Hydrogenation of Reduced Graphene Oxide via Water Electrolysis

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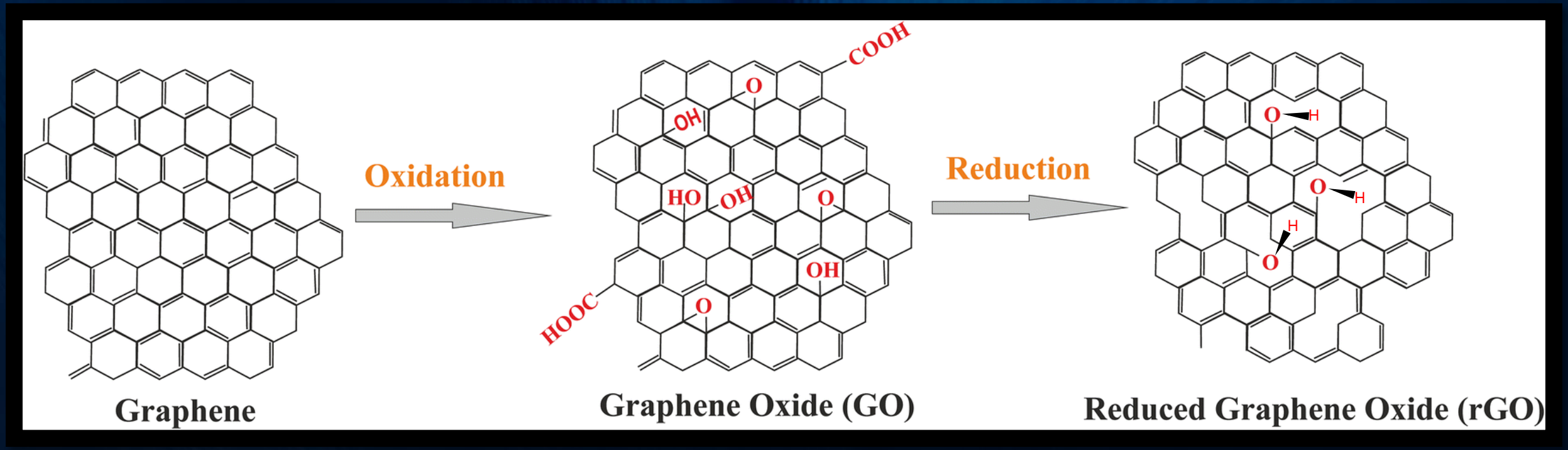
Hydrogen

- Hydrogen is the lightest element
- *Producing, transporting, and storing hydrogen is costly
- *Key challenges—reduce delivery cost, increase energy efficiency, maintain purity, and minimize leakage

*Office of Energy Efficiency & Renewable Energy, 2019, Energy.gov

Reduced Graphene Oxide

- Graphene Oxide (GO)—monomolecular layer of graphite containing oxygen functionalities *(Ray, 2015)*
- Reduced Graphene Oxide (RGO)—form of GO that has less oxygen functionalities *(Diemiev, Eigler,2017)*

