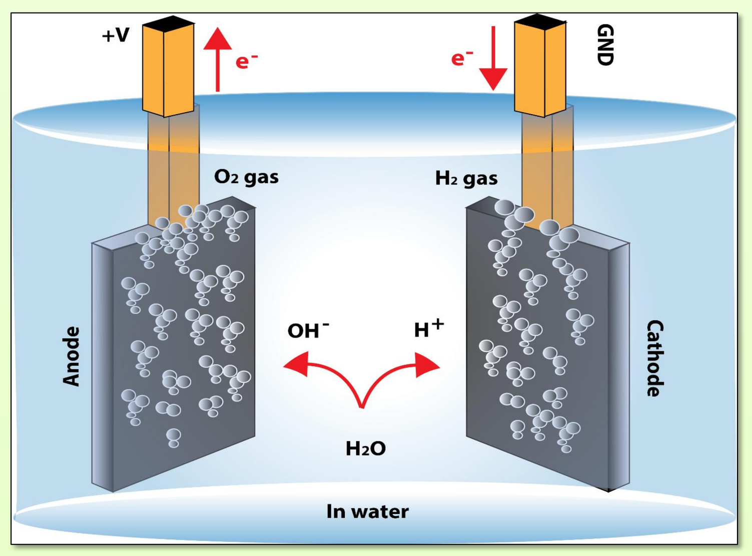
Investigation of Graphene-Based Coatings for Electroflotation Devices

Kaleo Norman, Richard C. Ordonez , Ken Uchida, Dr. Daniel Jenkins, Dr. David Garmire
University of Hawaiʻi at Mānoa, Dept. of Electrical Engineering
In collaboration with the University of Hawaiʻi at Mānoa College of Tropical Agriculture and Human Resources (CTAHR)

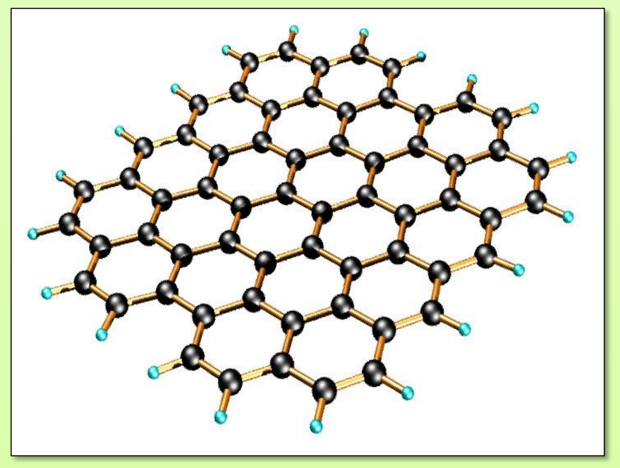
Introduction

Electroflotation is the process of generating tiny bubbles that float bacteria such as E. Coli to a water surface via electrolysis. Current electrode materials are inefficient in that metals will corrode as they become charged in an aqueous environment. There is a need for new materials that are resistant to corrosion and withstand the large currents needed for accurate bubble generation.

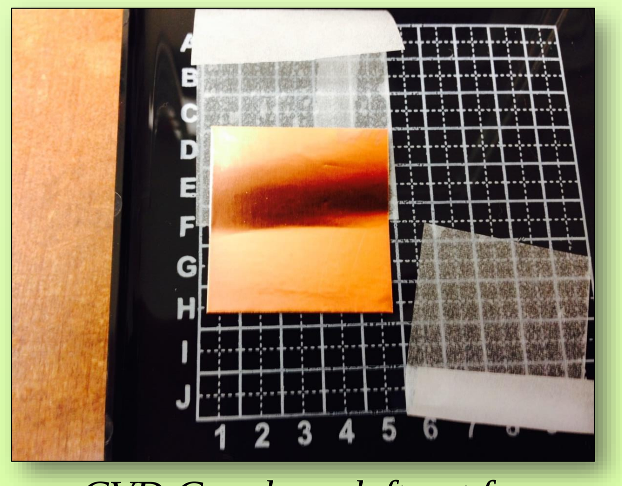


Visualization of Electrolysis Process

Graphene is a two-dimensional sheet of carbon atoms. Graphene gained popularity due to its excellent conductive properties. Furthermore, the strong carbon bonds also make graphene mechanically strong (300x stronger than steel) and impermeable to liquids. When coated on materials such as copper, graphene inhibits corrosion



