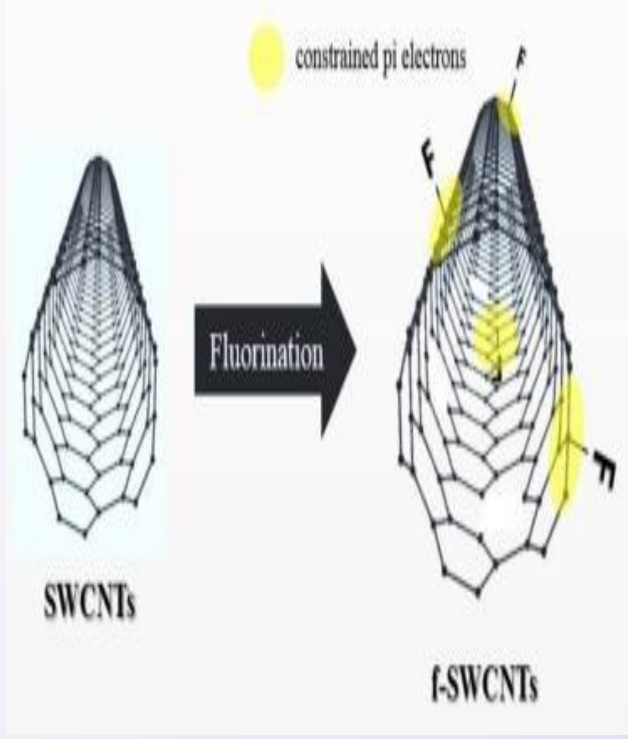
SELECTIVE REMOVAL OF DYES from Water Using Quality-Downgraded Fluorinated Single-walled Carbon Nanotubes

Promise Uzoamaka Otuokere, Victoria Robinson, Mohammed Tarequl-Islam and Dr. Yunxiang Gao (Faculty Advisor)

Department of Chemistry, Prairie View A&M University, Prairie View, TX   Email: yugao@pvamu.edu

Background of Quality-Downgraded Fluorinated Single-walled Carbon Nanotubes

Quality Downgraded Fluorinated carbon nanotubes (QD-FSWNTs) have emerged as valuable materials in renewable energy applications due to their unique properties, offering superior performance in supercapacitors and energy storage systems. These nanotubes enhance specific capacitance, rate capability, and cycling stability compared to non-fluorinated variants. However, their production is both costly and energy-intensive, making their sustainable use essential. While efforts have focused on recycling metals like lithium and cobalt from spent batteries, the reuse of high-performance materials such as QD-FSWNTs remains underexplored. A promising solution is repurposing quality-downgraded fluorinated carbon nanotubes (QD-FSWNTs) from the battery industry for other applications. By reusing QD-FSWNTs in areas like environmental remediation, such as removing dyes from contaminated water, the industry can reduce waste and promote a circular economy. This approach presents a valuable opportunity to advance sustainable materials science while extending the lifecycle of high-performance energy storage materials, supporting broader efforts in sustainability within the renewable energy sector

