Improving Fluorescence Emission of Graphene Quantum Dots through Surfactant-Assisted Stabilization

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ABSTRACT

Graphene Quantum Dots (GQDs) are nanoscale carbon based graphene sheets that exhibit unique fluorescent properties throughout a wide range of wavelengths. Given their uniquely small size, low toxicity, biocompatibility, and fluorescent capabilities, GQDs have many unique and important roles. To name a few, GQDs are used in drug delivery, fluorescent imaging, and biosensing thanks to their unique ability to fluoresce under different wavelengths of light. Furthermore, there are different types of GQDs with their own unique properties. Knowing this, five amphipathic molecules, called surfactants, were added to two different types of GQDs to test if they would impact the resulting fluorescence. Furthermore, concentrations of these added surfactants were varied to test how different concentrations of a given surfactant might affect the fluorescence for a given GQD. We observed that some of these surfactants provided a beneficial boost to GQDs fluorescence, while others slightly inhibited the fluorescence. Moreover, we saw that the increase in fluorescence varied based on the concentration of surfactant added yielding lower fluorescence for extremely low and high concentrations, while increasing the fluorescence at a more moderate concentration.

INTRODUCTION

Graphene Quantum Dots (GQDs) fluoresce (glow) under specific wavelengths of light.
This study focuses on two types of GQDs:

- NGQDs (nitrogen-doped): graphene sheets with nitrogen and oxygen-containing groups.
- rGQDs (reduced): similar structure, but without nitrogen—only graphene and oxygen.

A third GQD, Nd-NGQDs (neodymium-doped), will be tested in future work; it glows in the near-infrared (NIR).

Goal: Understand how different surfactants affect the fluorescence of NGQDs and rGQDs.

Hypothesis: Surfactants influence fluorescence by interacting with GQDs hydrophobic ends face the GQDs, and hydrophilic ends face water, enhancing light emission.

Surfactants tested:

- Sodium dodecyl sulfate (SDS)
- Sodium deoxycholate (SDC)
- Sodium dodecylbenzene sulfonate (SDBS)
- Pluronic F127 (P-F127)
- Sodium cholate (SC)

METHODS

Synthesis

Synthesis of GQDs
- Batches of NGQDs were synthesized through a microwave synthesis process
- 2.156g of glucosamine was added to a 500mL flask containing 250mL of DI water
- Flask was placed in microwave at power level three for one hour

Synthesis of rGQDs
- Batches of rGQDs were synthesized through a microwave synthesis process
- 5g of reduced graphene oxide dissolved in a 20mL aliquot of DI water
- 1 mL of Sodium Hypochlorite is added to the solution
- Solution is stored in darkness and allowed to sit for 48 hours
- Both NGQD and rGQD batches were dialyzed and filtered to remove impurities (byproducts and leftover reactants)

Surfactant Test

Addition of surfactant
- 10% surfactant by weight was added to a 10mL aliquot of both NGQDs and rGQDs

Sonication
- Individual aliquots were sonicated to ensure normalized distribution of GQDs and surfactant

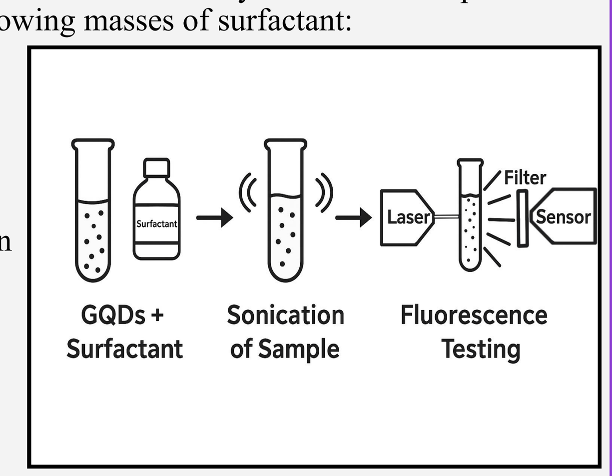
Testing
- 4mL samples were pipetted into cuvettes which were placed in our fluorescence setup
- NGQD samples were configured with a 400 nm laser with a corresponding broadband filter
- rGQD samples were configured with an 808 nm laser with a corresponding longpass filter
- NGQD samples were subjected to the laser for one second while rGQD samples were subjected to the laser for 15 seconds
- Data was recorded via an Avantes spectrophotometer