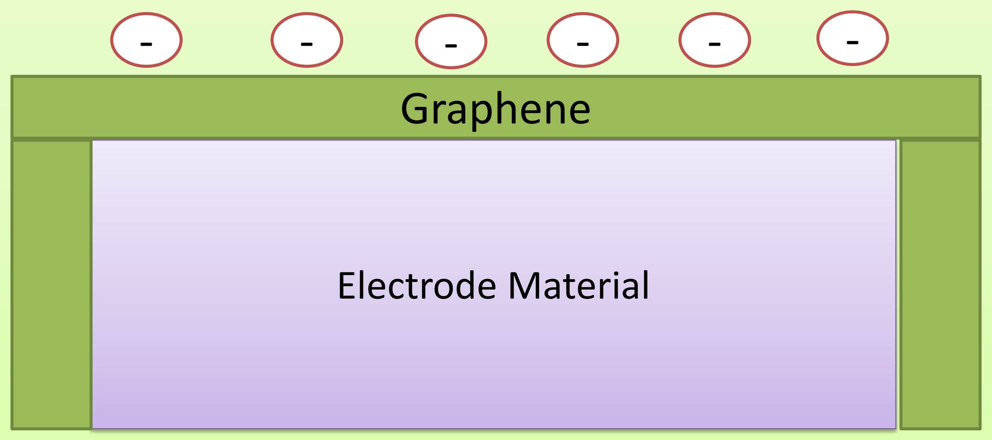
Graphene Honeycomb Crystal Lattice



CVD Graphene left out for several months

Objective

Our research aims to explore graphene coated electrodes for electroflotation devices. Due to graphene's high conductivity, charges will still accumulate around the conductor and allow electrolysis to occur. The uniformity of carbon atoms and corresponding charge distribution within a graphene monolayer may lead to the formation of tiny bubbles



Graphene Coated Electrode

Methods

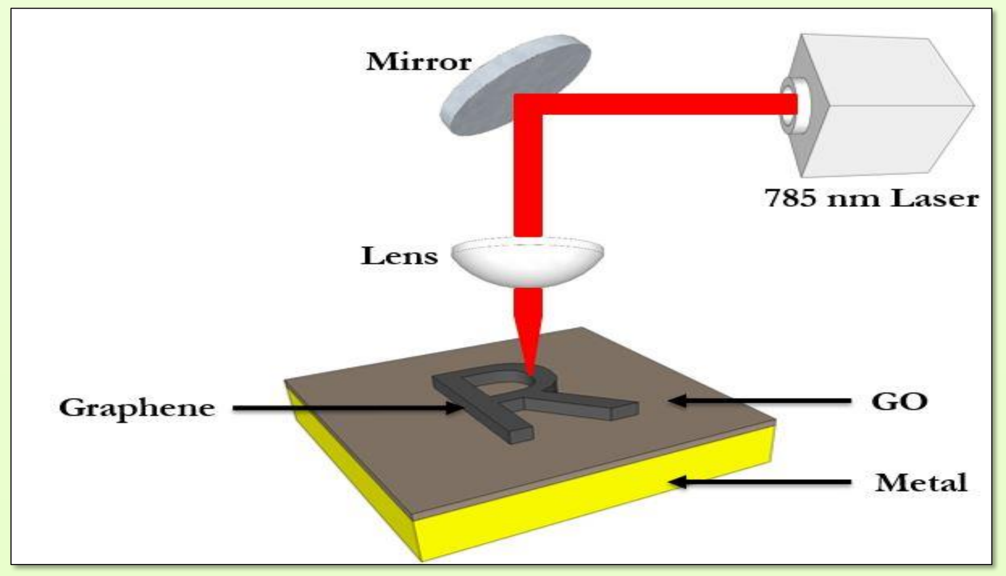
To coat graphene onto conductive materials both a laser irradiation and thermal exfoliation method was used. In both methods graphene oxide is used as a carbon source and synthesized into a graphene stack