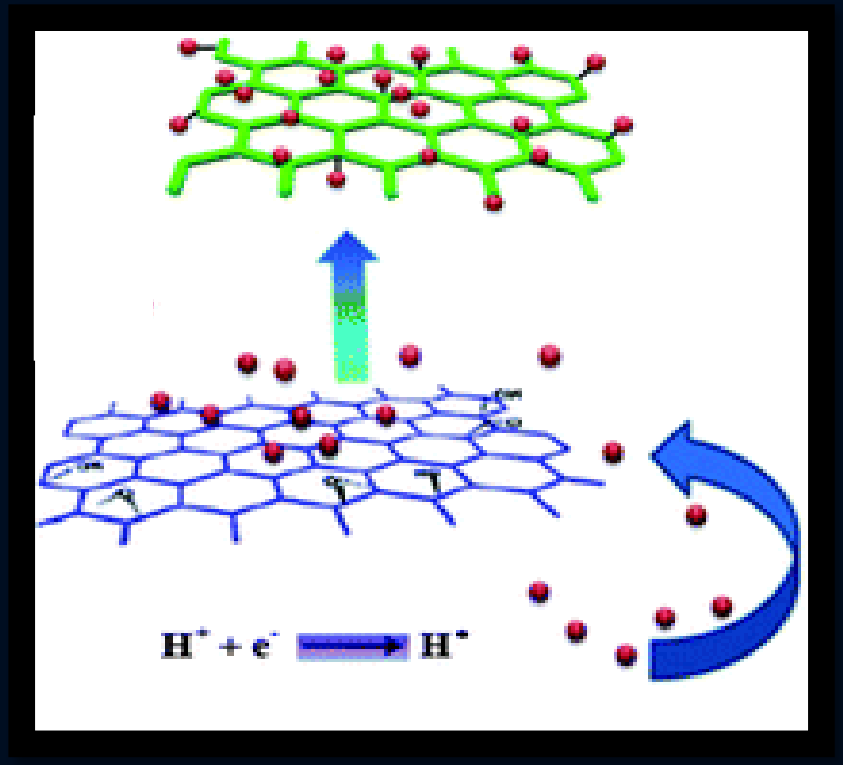


Priyadarsini, S., Mohanty, S., Mukherjee, S. et al.

Hydrogenation

- A general term used to describe the addition of hydrogen through a chemical process

