Synthesis of Quantum Dots for Cancer Bioimaging

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**Abstract :** the synthesis process, the size and shape allow for continual tuning and exact control of the emission wavelengths [(Liang et al., 2021)](https://paperpile.com/c/TUrRUm/94eQ). Multiple molecular targets are being analyzed at once using such multicolor QD-based probes. This feature reduces the number of tissue slices that need to be cut for biomarker analysis and is highly advantageous when using confocal microscopy to perform nanometer-resolution co-localization of multicolor QDs [(Moniruzzaman et al., 2020)](https://paperpile.com/c/TUrRUm/ZVpR).Due to their ideal surface chemistry, QDs can form flexible probes for use in biomedical applications by binding to targets like peptides, antibodies, or small molecules [(Janani et al., 2021; Kachhara et al., 2021; Subramanian et al., 2023)](https://paperpile.com/c/TUrRUm/nicJj+DjXsN+9ltyu).Bioimaging and cancer diagnosis are two examples of these applications. Furthermore, long-term resistance to bleaching makes it possible to obtain crisp, well-contrast images, which are particularly helpful for 3D optical sectioning of tumors and their surroundings, where bleaching of fluorophores affects the accuracy of 3D structure reconstruction [(Venkatachalam, 2024)](https://paperpile.com/c/TUrRUm/cAQE). Additionally, their deep penetration, wide and continuous excitation spectrum, great brightness, and long-term stability make them perfect for bio-imaging and in vivo cancer diagnostics [(Mohammadi et al., 2025)](https://paperpile.com/c/TUrRUm/wdUh).

**Keywords:** SEM image of quantum dots,Characterization of GQDs, FT-IR spectrum for quantum dots

# Introduction

One of the biggest health risks in the world is cancer. Despite significant advancements in cancer diagnosis, detection, and treatment, patient survival rates have remained low for decades [(Borovaya et al., 2021)](https://paperpile.com/c/TUrRUm/6KFp). In order to investigate the original tumor, identify suitable cancer treatment options, and assess the curative effects and recurrence, cancer detection and bioimaging are essential clinical tools [(Ramsundar et al., 2023; Rieshy et al., 2023; Singh et al., 2023)](https://paperpile.com/c/TUrRUm/8wZC3+NEJ47+2F5sb). At the moment, cancers are detected and imaged using MRI, computed tomography, ultrasound, radionuclide imaging, and X-ray [(Liang et al., 2021)](https://paperpile.com/c/TUrRUm/94eQ). Nevertheless, practically every one of these methods has drawbacks. For example, they lack the sensitivity to identify primary or metastatic regions with a low concentration of cancerous cells. Likewise, several cancer surface biomarkers cannot be detected by current imaging methods. Furthermore, they pose varied degrees of risk to humans [(Pavithra et al., 2023; Shenoy et al., 2023; Thomas & Jain, 2023)](https://paperpile.com/c/TUrRUm/rsU4C+wVtwg+LKhDI). Therefore, there is an urgent need to develop new methods with high sensitivity, specificity, and fewer risks [(Fang et al., 2012)](https://paperpile.com/c/TUrRUm/zQTK) . Nanotechnology has recently been applied in a number of disciplines, such as chemistry and medicine. In nanotechnology, Quantum Dots (QDs)—often referred to as "artificial atoms"—are a popular issue. In 1981, Alexey Ekimov made the initial discovery of QDs in a glass matrix. Louis Brus created the first colloidal semiconductor nanocrystallite solution four years later. In 1998, Mark Arthur Reed first used the term "quantum dots" [(Mughal et al., 2019)](https://paperpile.com/c/TUrRUm/lOCF). Because of QDs' exceptional optical and electronic characteristics, including their high fluorescence intensity, robust resistance to photo-bleaching, size-tunable light emission, and multiple fluorescent colors emission under single-source excitation, numerous researchers started assessing the potential uses of QDs, particularly in the diagnostics field [(Doshi et al., 2023; Lampl et al., 2023; Pandiyan et al., 2023)](https://paperpile.com/c/TUrRUm/iTzsF+ZUwFC+2Zyfr). Because of these characteristics, they are superior to traditional fluorophores such fluorescent proteins and chemical dyes [(Gil et al., 2021)](https://paperpile.com/c/TUrRUm/EHHy). Moreover, QDs are excitable by a single wavelength and have broad absorption profiles that enable the simultaneous excitation of an infinite number of distinct hues.Also, during the synthesis process, the size and shape allow for continual tuning and exact control of the emission wavelengths [(Liang et al., 2021)](https://paperpile.com/c/TUrRUm/94eQ). Multiple molecular targets are being analyzed at once using such multicolor QD-based probes. This feature reduces the number of tissue slices that need to be cut for biomarker analysis and is highly advantageous when using confocal microscopy to perform nanometer-resolution co-localization of multicolor QDs [(Moniruzzaman et al., 2020)](https://paperpile.com/c/TUrRUm/ZVpR).Due to their ideal surface chemistry, QDs can form flexible probes for use in biomedical applications by binding to targets like peptides, antibodies, or small molecules [(Janani et al., 2021; Kachhara et al., 2021; Subramanian et al., 2023)](https://paperpile.com/c/TUrRUm/nicJj+DjXsN+9ltyu).Bioimaging and cancer diagnosis are two examples of these applications. Furthermore, long-term resistance to bleaching makes it possible to obtain crisp, well-contrast images, which are particularly helpful for 3D optical sectioning of tumors and their surroundings, where bleaching of fluorophores affects the accuracy of 3D structure reconstruction [(Venkatachalam, 2024)](https://paperpile.com/c/TUrRUm/cAQE). Additionally, their deep penetration, wide and continuous excitation spectrum, great brightness, and long-term stability make them perfect for bio-imaging and in vivo cancer diagnostics [(Mohammadi et al., 2025)](https://paperpile.com/c/TUrRUm/wdUh).