Method 1: Laser Irradiation

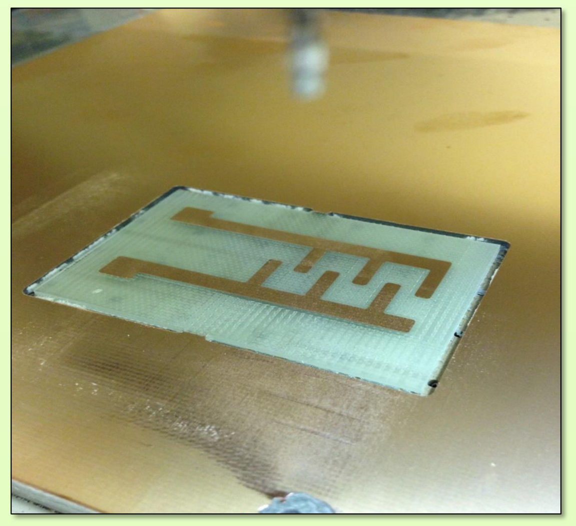
Graphene oxide was exposed to a focused laser source. The laser provided the necessary heat to synthesize the graphene stack.

Steps:

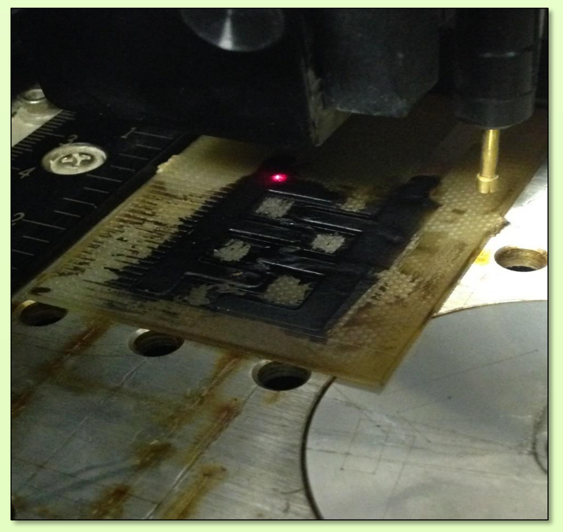
1. An electrode layout was fabricated using CNC Mill
2. Aqueous GO is dried onto the electrode
3. A CO2 laser engraver was used to pattern into graphene.



Laser Setup



Fabricated Electrode



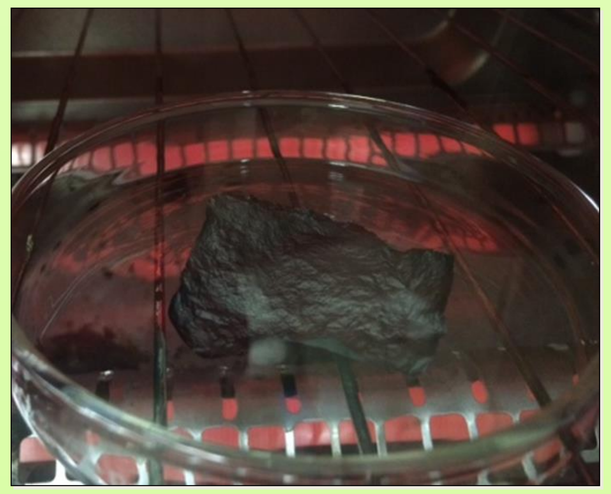
Irradiating Copper Surface

Method 2: Thermal Exfoliation

A conventional oven was used to synthesize a graphene stack on copper

Steps:

1. An electrode layout was fabricated using a CNC Mill
2. Aqueous GO is dried onto the electrode
3. Heat (200°C) was provided by a conventional oven with the convection cycle ON.