- Hydrogenation of graphene shows C-H stretching *(Subrahmanyam, et al. 2011)*



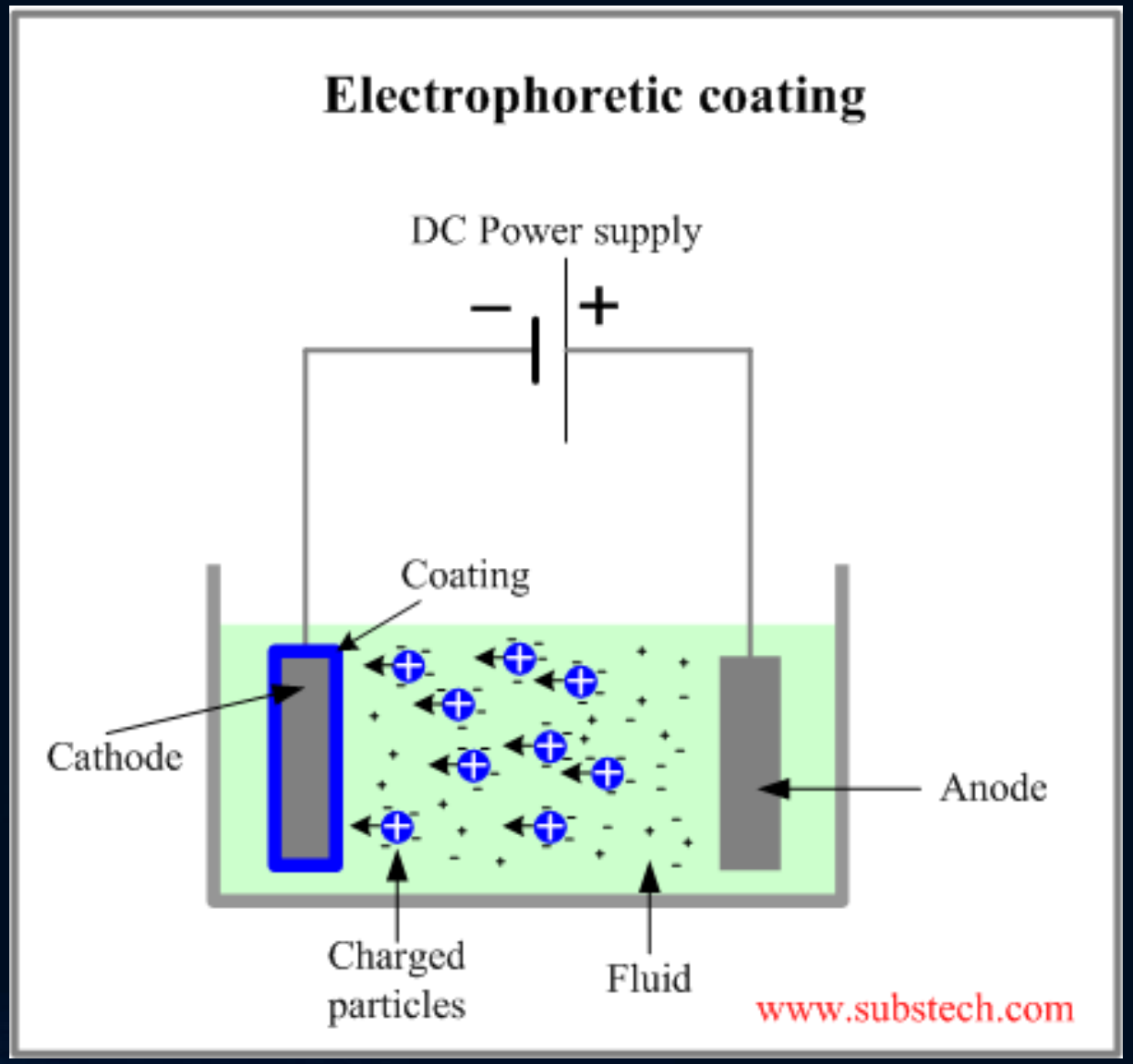
J. Mater. Chem., 2012,**22**, 10457-10459