# MATERIALS & METHODS

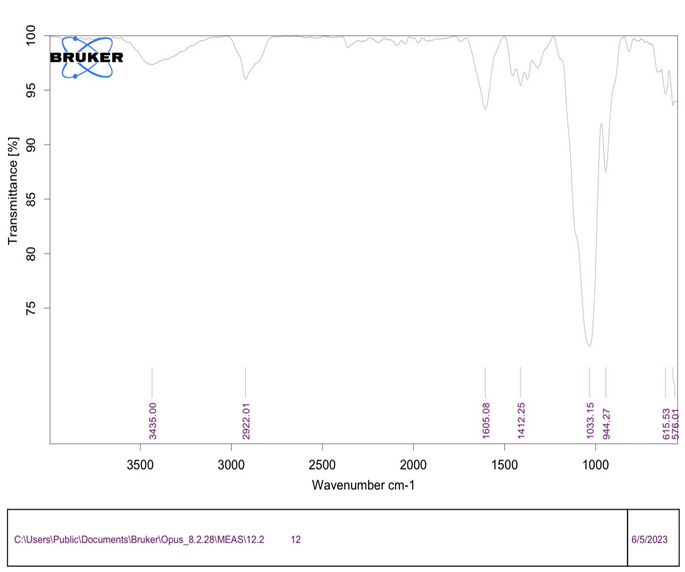
## Synthesis of GQD

To synthesize GQDs, an oxidative cutting method was chosen. 0.15 g of Graphene Oxide (GO) powder was added to the mixture of 30 mL Sulphuric acid and 10 mL Nitric acid, and it was constantly agitated for one hour. After that, the mixture was ultrasonically agitated for two hours while the beaker was fully covered. It was then heated for three to four hours at 100 °C while being constantly stirred. There was a noticeable shift in color from black to brown and finally to yellow. After setting the resultant solution aside for 24 hours to eliminate any remaining heat, 40 milliliters of distilled water were added. 0.1 M NaOH or HCl was added to the solution for optimal pH ( ̴ 7) [(Mehata & Biswas, 2021)](https://paperpile.com/c/TUrRUm/Bpdc).