Thermal Exfoliation Oven

Oven Synthesized Graphene Stack

Results

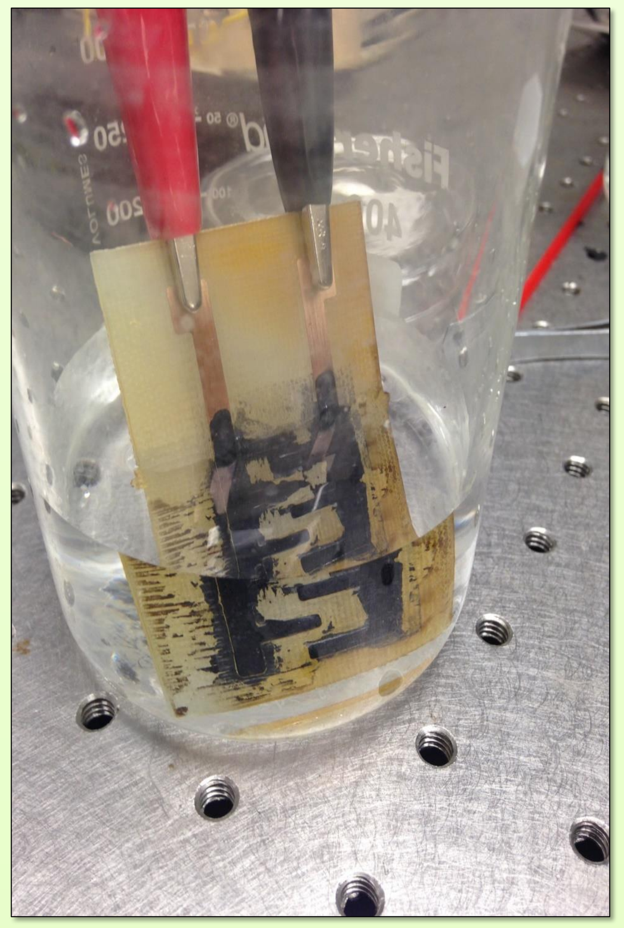
Method 1: Laser Irradiation

Pros

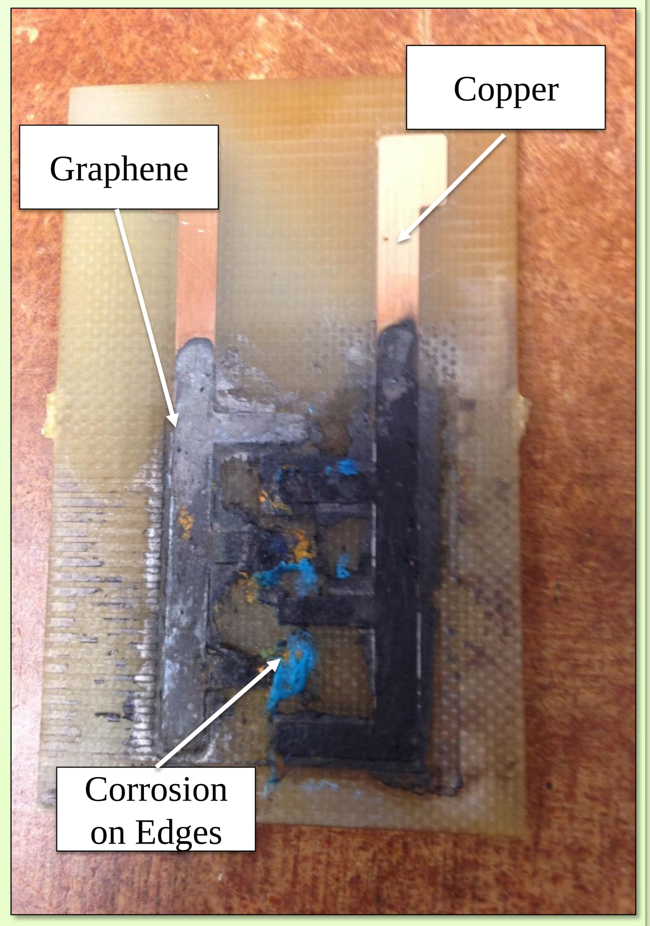
- Measured resistance of graphene coated material ~1Kohm.
- Bubbles generated on graphene surface during electrolysis
- Underlying copper protected from water