Initial Goals

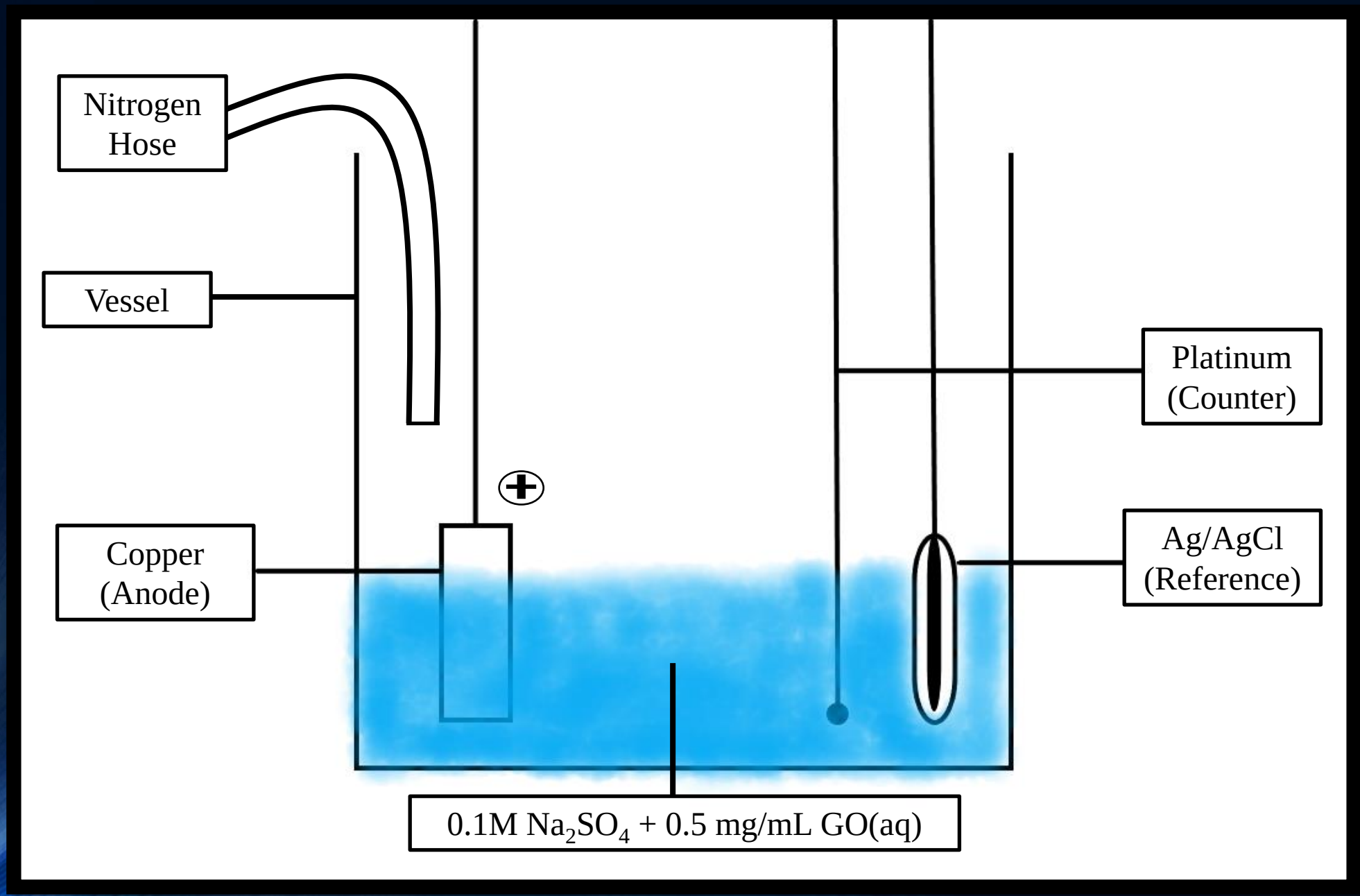
- Electrophoretic deposition (EPD) of Electrochemically Reduced Graphene Oxide (erGO)
- Use coated electrodes to perform water electrolysis
- Analyze storage yield of hydrogen