## Characterization of GQDs

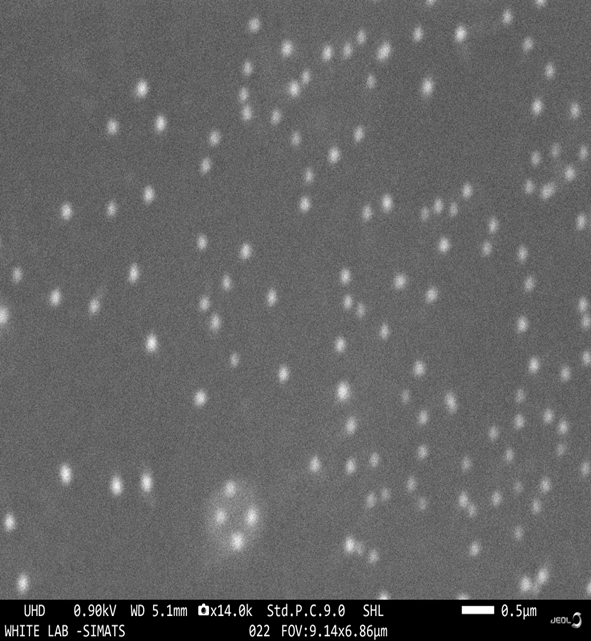
The morphological analysis of synthesized GQDs was done using Scanning Electron Microscopy (SEM). The Fourier Transform Infrared (FT-IR) spectroscopy analysis was performed to study the presence of functional groups with scanning wavelength ranges from 1000 to 3500 cm-1. The GQD synthesized exhibited green fluorescence under UV light. FTIR provides insights into the functional groups and oxidation state of GQDs, while SEM reveals the morphology, size, and aggregation behavior. The hormone-dependent breast cancer cell line MCF-7 [(Choppadandi et al., 2021; Mehata & Biswas, 2021)](https://paperpile.com/c/TUrRUm/Bpdc+ucV1) was used to perform fluorescent cell imaging of GQDs under Confocal Fluorescence Microscopy.

# Results



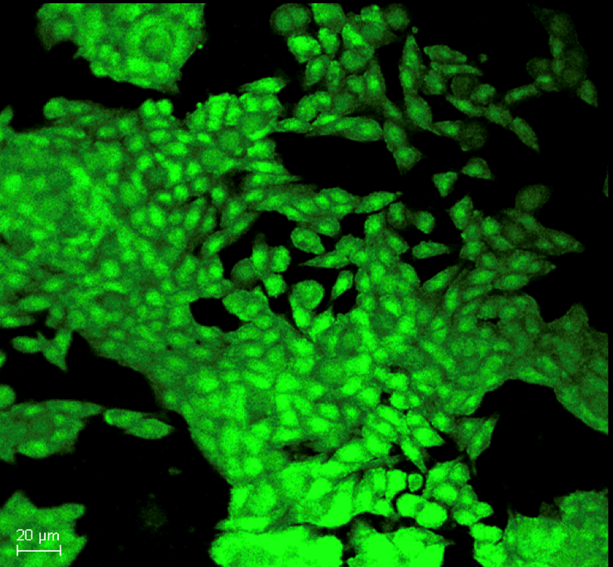
**Figure 1:** FT-IR spectrum for quantum dots

FTIR results confirm the presence of OH, COO, CO3, NH groups in the prepared quantum dots. SEM analysis shows that the prepared QD are 5-7nm in size, has spherical morphology, uniform distribution and no agglomeration. Therefore from the results it is confirmed that the size of the QD is in nm. The fluorescence image confirms that the cells can uptake the QD and emit fluorescence which is green in color. This can be used for bioimaging application.



