Analytical Methods

ROYAL SOCIETY OF CHEMISTRY

PAPER

View Article Online
View Journal

Cite this: DOI: 10.1039/d5ay00180c

Sustainable synthesis of tunable emissive sulphur-doped CDs: a synergistic approach for metal ion sensing and antimicrobial applications†

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Over the last two decades, materials from the carbon family attracting increasing attention, carbon dots (CDs) have been synthesized *via* naturally or synthetically derived precursors, which are mostly limited to single fluorescence emission. Tunable emissive CDs have great importance in multiple applications. Therefore, in the present study, multi-emissive sulphur doped carbon dots (S-CDs) were synthesized using the leaves of *Nyctanthes arbor tristis*, commonly known as night-flowering jasmine (NFJ), as a precursor, by a simple acid carbonization method. Interestingly, different synthesis parameters were employed for tuning the optical properties of the S-CDs, of which the synthesis time played a vital role for tuning the fluorescence emission of the S-CDs. Bright blue (BB-CDs), yellow (Y-CDs), and cyan blue (CB-CDs) fluorescence emissions with reaction times of 1, 6, and 8 h were observed. These three CDs have emission ranges of 391, 661 and 408 nm with corresponding quantum yields of 38.96, 6.59, and 25.06%, respectively. The structural and functional morphology of all three S-CDs were analyzed using various characterization techniques. S-CDs showed both excitation dependent (BB-CDs, CB-CDs) and independent (Y-CDs) emission behavior with good photo and pH stability. Furthermore, all the S-CDs were utilized as fluorescent probes for the detection of metal ions, and BB-CDs selectively detect Fe^{3+}, Y-CDs detect $Cr^{6+}$and Mn^{7+}, and CB-CDs detect Cr^{6+} and Fe^{3+}ions with corresponding LODs of 0.1, 1.66, 0.96, 2.18 and 1.56 μg mL^{-1}, respectively. The static quenching mechanism was observed for BB-CDs and CB-CDs, while in the case of YB-CDs, Cr^{6+} shows the dynamic quenching mechanism. In addition, the antibacterial behavior of all three S-CDs was analyzed against *S. aureus* and *K. pneumoniae* (Gram positive and Gram negative) bacteria. These S-CDs show good potential in metal ion sensing in environmental water samples and biological activity.

Received 3rd February 2025
Accepted 6th April 2025

DOI: 10.1039/d5ay00180c

rsc.li/methods

1 Introduction

Tunable emissive carbon dots (CDs) have attracted much attention owing to their excellent properties, such as high water solubility, excellent biocompatibility, low toxicity, facile synthesis and ease of surface functionalization.[1–4] CDs have been applied for various applications such as fluorescence sensing, bio-imaging, anti-counterfeiting, drug delivery, photothermal therapy (PTT), LEDs, bone tissue engineering and many more.[5–8] Therefore, CDs have generated broad interdisciplinary research interest in materials science, biology, medicines and core chemistry.[7,9,10] Owing to their outstanding advantages, CDs have been regarded as a new generation of fluorescent materials. The tunable fluorescence behavior of CDs is one of their outstanding properties. Over previous years, many reports have demonstrated the multicolor photoluminescence (PL) behavior of CDs upon varying their physical and chemical parameters. Iyer *et al.* have synthesized CDs with emission in the blue and green regions *via* a hydrothermal and microwave method using orange peel biomass as a carbon precursor.[11] In another report, Wang *et al.* experimented on spinach with water, acetone and ethanol as a solvent to achieve blue, red and greyish white luminescent CDs.[12] Similarly, researchers have achieved multicolor CDs by optimizing different parameters, such as the selection of the precursor, synthesis method, heteroatom/metal ion doping and solvents.[13–15] However, it is still a challenge to obtain multicolor CDs in one synthesis method with one precursor.

The synthesis of CDs can be achieved by both top-down and bottom-up approaches. Several bottom-up methods such as hydrothermal, microwave irradiation, thermal decomposition

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† Electronic supplementary information (ESI) available. See DOI: https://doi.org/10.1039/d5ay00180c