NIRvana in Bioimaging: Crafting Biocompatible Graphene Quantum Dots from Everyday Precursors

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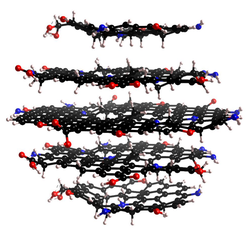
Abstract

Graphene quantum dots (GQDs) have gained attention in the bioimaging community due to their biocompatibility and enhanced imaging depth in the near infra-red (NIR). Developing and optimizing a facile synthesis method of biocompatible NIR fluorescent GQDs from a variety of precursors remains, therefore, a critical task. Herein, we synthesized various GQD structures capable of fluorescing in the NIR via facile bottom-up pyrolysis of precursor materials (ascorbic acid, chitosan, citric acid, dextran, glucose, glucosamine hydrochloride, hyaluronic acid, l-glutamic acid, polyethylene glycol (PEG), sodium cholate, or sodium citrate). All synthesized GQD structures exhibit remarkable biocompatibility at concentrations of up to 1 mg/mL evaluated by an MTT assay which makes them suitable for a variety of therapeutic applications. All 11 GQD structures are successfully tracked by their NIR fluorescence in vitro bioimaging while exhibiting effective cellular internalization maximized at 12 hours in HEK293 cell line. This work provides a unique comprehensive study exploring a scalable and cost-effective process to synthesize NIR-emissive highly biocompatible GQDs from 11 precursor materials, while theoretically describing their optical properties. Due to their exceptional biocompatibility and photostable NIR emission, GQD structures developed here are expected to become prominent candidates for future clinical fluorescence imaging applications.

Introduction

Graphene Quantum Dots (GQDs)

- Water soluble
- Nano-sized
- Can be used for:
  - Drug delivery
  - Cell imaging
  - Gene targeting



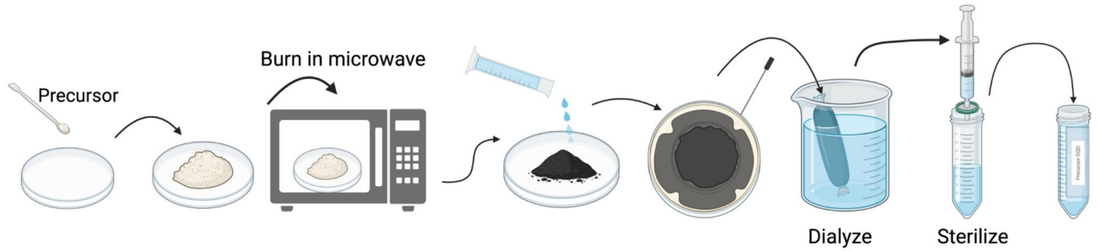
Bottom Up Synthesis

- Polymerization of carbon-based molecules
- Scalable
- Uniform structures
- Cost-effective

The Current Scenario:

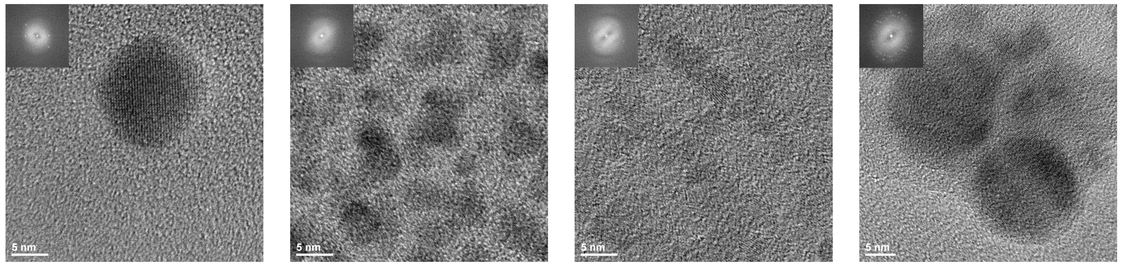
- Optical and Morphological Characterization
- Biocompatibility - MTT Assays
- In-vitro NIR fluorescence Imaging

