Tiny Dots, Big Feelings: Graphene Quantum Dots Sniffing Out Dopamine

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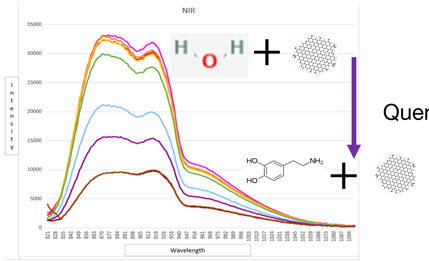
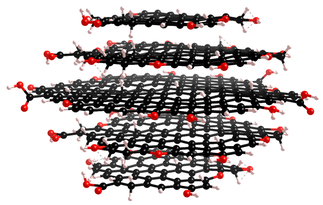
Introduction

Graphene quantum dots (GQDs) is an emerging nanocarbon platform that is now actively utilized for therapeutic applications. Their increasing popularity arises due to relatively high biocompatibility, water solubility, optical properties enabling multi-color fluorescence imaging and the ease of functionalization with a variety of therapeutic agents. Such properties pave the way for a variety of imaging and sensing applications. Detecting dopamine can provide insights about the neural health and the activity of neurotransmitters in the brain. However, due to the presence of dopamine receptors throughout our body, this will also help assess other vital functions including secretion of pituitary hormones, gut motility, immunomodulatory effects in inflammation-related diseases and cardiovascular effects (dopamine can act as both autocrine or paracrine compound in the mammalian heart).



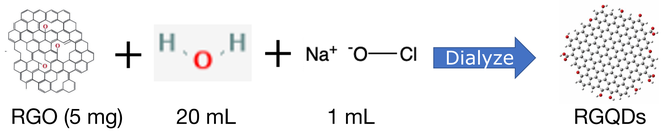
Molecular Structures of RGQDs



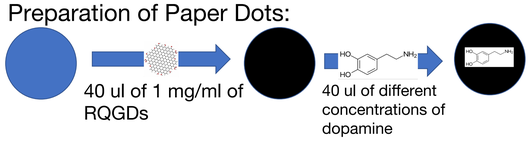
Preparation

We are utilizing RGQDs (reduced graphene quantum dots) synthesized top down from reduced graphene oxide for dopamine sensing.

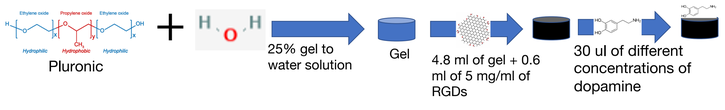
Preparation of RGQDs:



Preparation of Paper Dots:

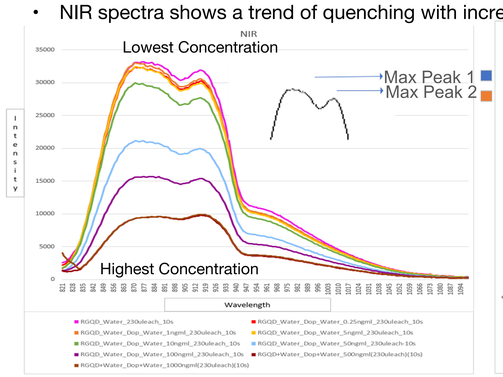


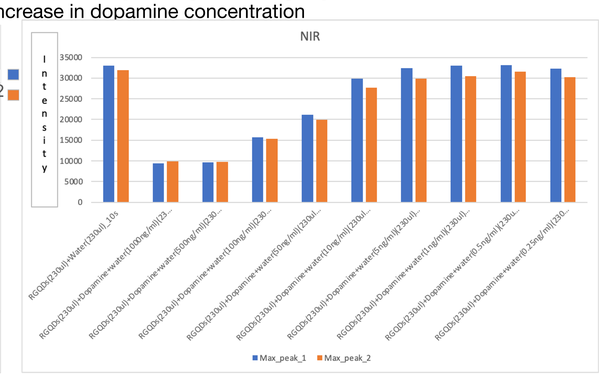
Preparation of Gel Dots:



NIR Spectra

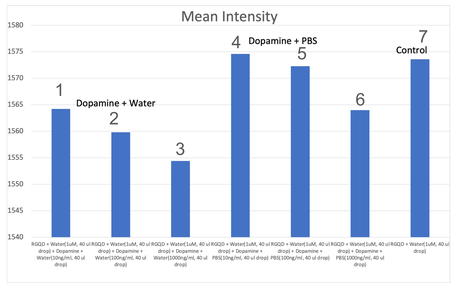
- 250 ul of 1mg/ml RGQD was mixed with 250 ul of dopamine [1000 ng/ml to 1 ng/ml]
- NIR spectra shows a trend of quenching with increase in dopamine concentration

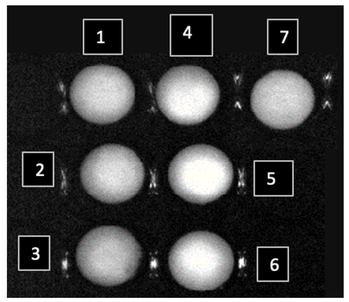




Paper Dots Imaging

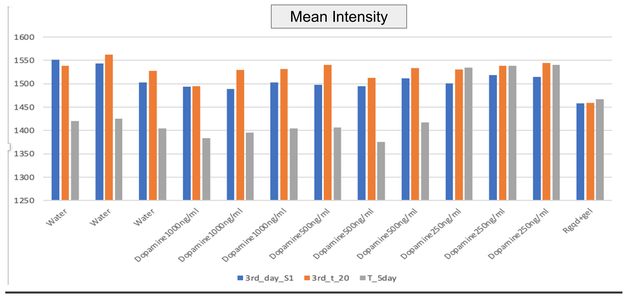
- 40 ul of 1 mg/ml of RQGDs was added to paper dot and was allowed to dry for 15-20 minutes
- 40 ul of different concentrations of dopamine was added [1000 ng/ml to 1 ng/ml]
- Imaging at NIR 808 nm shows a trend of quenching with increase in dopamine concentration (NIR 808 filter was used)

