Graphene Quantum Dots as Novel Free Radical Scavenging Agents

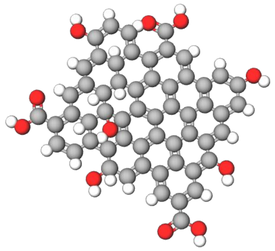
Steven Nguyen‡ [1], Adam Bhaloo‡ [2] , Bong Han Lee[3], Olivia Fannon[3], Anton V. Naumov[3]

1 International Leadership of Texas, Keller-Saginaw High School, 2 Trinity Valley High School Fort Worth, Texas 3 Department of Physics and Astronomy, Texas Christian University, Fort Worth, Texas. ‡ Both authors contributed equally to this work

Abstract

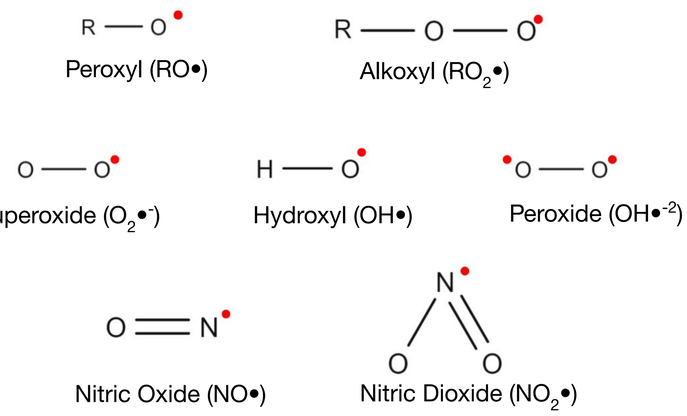
Oxidative stress, an imbalance of reactive oxygen species, has been shown to participate in a multitude of diseases, from Alzheimer's to cancer. Thus, there is a search for radical scavenging agents capable of circumventing oxidative stress. Due to their remarkable properties, quantum dots are known to be utilized in various applications, including the binding of reactive oxygen species (ROS). However, the translation of nanomaterials to the clinic is often hampered by their off-target toxicity. Thus, our work aims to develop and test fully biocompatible graphene quantum dots (GQDs) with a variety of dopants that will tune the radical scavenging activity (RSA) of the GQD. We have synthesized and tested over ten types of doped GQDs and accessed their radical scavenging ability via DPPH, KMnO4, and RHB assays. Among those, thulium and aluminium-doped GQDs show superior scavenging.

Introduction



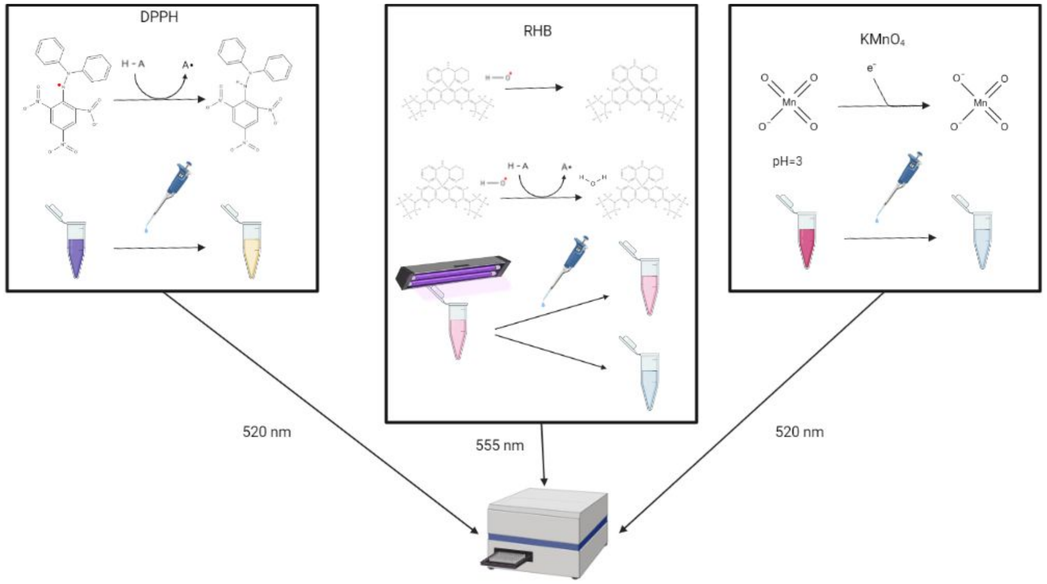
- GQDs are a derivative of graphene.
- Free radical scavenging agents (FRSA) are capable of neutralizing ROS by donating an electron
- GQDs can be doped with a variety of elements that can act as a FRSA

Common Reactive Oxygen Species (• = Lone Pair)



- ROSs are unavoidable, being produced from oxidative phosphorylation, UV radiation, drugs, pollution, and pesticides
- The production of ROSs leads to oxidative stress which has been associated with a plethora of diseases such as cancer, Alzheimer's. Parkinson's, diabetes, and strokes