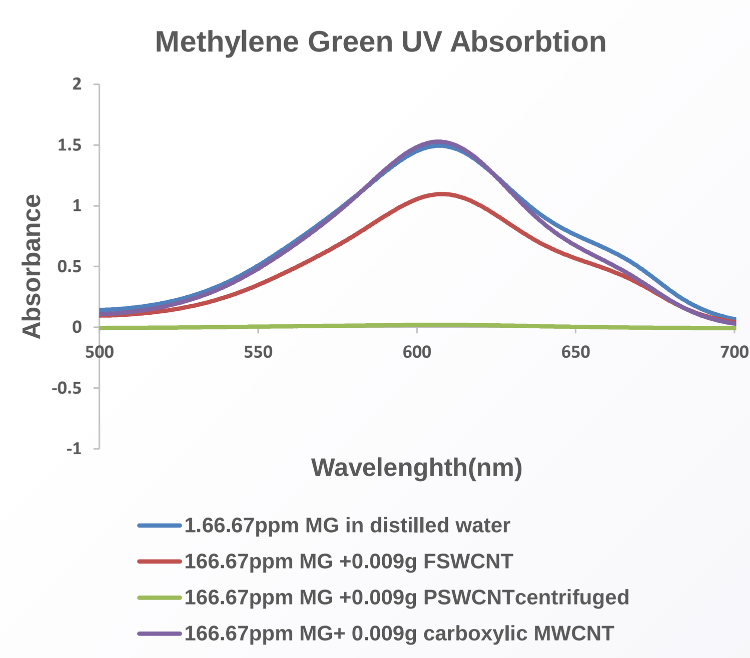


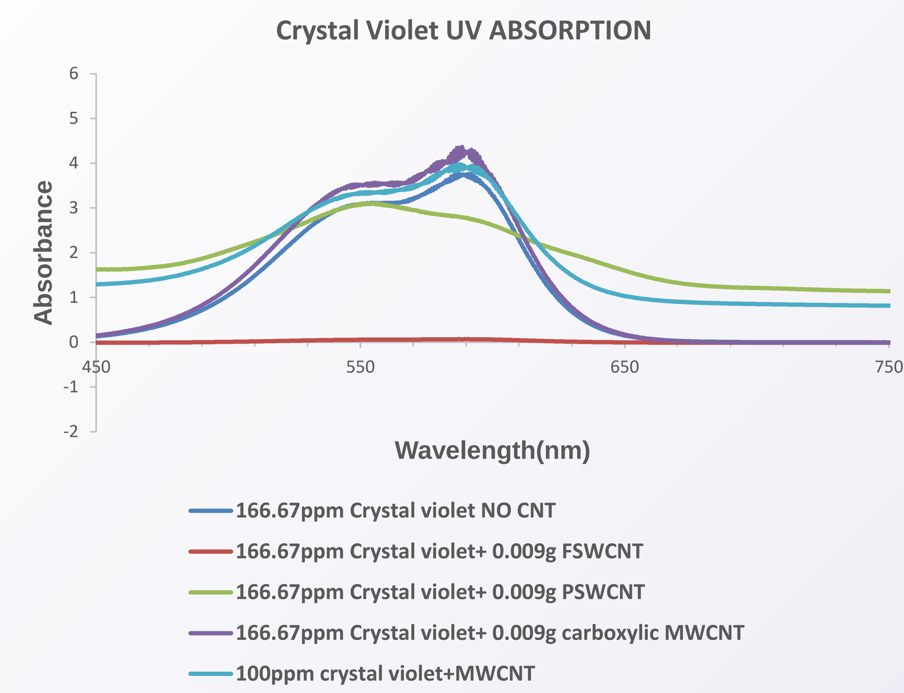
F. Chamssedine, K. Guérin, M. Dubois, E. Disa, E. Petit, Z. El Fawal, A. Hamwi
Fluorination of single-walled carbon nanotubes at low temperature: towards the reversible fluorine storage into carbon nanotubes
J. Fluor. Chem., 132 (12) (2011), pp. 1072-1078

Synthesizing Carbon Nanotubes in Solution

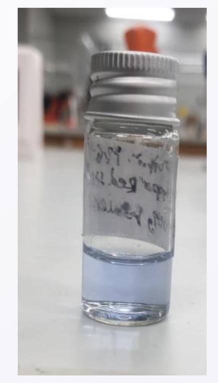
To prepare the QD-FSWNT/dye solution, a dye concentration of 166.67 ppm was first dispersed in 30 mL of deionized (D.I.) water. The solution underwent mild sonication for 5 minutes to ensure the even distribution of the dye molecules. Following this, 9 mg of quality downgraded-flourinated carbon nanotubes (QD-FSWNTs) were introduced into the dye solution. The resulting mixture was subjected to a more vigorous sonication process at 360 W for an additional 20 minutes, promoting uniform dispersion of the QD-FSWNTs within the dye matrix. To finalize the preparation, the composite solution was filtered using a 0.2 µm membrane filter to remove any large aggregates or impurities, yielding a well-dispersed QD-FSWNT/dye composite suitable for subsequent analysis and application. This method ensures proper incorporation of QD-FSWNTs within the dye solution, optimizing both the dispersion and interaction between the components for enhanced material performance in the intended application.