Cons

- Difficulty irradiating edges of copper traces
- Copper edge left exposed to water and oxidized



Electrolysis Experiment



After Electrolysis

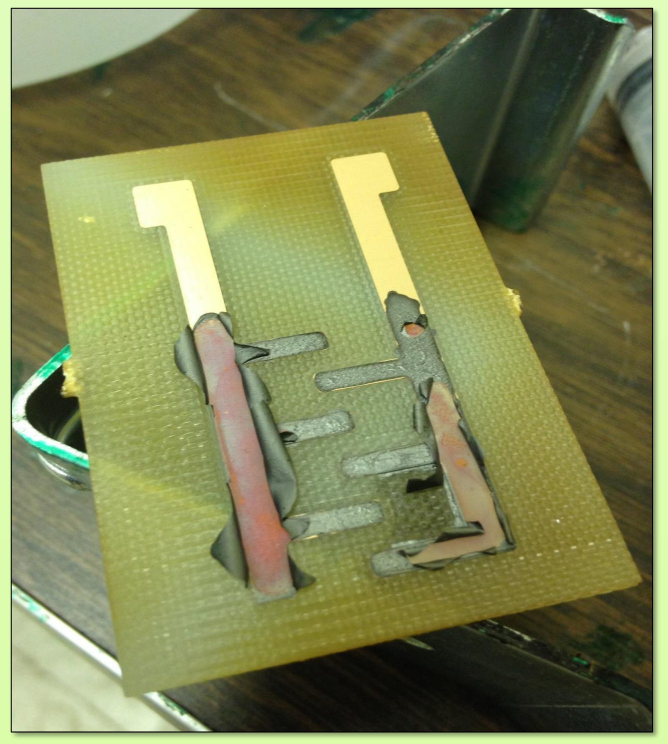
Method 2: Thermal Exfoliation

Pros

- GO easily synthesized into graphene stack at around 200ºC in conventional oven
- Large surface area can be coated

Cons

- Must carefully control temperature profile to prevent copper surface from oxidizing underneath graphene coating
- If temperature are too high, the graphene coating will peel off



Thermal exfoliated graphene stack in oven. Copper got too hot that graphene stack lifted off surface

Conclusion

Method 1: Laser Irradiation

- Laser irradiated graphene stack was very conductive
  - Before irradiation: R ~ 10 Mohm
  - After irradiation: R ~ 1Kohm
- Graphene stack increased durability of electrodes during electrolysis – 10V for 25 mins with no corrosion
- Electrodes oxidized along copper edges that were not coated

Next Step: Fully coat graphene oxide edges.