**Figure 2:** SEM image of quantum dots

The image shows bright spots scattered across a dark background, which likely represent individual graphene quantum dots. The distribution appears relatively uniform, indicating a well-dispersed sample [(Gandhi et al., 2021; Katyal et al., 2023; Priyadharshini et al., 2023)](https://paperpile.com/c/TUrRUm/Qyofr+TsONk+H5EbS). The scale bar at the bottom right (0.5 µm) suggests that the observed particles are in the nanometer range. Given the magnification (14,000X), the GQDs seem to be in the expected size range of a few nanometers to tens of nanometers(Saadh et al., 2024). The high contrast of the image indicates a robust interaction with the electron beam, characteristic of the GQDs' ability for improved photoluminescence and better optical properties [(Chokkattu et al., 2023; Dharman et al., 2023; Govindaraj & Shanmugam, 2023)](https://paperpile.com/c/TUrRUm/OFJjv+P4TCD+7YNHQ). uch features render GQDs as ideal candidates for high-resolution, biocompatible imaging probes for early detection and diagnosis of cancer by targeted fluorescence imaging and real-time monitoring of tumor growth (Almatrafi et al., 2024). Additional characterization including fluorescence emission experiments and cytotoxicity tests, will be necessary to ascertain their appropriateness for in vivo usages [(Rajeshkumar & Lakshmi, 2021; Sivakumar et al., 2021)](https://paperpile.com/c/TUrRUm/elDUw+wniAF).



**Figure 3:** Cells were treated with quantum dots observed using confocal Fluorescence microscope

The confocal fluorescence microscopy image of QD-treated cells exhibits intense green fluorescence. This indicates successful cell uptake of the QDs, which demonstrates their bioimaging capability. The distribution of fluorescence reveals that the QDs are localized in the cytoplasmic region mainly, with partial accumulation in the perinuclear region. The homogeneous and strong fluorescence verifies the stability and proper dispersion of the QDs within the cellular structures. This finding indicates the potential of these QDs for cancer bioimaging applications, as they can visualize cellular structures at high contrast. Further analysis, such as colocalization with organelle dyes, could confirm the intracellular localization at the single-site level. It would also be important to determine their biocompatibility and cytotoxicity before using them for live-cell imaging and targeted cancer diagnostics.

# Discussion

Carbon-based nanoscale particles known as graphene quantum dots (GQDs) have outstanding physical, chemical and biological characteristics that enable them to prosper in a variety of nanomedicine applications. The distinct electronic structure of GQDs allows for the absorption of incident radiation for use in photothermal and photodynamic therapy, which are cancer-killing methods, as well as strong and adjustable photoluminescence for application in fluorescence bioimaging and biosensing [(Chung et al., 2021)](https://paperpile.com/c/TUrRUm/RL3d).GQDs are a viable option for bioimaging because of their distinctive physical and chemical characteristics, which include small size, chemical inertness, excellent photoluminescence stability, minimal cytotoxicity, and strong biocompatibility [(Chung et al., 2021; Handayani et al., 2023)](https://paperpile.com/c/TUrRUm/RL3d+Uwum).

# Conclusion

The prepared GQDs are in nanosize and are able to absorb and emit fluorescence color which is essential for tracking and bio imaging application and are cost effective. Therefore, this could be a preferred biomedical application after further evaluation. Our study concluded that Bio imaging property using prepared QDs and Fluorescent quantum dots can be used for long-term and multicolor imaging of cellular and molecular interactions. For labelling specific cellular proteins, QDs must be conjugated to biomolecules that provide binding specificity without any damage to the properties of the molecules. Future studies will include the development of QDs with direct bio imaging to tissues. These new imaging agents will also be useful for creating precise biosensors, drug delivery systems, long-term multicolor cell imaging, and other biomedical research.

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