Continuous Hydrothermal Flow Synthesis of Blue-Luminescent Carbon Quantum Dots as Nanosensors for Chromium (VI) Detection

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Motivation

Properties:

- High photostability
- Good biocompatibility
- Excellent optical
- Eco-friendly

Interest inspired by carbon quantum dots properties and applications.

Applications:

- Sensors
- Bio-imaging & bio-tagging
- Optoelectronics
- Photocatalysis

Herein, we present, a facile, green, one-step Continuous Hydrothermal Flow Synthesis (CHFS) route using citric acid as a carbon source and ammonia as nitrogen source for the large-scale production of blue-luminescent nitrogen doped carbon quantum dots (NCQD) nanosensors.

Experimental Procedure

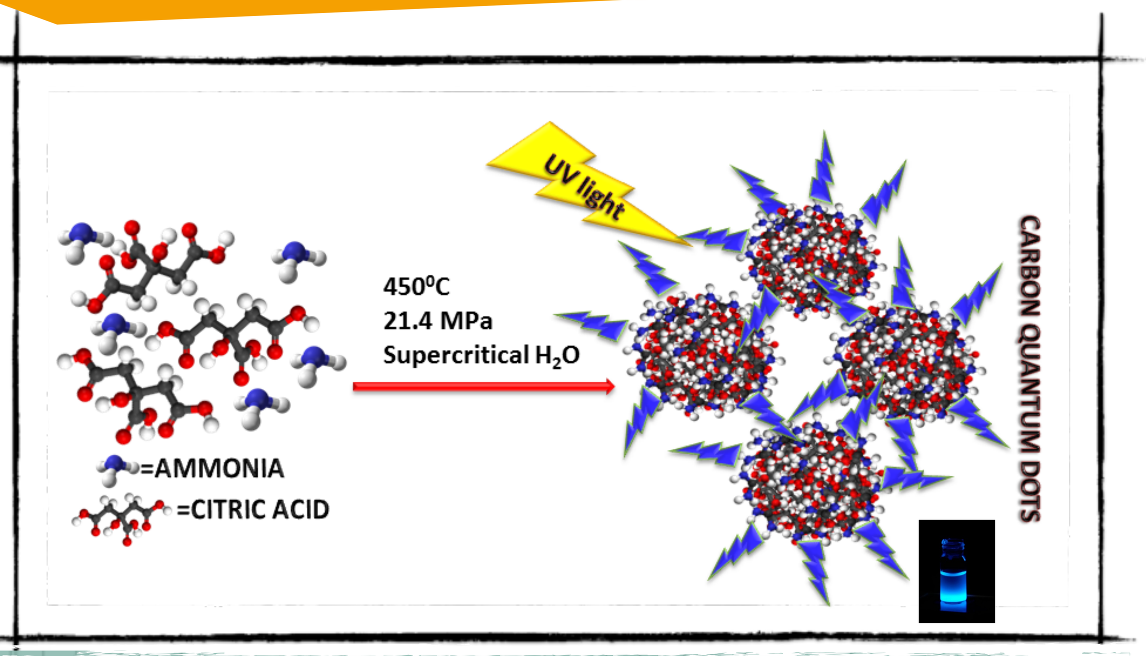

Fig. 1 Schematic for the synthesis of nitrogen doped carbon quantum dots via CHFS using citric acid as the carbon source in the presence of ammonia. Reaction conditions : T = 450 °C and P = 24.8 MPa