Concentration Test

Addition of surfactant
- Starting with the control with no surfactant, surfactants were added incrementally to a 10 mL sample of rGQDs which were then tested for peak fluorescence at the following masses of surfactant:
- 1mg, 5mg, 10mg, 50mg, 100mg, 500mg, and 1000mg

Sonication
- Sonicated in between each individual test in the same manner as the surfactant test

Testing
- 4mL samples were pipetted into cuvettes which were placed in our fluorescence setup with an 808 nm laser and corresponding longpass filter
- Samples were subjected to the laser for 15 seconds
- Data was recorded via an Avantes spectrophotometer



CONCLUSIONS

Our experiment showed that some surfactants were more effective than others in enhancing fluorescence. Specifically, SC, SDC, and PF127 noticeably increased the fluorescence of rGQDs in the NIR, with SC performing the best in both the NIR rGQD and visible NGQD tests. At low concentrations, SC inhibited the fluorescence of rGQDs, likely due to interactions with RGQD functional groups while maximum fluorescence was observed at ~10% by mass. We theorize these results were due to the hydrophobic interactions between the GQDs and the surfactant's nonpolar regions while hydrophilic parts interacted with water, reducing inhibition. Similar trends were observed with SDC and PF127, which we also theorize enhanced fluorescence through hydrophilic interactions. However, less effective surfactants appeared to suppress fluorescence, likely due to unfavorable interactions with GQDs that diminished their inherent fluorescence, similar to what we saw with SC at low and very high concentrations. Future work will expand surfactant testing to Nd-GQDs and investigate concentration effects on both NGQDs and Nd-GQDs.

RESULTS

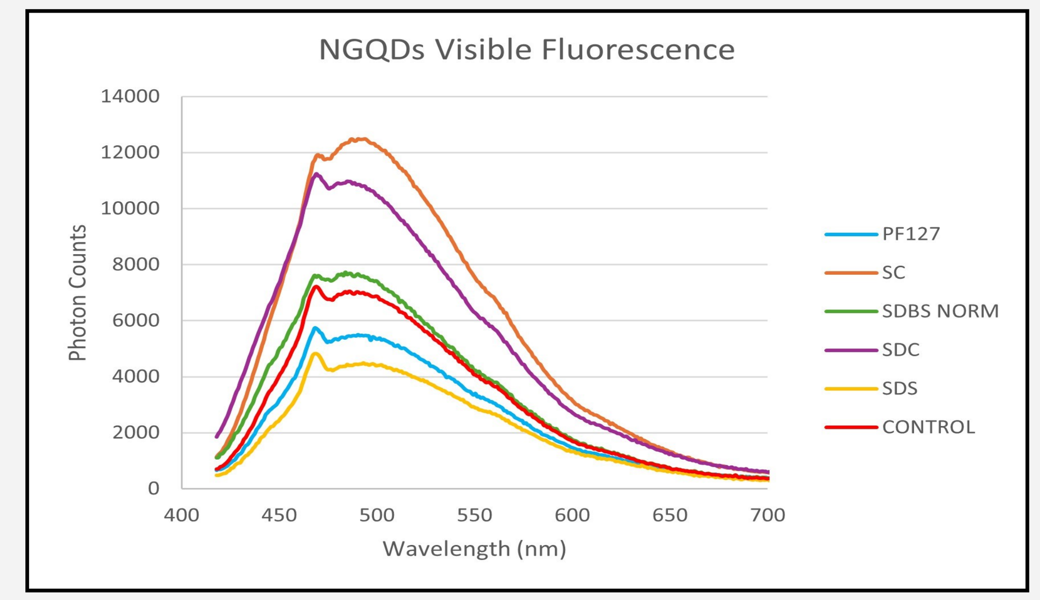


Figure represents the recorded fluorescence spectrum in the Visible for NGQDs upon the addition of 10% surfactant by mass