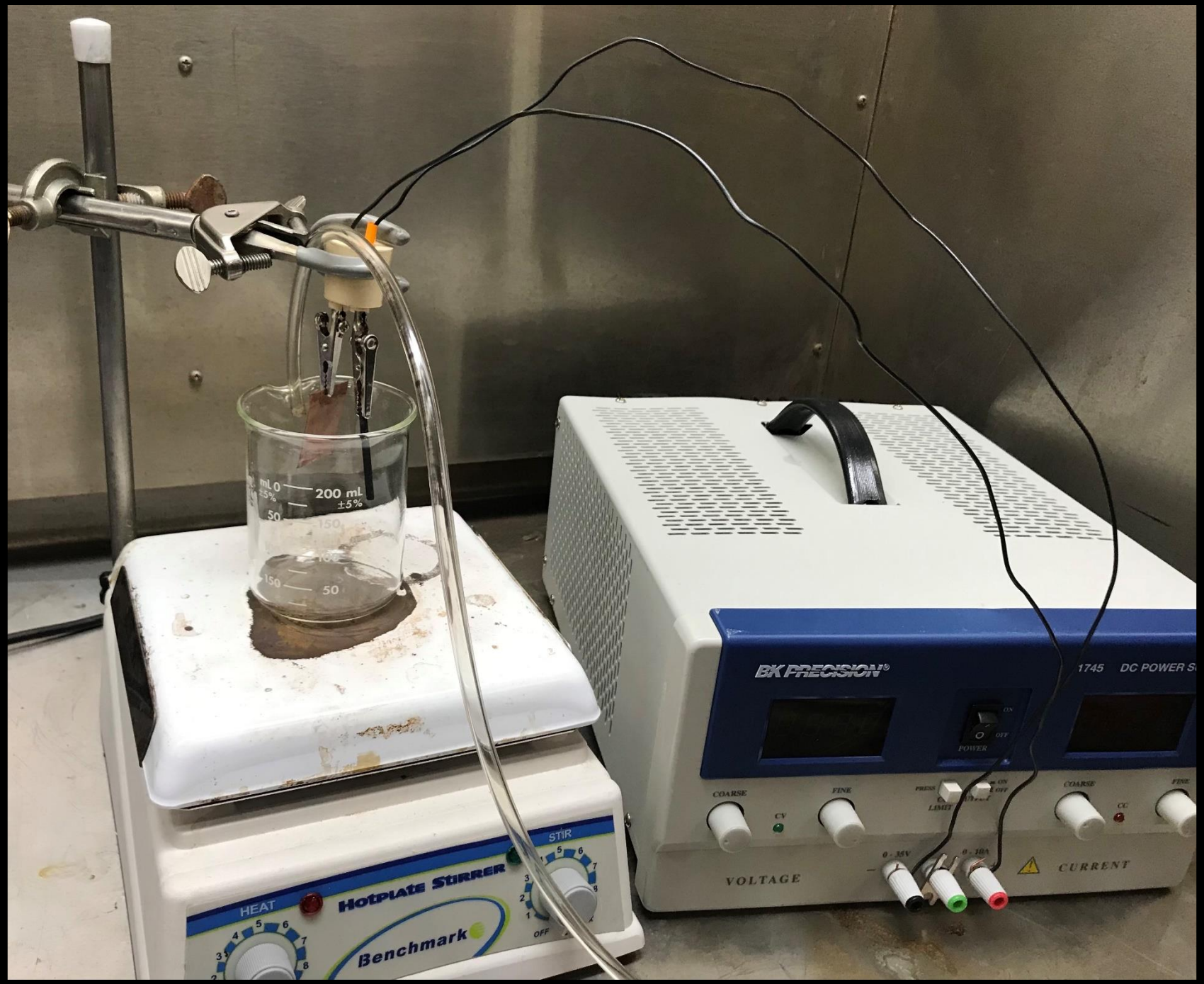
Electrophoretic Deposition

- "Particles suspended in a colloid solution are collected onto a substrate."*(Augello, Liu, 2015)*
- Copper (Cu) was used as a substrate
- Substrate acted as an anode
- GO undergoes reduction and becomes erGO