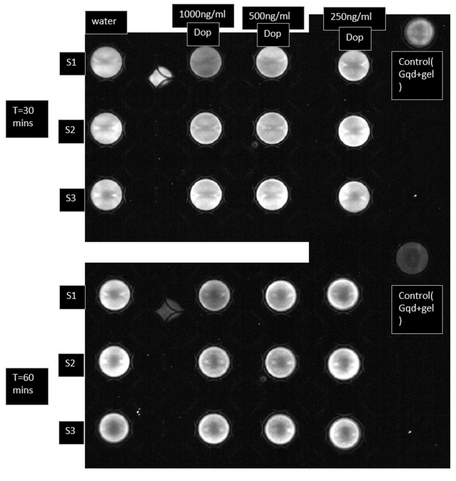




Gel Imaging

- Pluronic and water were added in 1:4 ratio to make a gel
- 0.6 ml of 5 mg/ml of RGDs was added to 4.8 ml of gel
- 30 ul of different concentrations [1000 ng/ml to 100 ng/ml] of dopamine and was let to dry 2 hours
- Imaging at NIR 808 nm shows no trend of quenching with increase in dopamine concentration (BP 1000 filter was used)

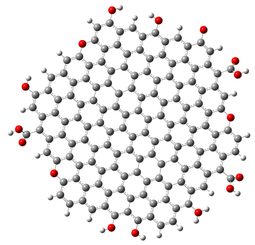




Conclusion & Application

- For imaging using paper dots, we found that quenching follows the trend of the higher the dopamine concentration, the more quenching that occurs of RGQD fluorescence.
- For both dopamine solution in water and PBS, the quenching was noticed. However, the dopamine PBS solutions had higher fluorescence.
- No such trend was noticed for gel samples
- Our spectra confirms the quenching action even for low concentrations that could not be confirmed in the imaging technique

RGQD

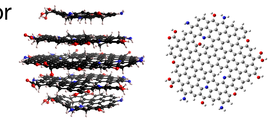


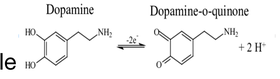
900 nm (928 nm)

Future Work

- Different motifs on GQDs for better sensing of dopamine
- Study the effects at different pH
- Use other GQDs (NGQDs, AlGQDs) to determine if and how they quench or fluoresce when in contact with dopamine
- In vivo studies for sensing applications using gels
- Interaction of GQD with dopamine-o-quinone to make sensing more specific with dopamine
- Studies with different biocompatible gels (PEGDA)

NGQD





References

1. Chatterjee, M., Nath, P., Kadian, S. *et al.* Highly sensitive and selective detection of dopamine with boron and sulfur co-doped graphene quantum dots. *Sci Rep* 12, 9061 (2022). https://doi.org/10.1038/s41598-022-13016-4

2. Weng, Shaohuang et al. "A unique turn-off fluorescent strategy for sensing dopamine based on formed polydopamine (pDA) using graphene quantum dots (GQDs) as fluorescent probe." *Sensors and Actuators B-chemical* 221 (2015): 7-14.

3.. Nira Ben-Jonathan, Robert Hnasko, Dopamine as a Prolactin (PRL) Inhibitor, Endocrine Reviews, Volume 22, Issue 6, 1 December 2001, Pages 724–763, https://doi.org/10.1210/edrv.22.6.0451

4. Graeme Eisenhofer, Anders Åneman, Peter Friberg, Douglas Hooper, Lars Fåndriks, Hans Lonroth, Bêla Hunyady, Eva Mezey, Substantial Production of Dopamine in the Human Gastrointestinal Tract, The Journal of Clinical Endocrinology & Metabolism, Volume 82, Issue 11, 1 November 1997, Pages 3864–3871, https://doi.org/10.1210/jcem.82.11.4339

5. Channer B, Matt SM, Nickoloff-Bybel EA, Pappa V, Agarwal Y, Wickman J, Gaskill PJ. Dopamine, Immunity, and Disease. Pharmacol Rev. 2023 Jan;75(1):62-158. doi: 10.1124/pharmrev.122.000618. Epub 2022 Dec 8. PMID: 36757901; PMCID: PMC9832385.

6. Feng YF and Lu Y (2021) Immunomodulatory Effects of Dopamine in Inflammatory Diseases. Front. Immunol. 12:663102. doi: 10.3389/fimmu.2021.663102

7. Neumann J, Hofmann B, Dhein S, Gergs U. Role of Dopamine in the Heart in Health and Disease. Int J Mol Sci. 2023 Mar 6;24(5):5042. doi: 10.3390/ijms24055042. PMID: 36902474; PMCID: PMC10003060.

Graphene quantum dots (GQDs) are tiny carbon structures gaining attention for medical use. They're biocompatible, soluble in water, and can light up at different wavelengths aiding imaging. These GQDs can also easily carry therapeutic substances because of their small size and specific targeting abilities. In this study, we discuss how using these properties of GQDs we can detect dopamine at very low concentrations in our body. Since dopamine receptors are widespread throughout the body, this detection can also shed light on other vital functions like hormone release and heart activity. GQDs offer a promising avenue for studying and treating various health conditions.