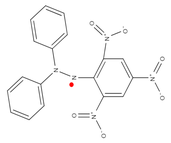
Assay Method and Mechanism

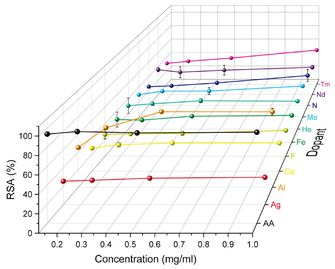


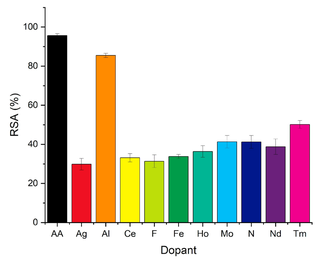
Results: Effect of Dopant on Radical Scavenging Activity

DPPH

$$RSA\ (\%) = \frac{(A_C - A_{GQD})}{A_C} \times 100$$

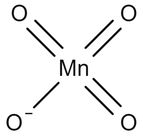


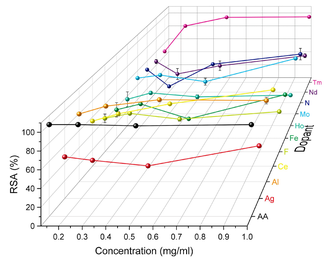


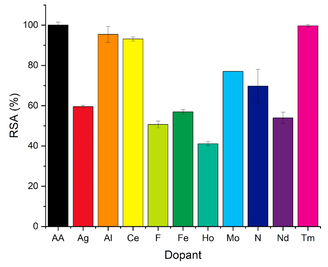


KMnO4

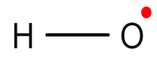
$$RSA\ (\%) = \frac{(A_C - A_{GQD})}{A_C} \times 100$$

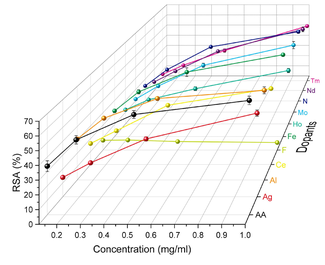


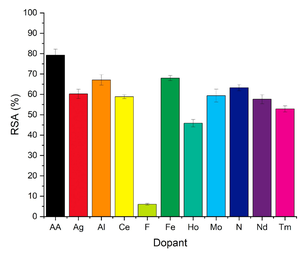




RHB

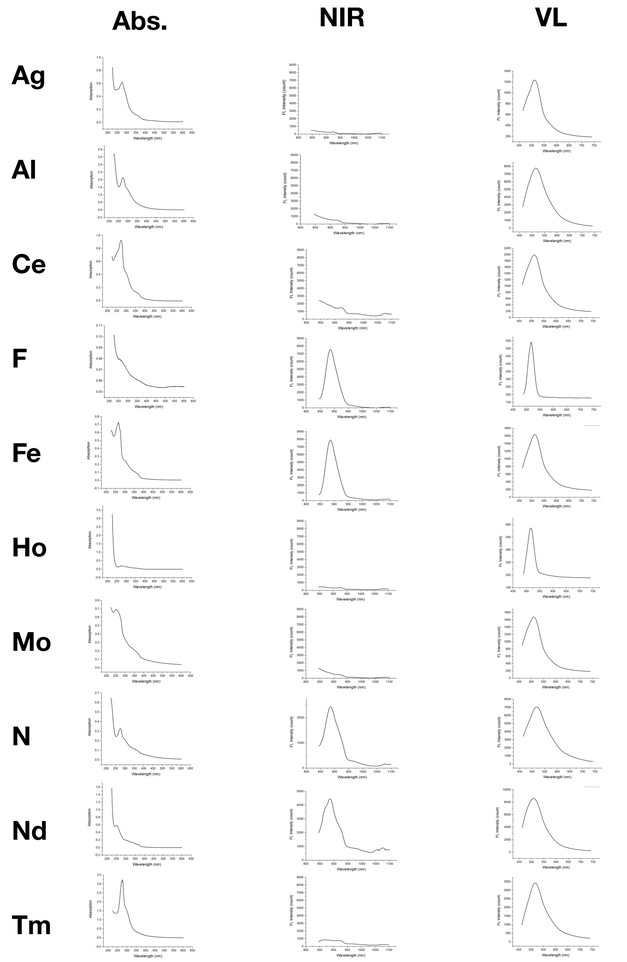






- A gradual increase in radical scavenging activity (RSA) is indicative of an agent capable of reducing ROS
- Ascorbic acid control remains high for all concentrations due to it being a known radical scavenging agent

Characterization: Absorption and Fluorescence



Conclusion and Outlook

- The radical scavenging activity of GQDs differ between assays, however, aluminum doped GQDs have high scavenging capability across all assays
- Silver, aluminium, cerium, iron, holmium, molybdian, nitrogen, neodymium, and thulium doped GQDs all exhibit free radical scavenging activity when utilizing the RHB assay
- The only GQD that did not reduce ROS were fluorine doped, which could be due to fluorine having a high electronegativity which results in a strong oxidant
- In the future, we hope to perform Escherichia coli antibacterial assays on the differently doped GQDs

References

- Hasan, Md. Tanvir, et al. "Rare-Earth Metal Ions Doped Graphene Quantum Dots for near-Ir in Vitro/in Vivo/Ex Vivo Imaging Applications." Advanced Optical Materials, vol. 8, no. 21, 2020, p. 2000897., https://doi.org/10.1002/adom.202000897.
- Mimic-oka, J I et al. "FREE RADICALS IN CARDIOVASCULAR DISEASES." (1999).