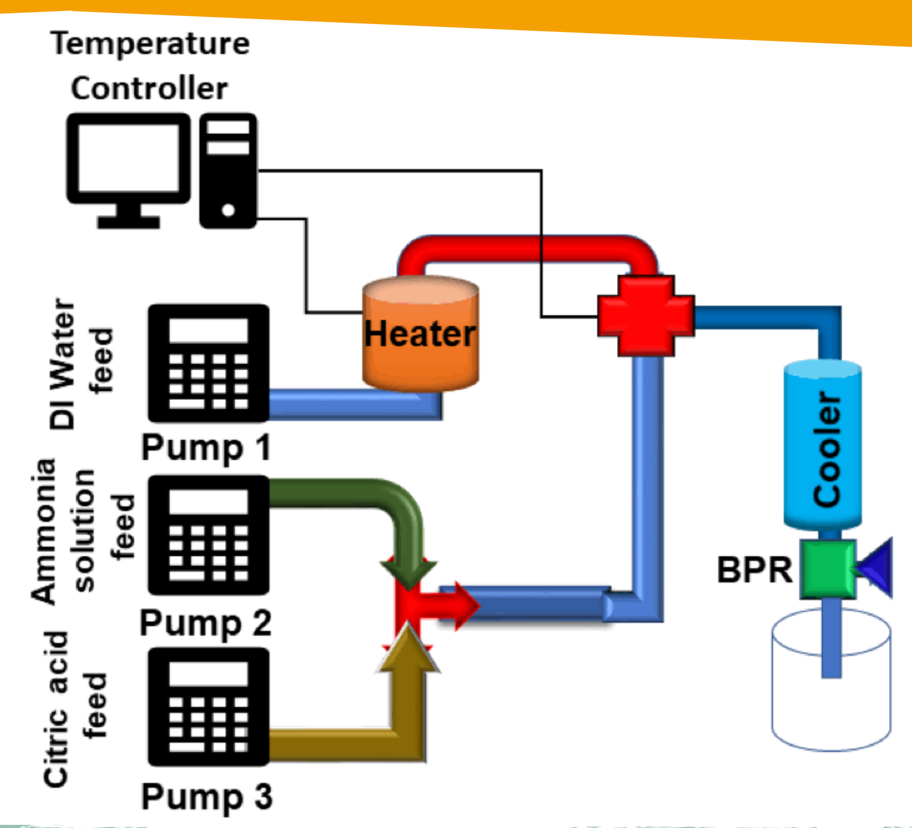

Fig. 2 Schematic of CHFS reactor used for the synthesis of NCQD [BPR=back pressure regulator].

CHFS Advantages

- ✓ Tunable
- ✓ Rapid
- ✓ Single step
- ✓ Green
- ✓ Scalable
- ✓ Nanosized materials
- ✓ High-surface area

C H F S

Research Findings

Optical Properties

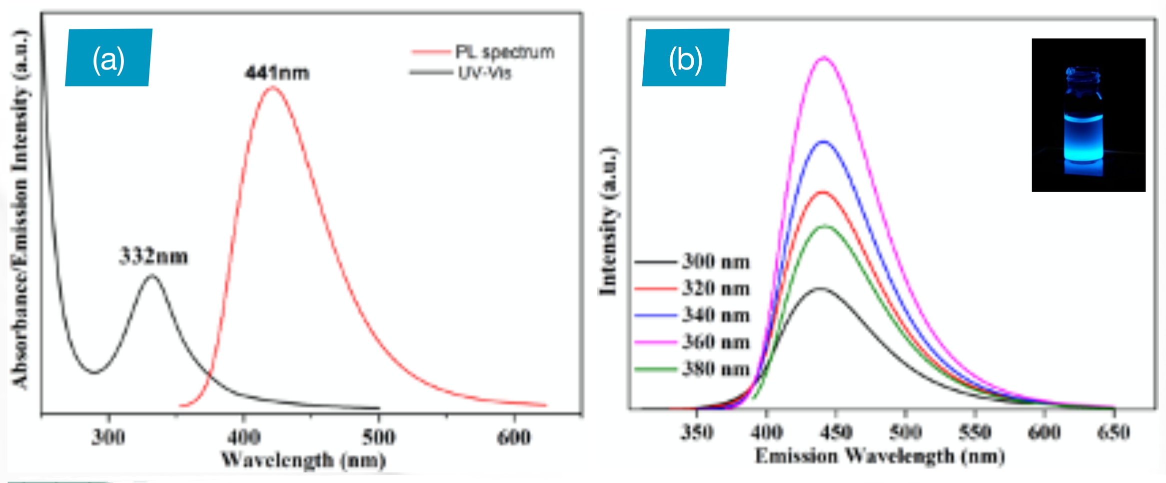

Fig. 3 (a) UV-Vis absorption spectrum (black curve) and photoluminescence (PL) spectrum (red curve) of NCQD at 360 nm excitation wavelength. (b) NCQDs excitation at wavelengths 320–380 nm. Inset: NCQD solution under UV-light (360 nm).

CHFS synthesised NCQD uniquely exhibits the following:

- excitation independence
- with a narrow FWHM (~78 nm)
- remoteness of the fluorescence emission (441 nm) from the UV excitation range (300–380 nm) (that usefully avoids auto-luminescence).
- Each of which are desirable features for sensing Cr(VI), a severe and highly toxic environmental pollutant.