Methods



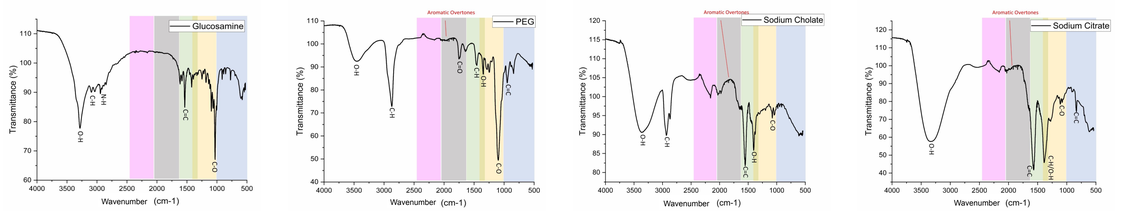
Morphological Characterization

TEMs



Glucosamine | PEG | Sodium Cholate | Sodium Citrate

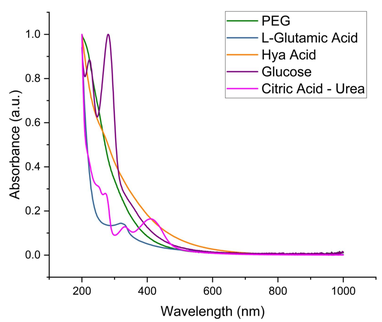
FTIR



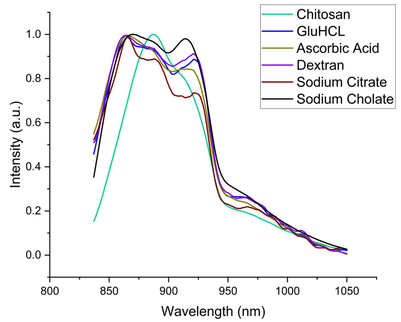
Glucosamine | PEG | Sodium Cholate | Sodium Citrate

Optical Characterization

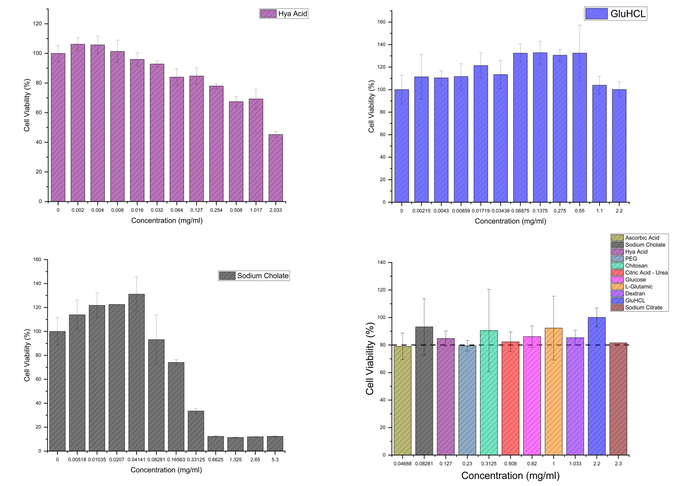
Absorption



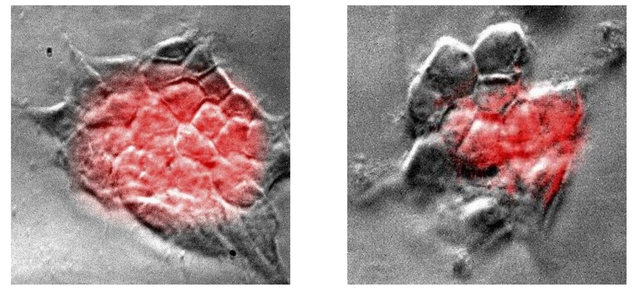
NIR Fluorescence



Biocompatibility



Cellular Imaging



Conclusion

This project has produced a novel method of synthesizing GQDs using the bottom-up approach through different precursors in the microwave. The GQDs have been characterized to show their properties: toxicity levels, strength of NIR fluorescence, functional groups, which can be obtained from the data presented above. Thus, each GQD can be further studied to find unique applications best suited to their properties.

References

Valimukhametova, A.R. *et al.* (2024) *IOPscience*, *2D Materials*. Available at: https://iopscience.iop.org/article/10.1088/2053-1583/ad1c6e