Cyclic Voltammetry



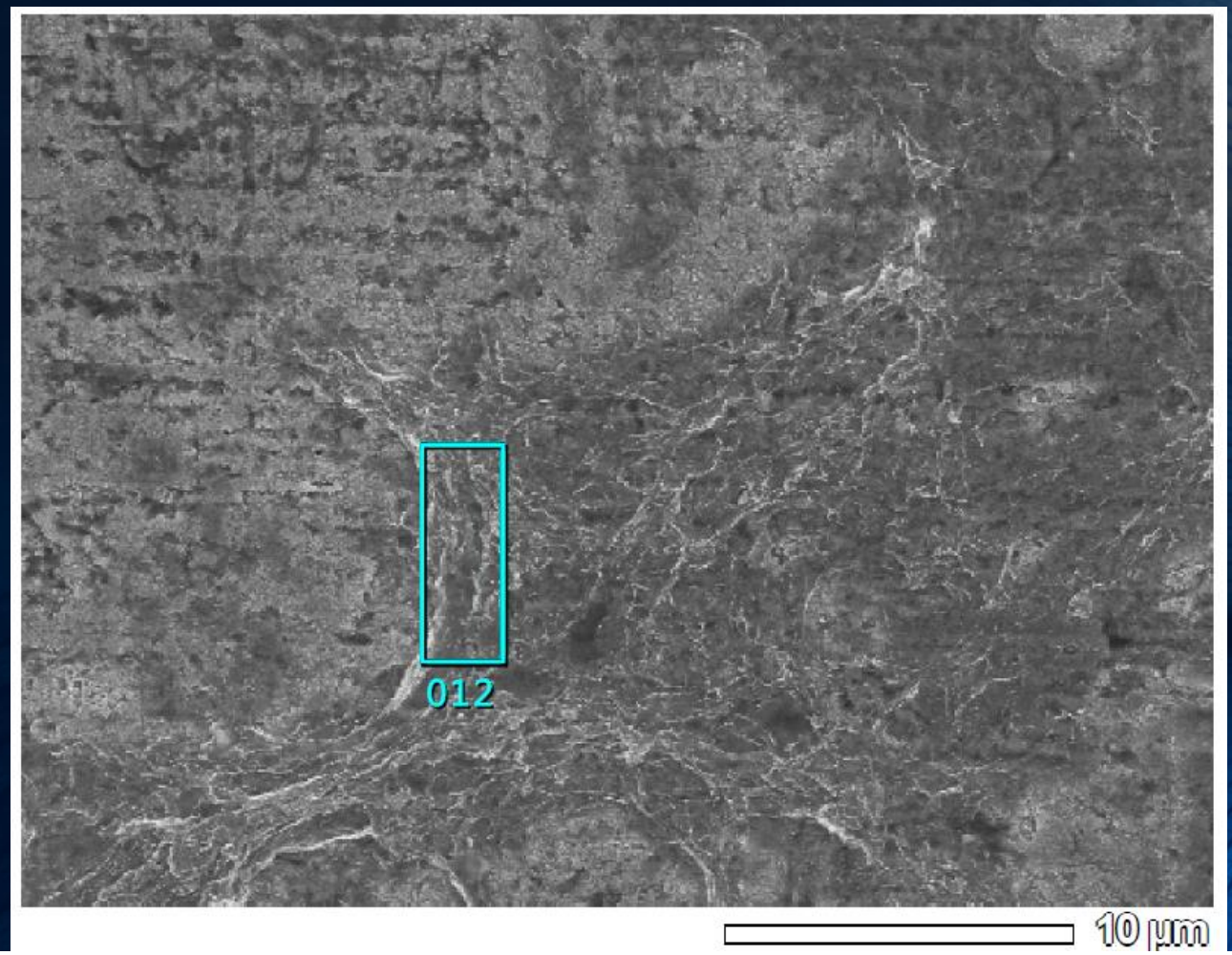

200 mL
±5%
HEAT
Hotplate Stirrer
STIR
Benchmark
OFF
BK PRECISION
1745
DC POWER
POWER
COARSE
FINE
CV
CC
VOLTAGE
CURRENT

Mass of erGO Deposited on Cu vs. Time

Time (mins)	Mass (mg)
10	0.135
20	0.197
30	0.189
40	0.192
50	0.256
60	0.180
90	0.394
120	0.441