Method 2: Thermal Exfoliation

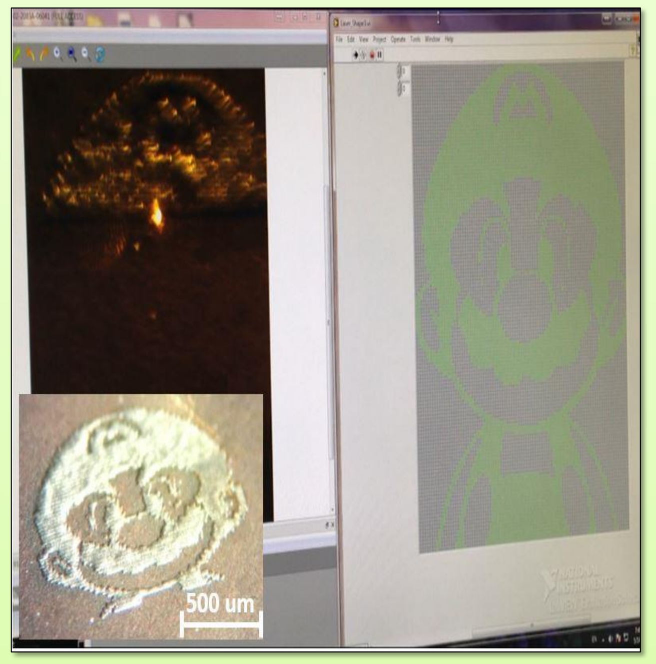
- Graphene stack synthesized from GO by thermal exfoliation.
- Exfoliation need to be done under controlled temperature profile .

Next Step: Adjust temperature profile in that GO will remain on electrode material.

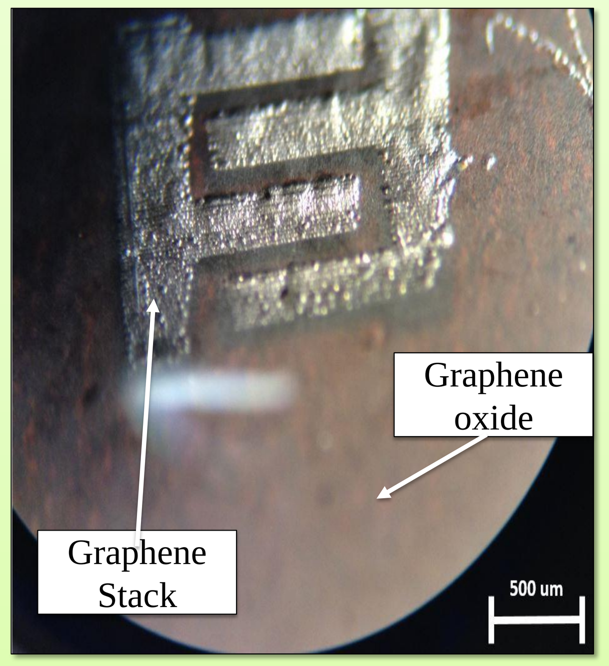
Future Work

Laser Irradiation at Micron-sized Structures

Since the synthesized graphene stacks did not corrode in our experiments we explored irradiating small electrode structures using a 785 nm TO-can laser diode with an optical power of 30mW. This will allow the design of very small electrode structures that will have the potential to generate very tiny bubbles



Laser irradiation of a complex structure with software written in labVIEW



Typical electroflotation design irradiated into graphene oxide

References

- A. K. Geim, K. S. Novoselov. “The rise of graphene.” Nature Materials, 6(3), 183-191. (2007)
- R.C. Ordonez, C. Hayashi, N. Kamin, M.C. de Andrade, D. Garmire, (2014). Charge Amplification of a Graphene-Integrated-CMOS (GIC) RF Detector, Proc. 2014 TechConnect World Conference: Nanotech, Washington D.C.
- Kim, Hyunwoo, Ahmed A. Abdala, and Christopher W. Macosko. "Graphene/Polymer Nanocomposites," Macromolecules Perspective 6515-6530. (2010)
- Tumsri, Kan, and Orathai Chavalparit. "Optimizing Electrocoagulation-electroflotation Process for Algae Removal," IPCBEE 6: (V2-452)-(V2-456). (2014)