	26.81		
Ni	1.18		
Pd	0.08		

b. Atomic Percentages of Energy Dispersive Spectroscopy (EDS) Results

Map Sum Spectrum

Element	Signal	Weight %	σ
C	63.02	0.76	
O	31.28	0.45	
Ni	5.05	1.03	
Pd	0.65	0.15	

c. Weight Percentages of EDS Results

Figure 2: Performed Electrical Conductivity

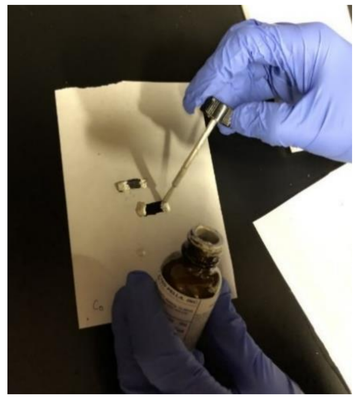


Table 1: Electrical Conductivity Results

Metal Sample:	Resistance without Carbon Growth	Resistance with Carbon Growth
Nickel	1.5 MΩ	13.3 Ω

Figure 3: Graphene Oxide/Carbon Nanofiber System Physically Suspended

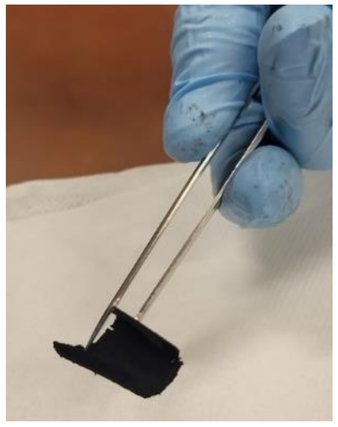
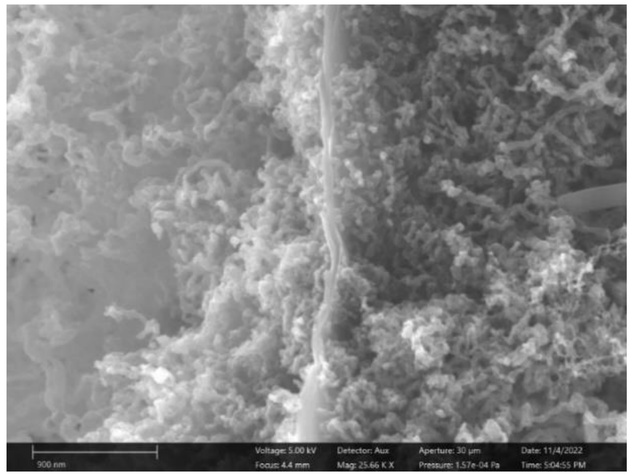
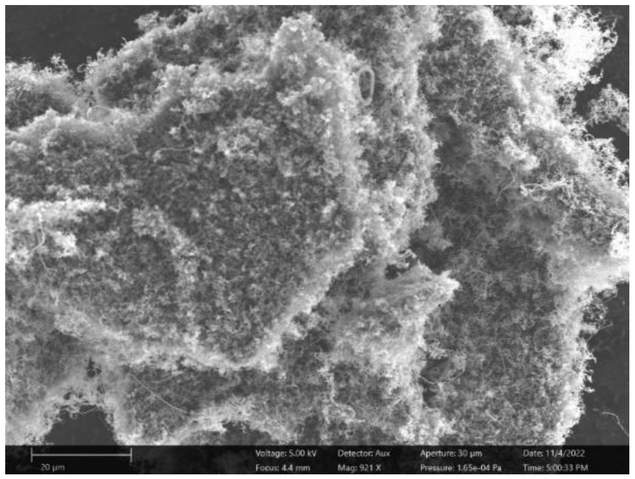


Figure 4: Scanning Electron Microscope Images of Nickel Samples After Thermal Chemical Vapor Deposition Process



a. Top and Bottom Growth of Carbon Nanofiber After Thermal Chemical Vapor Deposition (TCVD) Process



b. Carbon Nanofiber Interaction Between the Graphene Oxide Sheets After TCVD Process

Introduction

Graphene by itself undergoes agglomeration or breakage which makes it ineffective during fabrication methods. To improve on these weaknesses, carbon nanotubes (CNTs) or carbon nanofibers (CNFs) have been proposed to act as spacers between graphene sheets to enhance the overall material's surface area and electrical conductivity. Graphene oxide is a derivative of graphene that contains similar properties to graphene but is much easier to process. The goal in this research was to create a hierarchical system of vertically aligned carbon nanotubes between the graphene oxide sheets to create a self-standing structure. First, the electroless deposition process coats the chosen metal onto the graphene oxide to act as a catalyst for carbon nanotubes/nanofibers growth on the substrate. Next, the chemical vapor deposition process grows the carbon nanotubes/nanofibers on the graphene oxide surface. The successful growth of vertically aligned CNTs on the graphene oxide surface will create hybrid material with a lower tendency towards instability as well as an increase in electrical conductivity properties.

Conclusion

The research aimed to create a free-standing GO/carbon nanofiber structure by depositing the nanofibers on the top and bottom surfaces of GOs through the chemical vapor deposition method. Amorphous, dense carbon fiber growth from the TCVD was observed by the SEM. Verification that the top and bottom surfaces produced a growth of the carbon filament structures for all the samples was achieved. Furthermore, carbon interaction between the individual graphene sheets was visually observed under the SEM and physically determined by suspending the GO samples of both Ni and Co with tweezers. A free-standing structure was created using the TCVD method. Electrical conductivity tests performed on the Ni sample showed that the carbon growth on the graphene oxide greatly decreased the electrical resistance in the system. More improvements and adjustments to the PECVD parameters along with the implementation of the plasma will be performed in the future to develop more tube-like rather than fibrous-like carbon structures on the GO surface.

References

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[3] H. Rashid *et al.*, "Catalyst role in Chemical Vapor Deposition (CVD) process: A review," *Reviews on Advanced Materials Science*, vol. 40, pp. 235-248, 06/01 2015.