Sustainable Nanomaterials as Drivers for Application Development in Sensing and Clean Energy Applications

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Abstract

In recent years, carbon dots, a relatively new class of nanomaterials, have come to light.[1] Carbon dots are carbon, oxygen, nitrogen and hydrogen containing materials with the first two elements typically accounting for ~80% of their elemental composition. Moreover, they are typically water dispersible and can be prepared from an abundant number of inexpensive sources including small molecules such as citric acid, amino acids and sugars. While they are small in size (typically 1-10 nm), they can offer a high quantum yield of emission, a process that is controlled through passivation of the surface with an organic reagent. Of particular interest are their optical properties, which can be tailored via careful selection of the starting precursors and the desired synthesis route resulting in the ability to generate fluorescence from the blue to the near infrared regions of the spectrum (Fig. 1).

Their versatile optical properties and the development of dual fluorescent systems allow us to develop ratiometric optical based sensing probes that can be used in biological systems focusing on temperature and pH sensing of physiological events in live biological model systems.[2,3] We also exploit the optical properties for environmental sensing applications focusing on heavy metals and emerging contaminants.

These carbon dots bare numerous chemical functionalities that we also exploit for the development of novel heterogeneous catalysts in green energy applications focusing on the transformation of refined and waste oils to biofuels such as biodiesel.[4] We report biodiesel conversions of >97% at 150 ºC and 1 wt% catalyst loading for our first-generation catalyst. Moreover, we demonstrate the stability and reusability of the nanocatalyst with sustained catalytic efficiency for at least five reaction cycles. Our second-generation catalysts allows for a significant reduction of the reaction temperature to 90 ºC, operate at ambient pressure without a significant increase to the catalyst loading.

Fig. 1. The fluorescence of the carbon dots can be tuned from the blue to the far red/near-infrared regions of the spectrum.

Recent Publications

1. de Medeiros, T. V.; Manioudakis, J.; Noun, F.; Macairan, J.-R.; Victoria, F.; Naccache, R. *J. Mater. Chem. C.* 7 (2019) 7175-7195.
2. Macairan J. R., Jaunky D. B., Piekny A. and Naccache R. *Nanoscale Adv.* 1 (2019) 105-113.
3. Macairan J. R., Zhang I., Clermont-Paquette A., Naccache R. and Maysinger D. *Part Part Syst Charact.* 7 (2019) 1900430.
4. de Medeiros T., Macina A. and Naccache R. *Nano Energy* 78 (2020) 105306.

Biography

Rafik Naccache obtained his PhD (2012) in Chemistry at Concordia University in Quebec, Canada working on lanthanide-doped upconverting nanoparticles for imaging applications. There, he was the recipient of the Distinguished Doctoral Dissertation Prize and the Governor General Gold Medal in the area of Technology, Industry, and the Environment. He subsequently carried out his NSERC postdoctoral training in nanobiophotonics at l'Institut National de la Recherche Scientifique developing Terahertz sensing applications in nanobiophotonics. In December 2015, he accepted a tenure track faculty position as a strategic hire in the Department of Chemistry and Biochemistry at Concordia University. He is currently an Associate Professor, the Director of the Centre for NanoScience Research and a University Research Chair. His group's research focuses on the study of the fundamental properties of fluorescent carbon nanomaterials and hybrid nanosystems for the development of sensing, imaging and catalysis applications. He has published over 60 manuscripts and has an *h*-index of 33 with nearly 6000 citations (Scopus).

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