Synthesis of Carbon Quantum Dots as a Fluorescent Probe for Trace Detection of 2,4-DNPH

Yuh-Lang Lee [a] * *and Divya Dagar* [a]

[a] * and [a] *Department of Chemical Engineering, National Cheng Kung University, Tainan, Taiwan*

yllee@mail.ncku.edu.tw

Nitroaromatic compounds (NACs) are persistent environmental pollutants that pose serious ecological and health risks. Therefore, rapid detection methods with high sensitivity and selectivity toward NACs are urgently required. In this work, a carbon quantum dot (CQD) probe was prepared via a simple, green hydrothermal method using *o-aminophenol* and *tartaric acid* as low-cost precursors. The prepared CQDs were systematically characterized and then employed as fluorescent probes for targeted detection of NACs; furthermore, the underlying sensing mechanisms were investigated. The results show that the as-prepared CQDs exhibit strong blue fluorescence with a quantum yield of 74.3%. The emission wavelength is centered at 420 nm and is independent of excitation wavelength. The characterization using UV-vis, FTIR, and XPS reveals that there are abundant oxygen- and nitrogen-based functional groups (C=O, C–O, C=C, O–H, N–H) on the CQDs, which also indicates the nitrogen-doped nature of the CQDs. Upon applications of the CQDs for NACs detection, several compounds, including 2,4-dinitrophenylhydrazine (2,4-DNPH), picric acid, 4-nitrobenzyl alcohol, 1,2-/1,3-/1,4-dinitrobenzene, and 2,4-dinitrotoluene, were selected as target analytes. The experiments demonstrate that only 2,4-DNPH induces a pronounced fluorescence-quenching response, indicating its high selectivity for 2,4-DNPH. Mechanistic investigations indicate that the fluorescence quenching arises mainly from the inner filter effect (IFE), along with the dynamic quenching process. For quantitative analysis, the CQD probe achieves a remarkable quenching efficiency of 94% and a low detection limit of 15 nM. Notably, the CQDs exhibit reversible photoluminescence, underscoring their stability, reusability, and suitability for continuous monitoring applications. Overall, these CQDs provide a high-performance, low-cost, and eco-friendly sensing platform for reliable 2,4-DNPH detection, offering significant promise for real-world environmental and analytical applications.

Keywords:
Carbon quantum dots; Nitrogen-doped CQDs; Fluorescent sensing; 2,4-DNPH; Inner filter effect; Environmental monitoring