Results: UV Carbon Nanotubes in Dye Solution



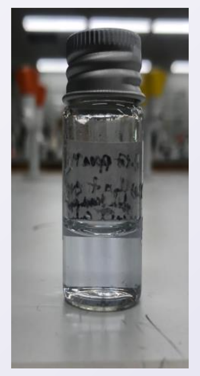


166.67ppm Methylene Green before dye absorption



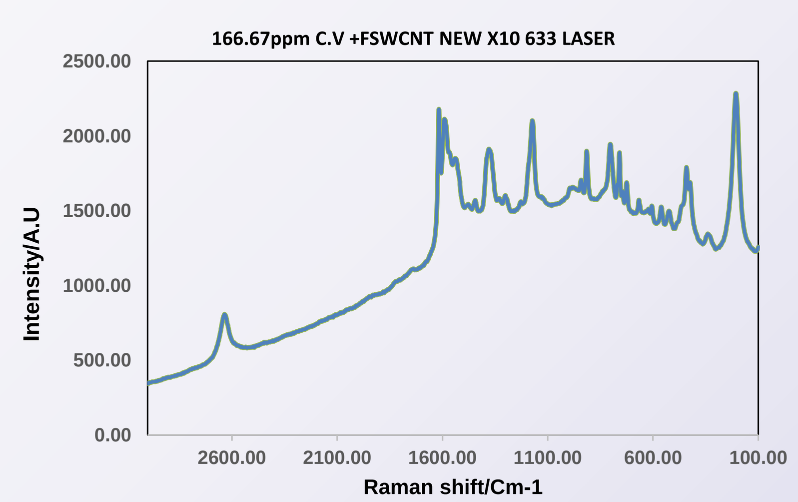
166.67ppm Methylene Green after dye absorption

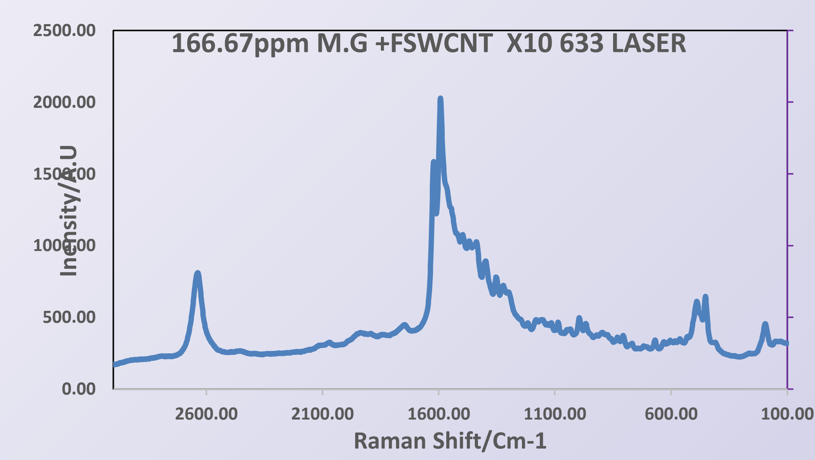
166.67ppm Crystal Violet before dye absorption