Electron Microscopy Images

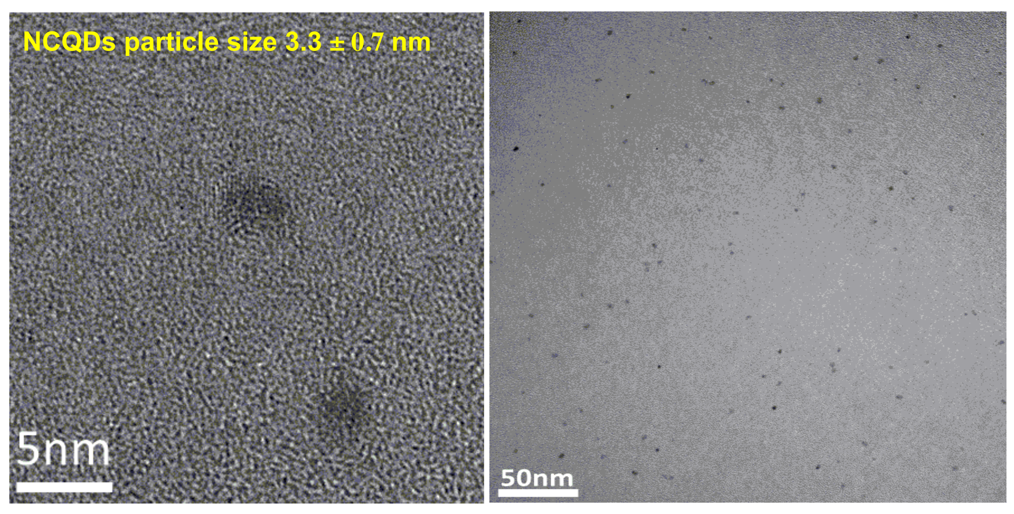

Fig. 6 High Resolution Transmission Electron Microscopy (HRTEM) images of NCQDs.

NCQDs exhibit graphitic core arrangement with lattice spacing = 0.22 nm.

Surface Chemistry

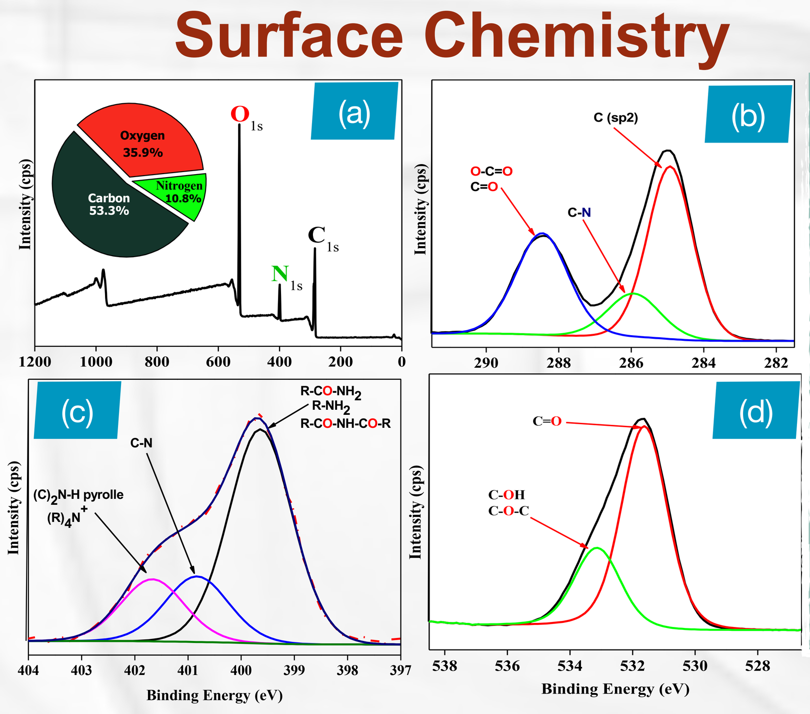

Fig. 4 XPS survey scans of NCQD: (a) survey spectrum showing C(1s), N(1s) and O(1s) core levels, (b) – (d) fitted high resolution spectra of C(1s), N(1s) and O(1s) regions, respectively.