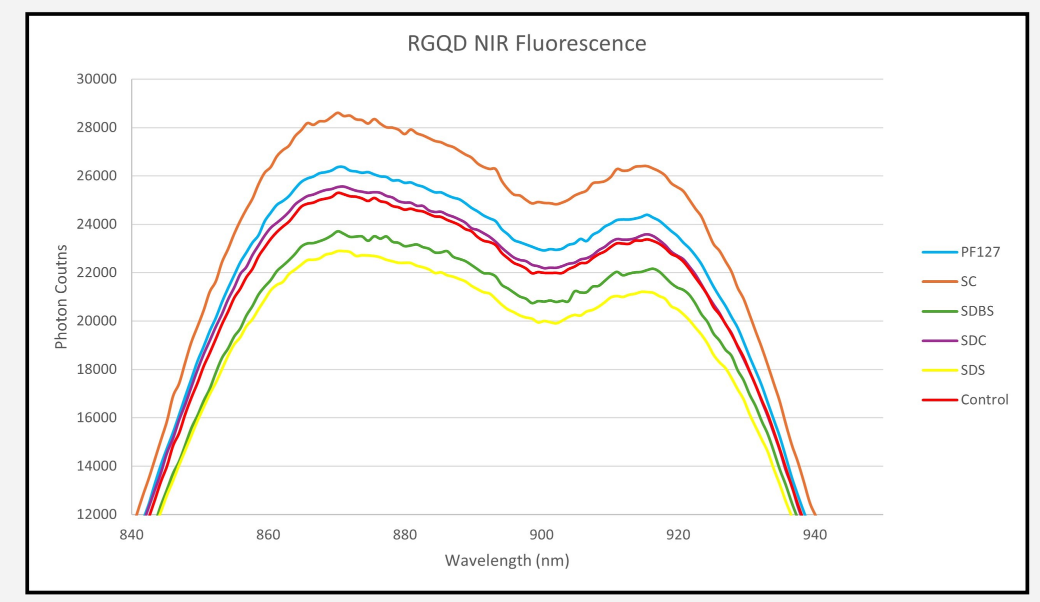


Figure represents the recorded fluorescence spectrum in the near infrared (NIR) for RGQDs upon the addition of 10% surfactant by mass

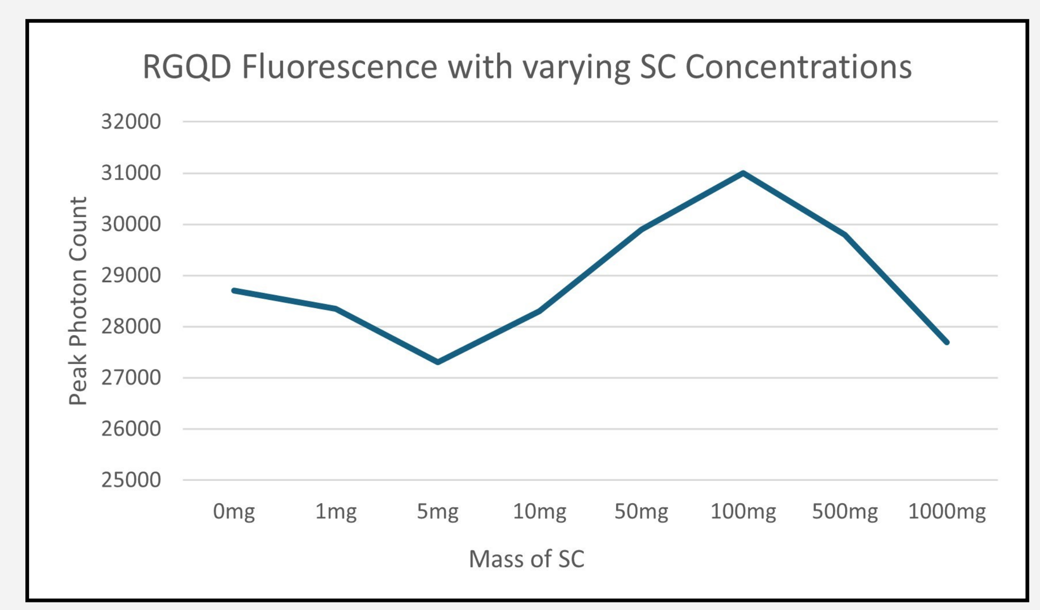


Figure represents the recorded fluorescence peaks for RGQDs with varying concentrations of SC

Overview

We studied how soap-like molecules (surfactants) affect the glow (fluorescence) of tiny carbon particles called graphene quantum dots (GQDs). These dots can be used in things like medical imaging or sensors. We found that different surfactants can either make the dots glow more or less depending on how they interact. Understanding this helps us control the glow, which is important for future uses in science and technology.

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