166.67ppm Crystal Violet after dye absorption

Raman Showing Q-DFSWCNTs with dye

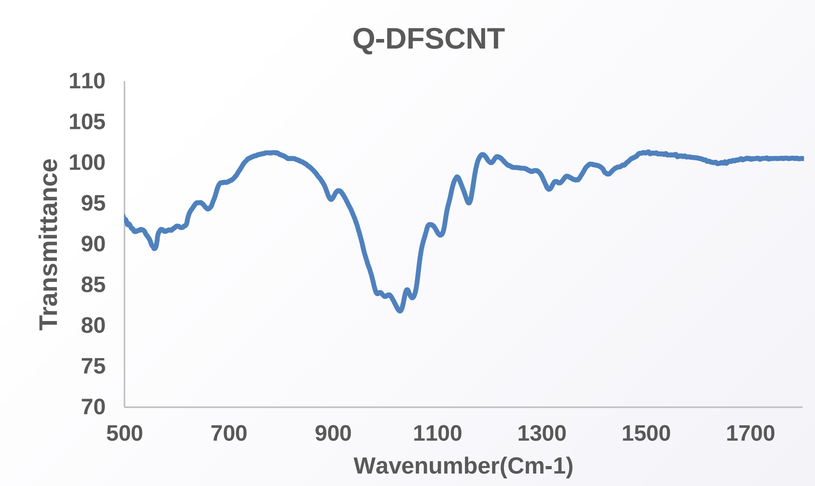


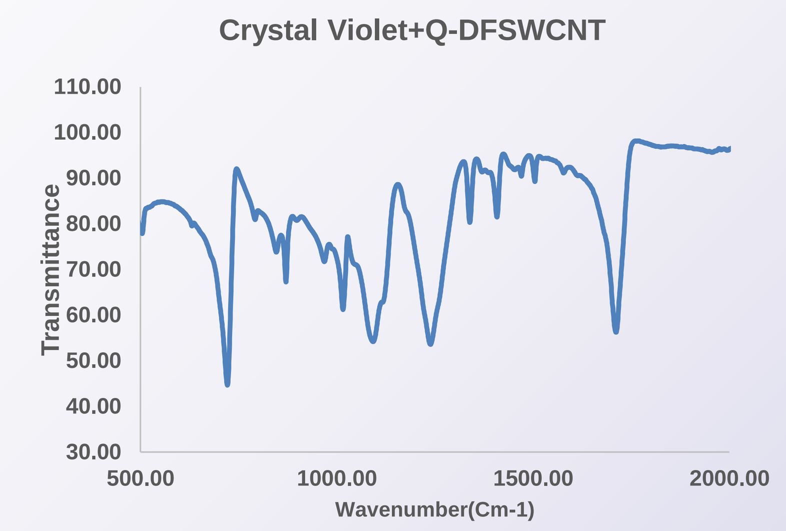


•**Crystal Violet Peaks (0-1000 cm⁻¹):** Prominent Raman peaks confirm the adsorption of crystal violet on QD-FSWNTs, with strong signals around 420, 445, 725, and 917 cm⁻¹. **D-band (~1350 cm⁻¹):** Increased intensity in the D-band suggests enhanced defects or interactions between crystal violet and the nanotubes due to adsorption. **G-band (~1580 cm⁻¹):** The G-band, characteristic of the graphitic structure of the nanotubes, may indicate electronic interactions or charge transfer between crystal violet and QD-FSWNTs. **Higher Wavenumber Region:** Overtones and vibrational combinations appear in the 2000-3000 cm⁻¹ range, with diminishing intensity typical for nanotube spectra.

Methylene Green Peaks (0-1000 cm⁻¹): Prominent Raman peaks confirm the adsorption of methylene green on QD-FSWNTs, with strong signals around 420, 445, 725, and 917 cm⁻¹.
D-band (~1350 cm⁻¹): The increased intensity in the D-band suggests enhanced defects or interactions between methylene green and the nanotubes due to adsorption.
G-band (~1580 cm⁻¹): The G-band, characteristic of the graphitic structure of the nanotubes, may indicate possible electronic interactions or charge transfer between methylene green and –D-FSWNTs.
Higher Wavenumber Region: Overtones and vibrational combinations appear in the 2000-3000 cm⁻¹ range, with diminishing intensity typical of nanotube spectra.

FT-IR Showing QD-FSWNTs with Dye





Before Adsorption: The FT-IR spectrum of QD-FSWNTs displayed a strong absorption band at 1220 cm⁻¹, representing C–F stretching vibrations, confirming the fluorination on the nanotube surface.
After Adsorption: Post adsorption, the intensity of the C–F peak was slightly reduced, indicating interaction between the fluorinated surface and the dye. New peaks appeared around 1400 cm⁻¹ and 1500 cm⁻¹, corresponding to the aromatic C=C stretching vibrations from crystal violet. These spectral changes confirm successful adsorption, suggesting that both physical adsorption (π-π stacking) and chemical interactions (like hydrogen bonding) contribute to the binding of crystal violet to QD-FSWCNTs. This demonstrates the potential of QD-FSWNTs as effective adsorbents for dye removal in water treatment.

Conclusion

This study confirms that carbon nanotubes, particularly quality-downgraded fluorinated single-walled carbon nanotubes (QD-FSWCNTs), can serve as highly effective materials for the selective adsorption of dyes from aqueous dye mixtures. Despite their downgraded quality, Q-D-FSWCNTs retain essential properties such as a high surface area, tunable surface chemistry, and functionalization with fluorine, which enhances their interaction with dye molecules in solution. These unique characteristics allow QD-FSWCNTs to selectively capture and remove dye contaminants, addressing one of the significant challenges in wastewater treatment.

The study highlights the potential of QD-FSWCNTs in providing an efficient and cost-effective solution for mitigating dye pollution, a prevalent issue in industrial effluents. The selective adsorption capability of these fluorinated nanotubes offers an environmentally friendly approach to. This method, with its potential for scalability, paves the way for the development of advanced waste water purification by effectively removing harmful dyes, thus contributing to cleaner water bodies waste treatment technologies that are not only efficient but also sustainable.

Acknowledgement

❑ We thank the United States Department Of Agriculture (USDA) for Sponsoring this project

❑ I personally appreciate Dr. Gao for his supervision and guidance all through this research