* 1.1V potential applied

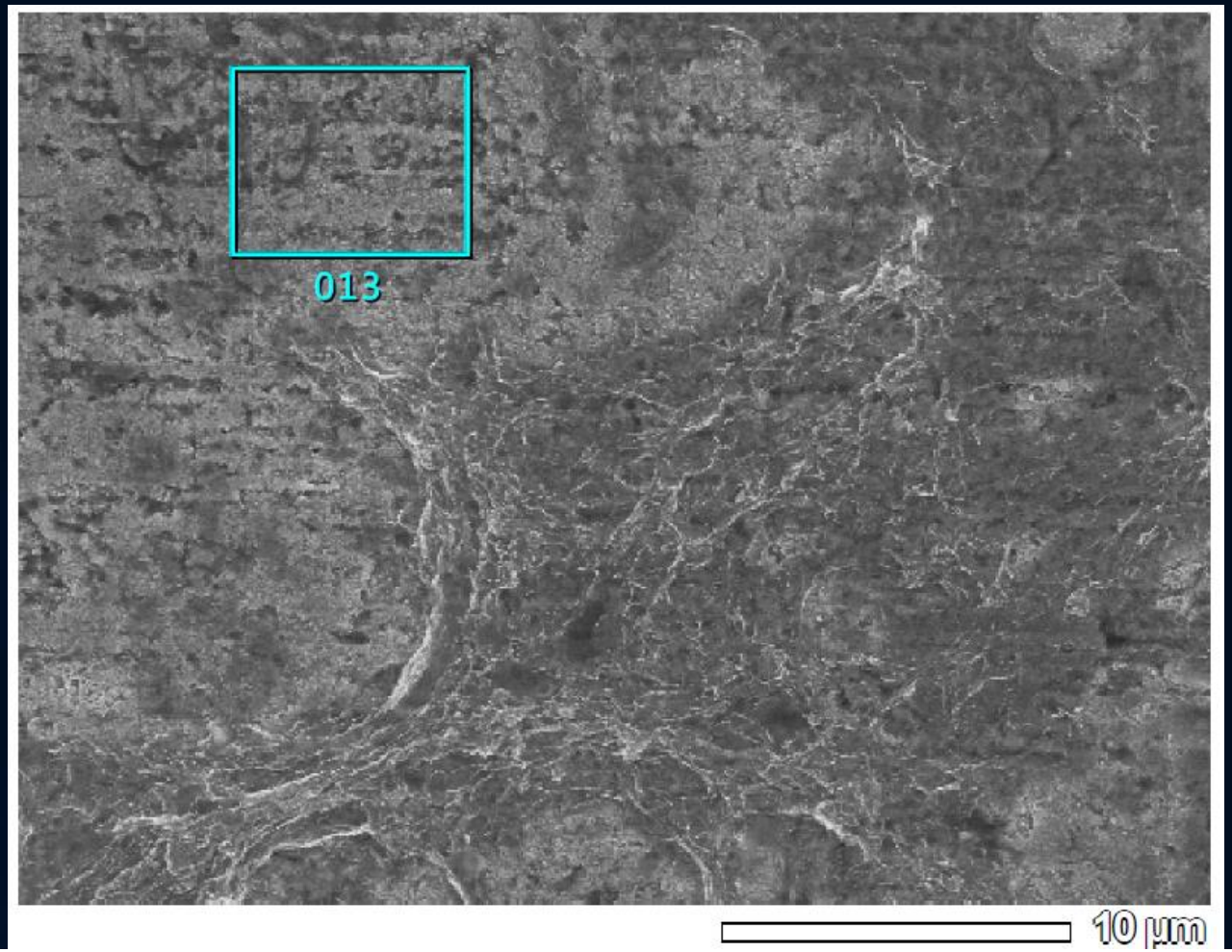
Cu Electrode



ZAF Method Standardless Quantitative Analysis
Fitting Coefficient : 0.1447

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	40.69	0.52	75.35				17.1746
O K	0.525	3.74	0.24	5.20				4.0609
Cu K	8.040	55.57	1.61	19.45				78.7645
Total		100.00		100.00				

Cu Electrode



ZAF Method Standardless Quantitative Analysis
Fitting Coefficient : 0.1035

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	9.31	0.26	34.64				2.2176
O K	0.525	0.75	0.11	2.09				0.8823
Cu K	8.040	89.94	1.82	63.26				96.9001
Total		100.00		100.00				

Conclusion and Future Work

- EPD of GO on copper could act as hydrogen storage vessel
- erGO could make storage and transportation of hydrogen safer and less expensive
- Various electrolytic cells made
- GO deposition confirmed by SEM
- Copper electrode can be reused
- Deposited erGO can be removed from electrode

Conclusion and Future Work

- erGO production corroboration
- Carbon, hydrogen, and oxygen ratio of hydrogenated erGO
- Scaled up hydrogenation for commercial use

Sources

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SciCom Disclaimer

Hydrogen is the most abundant element in the universe. Luckily, the ability to use it as an energy source means that it is a plentiful resource that leaves no toxic byproducts like coal and natural gas do. On earth, the greatest source of hydrogen is in water molecules. One major problem with using hydrogen as an energy source is that it likes to expand any container it is in—making it very dangerous to handle. In this project, I have explored storing hydrogen in a vessel that is not a normal container. This container will keep hydrogen from expanding and escaping traditional containers by attracting it to a very small sheet of carbon. By having these sheets of carbon put on an electrode, like one you would see in your batteries at home, we can extract hydrogen from water and store it safely in these sheets. This could change the way we look at producing, storing, and transporting hydrogen in a much safer and simpler process than is currently used.