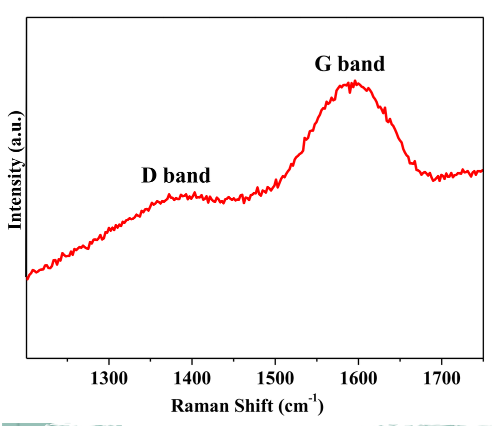

Fig. 5 Raman spectrum I_D/I_G ~0.76 typical of graphene oxide.

Chemosensing Properties: Chromium (VI) Detection

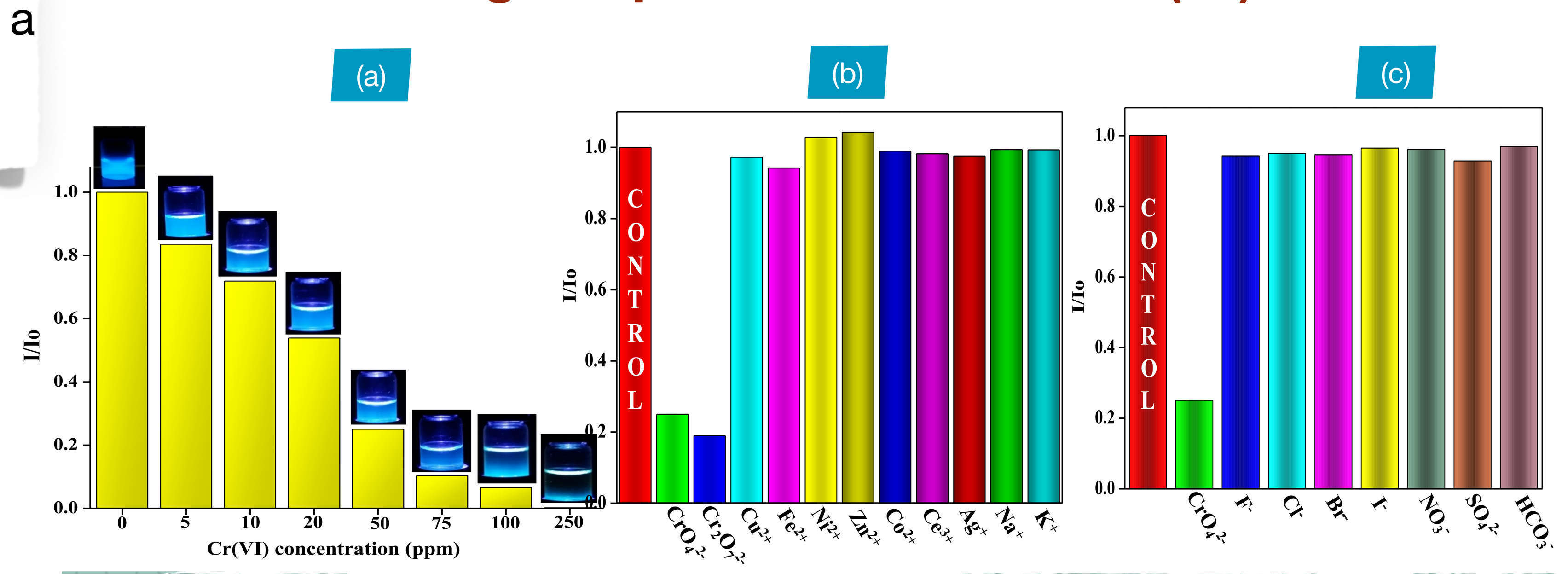

Fig. 7 (a) Cr (VI) sensing of NCQD via fluorescence spectroscopy showing I/I_0 versus the Cr (VI) concentrations (b) and (c) selectivity of the NCQD based sensor over other ions. **NCQD exhibited a high selectivity and sensitivity for the highly toxic and carcinogenic Cr(VI) ions.**

Conclusions

The nano-chemo-sensor delivers significant advantages including simplicity of manufacturing *via* a continuous, cleaner technology (using biomass precursor), high selectivity, sensitivity and fast response leading to potential applications in environmental industry as well photovoltaics, bio-tagging, bio-sensing and beyond.

References

*I. A. Baragau, N. P. Power, D. J. Morgan, T. Heil, R. Lobo, C. S. Roberts, M. Titirici, S. Dunn, and S. Kellici, *J. Mater. Chem. A*, 2020, 8, 3270-3279.

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