BIOGENIC SYNTHESIS OF NANOSTRUCTURES FOR SENSING, OPTOELECTRONICS, AND THERAPEUTICS

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Doctor of Philosophy

By

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7 Conclusion and Future Scope

The goal of this study was to find novel uses for carbon nanostructures and to take use of their promising applications. Carbon nanomaterials are a form of nanomaterial consisting completely of carbon and including at least one dimension of nanoscale structural units. The exceptional qualities of these materials are demonstrated in their high aspect ratio, high stability, strong conductivity, low toxicity, and eco-friendliness. This thesis utilizes applications of carbon nanotubes and carbon quantum dots the most frequently. Several methods exist for synthesizing these carbon nanomaterials, which can be generally categorized as top-down and bottom-up. Specifically. This thesis outlines the most significant aspects of CQDs, as well as the methodologies used to synthesize them and their practical applications. In recent years, carbon quantum dots (CQDs), a new family of fluorescent carbon nanomaterials, have attracted a great deal of interest due to their outstanding photoluminescence capabilities, photo-stability, low toxicity, and affordable price. Due to their adjustable synthesis methods and carbon source alternatives, these CQDs are more usable. The majority of investigations have applied them to bio-imaging and sensing applications, notably in various tissue types. In addition, we describe how to fabricate optoelectronic devices such as OLEDs and OLETs using SWNTs and CQDs as the dopant and electron transport layer, respectively. The purpose of this report was to advance this research further.

In the third chapter, we successfully synthesized chlorophyll-rich carbon quantum dots (CQDs) by a one-step solvothermal method using *Plumeria* plant leaves as precursors. The resulting CQD160 exhibited exceptional stability under various conditions and showed high sensitivity and selectivity in the simultaneous fluorometric detection of Hg^{2+} and As^{3+} ions. The detection limits for Hg^{2+} and As^{3+} ions were reported to be 0.99 nM and 12.15 nM, respectively. The proposed probe showed promising results in real water systems and accurately estimated the Hg^{2+} ion concentration in Lake Powai. Fluorescence lifetime measurements revealed a combination of static and dynamic quenching mechanisms with a dynamic quenching constant (K_D) of 8.0 x $10^{\wedge 4}$ M^{-1} for Hg^{2+} ions. X-ray photoelectron spectroscopy provided insights into the interaction between metal ions and CQD160 and attributed the fluorescence changes to the binding with oxygen functional groups on the CQDs. The CQDs were found to be biocompatible and less cytotoxic, making them suitable for bioimaging applications in various cellular environments.

In the fourth chapter, we have synthesized gold nanoparticles (GNPs) using extracts of Tulsi and *Vinca*. The mixed of Tulsi and *Vinca* extract for GNPs caused significant breast cancer tumour regression in mice model. The physical properties were evaluated using UV-VIS, TEM, XRD, PL, FTIR, XPS, Zeta and DLS. The synthesized GNPs have different shapes and sizes with higher crystallinity. The GNPs also have emitting properties ranging from blue to green at 280 nm excitation and absorb light at 280 nm and 555±15 nm. FTIR and XPS confirmed the presence of the different functional groups on the surface of the synthesized GNPs. These decorated GNPs showed that the zeta potential values for T-gold, V-gold and T+V-gold were -28.5 mV, -22.3 mV and -32.4 mV, respectively. The broad peak in the dynamic light scattering (DLS) measurements typically arises from the presence of particles with a broad size spectrum or the coexistence of multiple populations of particles in the synthesized samples. The inhibitory effects of T-Gold, V-Gold, and T+V-Gold on the growth of 4T1 cells were evaluated using the MTT assay. The combination of T+V-Gold exhibited higher cytotoxicity compared to bare T-Gold and V-Gold, which resulted in the rapid release of anti-cancer metabolites that easily reached the cell organelles, thereby exhibiting cytotoxicity but also showed less cytotoxicity on NIH-3T3 cells. In liver, control and GNPs injected mice exhibited minimal lesions, corresponding to normal liver. T-Gold, V-Gold, and T+V-Gold showed negligible toxicity. T+V-Gold nano-formulation demonstrated the better regression of tumour when compared to the untreated 4T1-tumour bearing mice treated with PBS. To understand the underlying mechanism of the reduced tumour burden post treatment with T-Gold, V-Gold, and T+V-Gold NPs, the anti-oxidant pathways altered in cancer, such as glutathione family including GST, GSH, as well as SOD in serum. NO and LDH showed increased oxidative stress that was well supported by the mechanism of tumour suppression in tumour-bearing animals after the administration of the formulation. The concentration of SOD enzyme was lower in tumour tissues under different conditions compared to normal tissues, indicating a potential role of SOD in preventing oxidative damage in tumours. The T+V-Gold treatment may have a positive effect on the GSH and GST activity in tumour tissue samples, which could potentially help reduce the risk of cancer progression. In summary, the T-Gold, V-Gold, and T+V-Gold nanoparticles demonstrated good stability, DPPH scavenging potential, cytotoxicity, and in vivo anti-cancer potential in 4T1 tumour bearing mice.

In fifth chapter, we have synthesized fluorescent functionalized carbon quantum dots (CQDs) by a facile one step hydrothermal method at 160^0C for 8hrs using *Plumeria* plant leaves as precursor and Tb^{3+} ions as a surface passivator. The prepared doped CQDs exhibit excitation-dependent PL emission and obtained strong peaks at 493, 554, 590, and 624nm, respectively, is due to doping of Tb^{3+} ions. The CQDs and CQDs+Tb^{3+} ions have amorphous in nature with narrow size distribution and show high fluorescence quantum yield (26.33%, and 39.49%). The additive agent Tb^{3+} has engaged in reaction following the synthesis of the CQDs, as shown by the structural characterisation of the CQDs studies. We paired the single CQD phosphor film with the UV chip to create a WLED that emits cool white light with a CIE coordinate of (0.33, 0.34), a corresponding colour temperature of 4995K with CRI 84.2, and favourable Electroluminescence behaviour as a white-light converter for white LED.

In sixth chapter, boron nitrate nano-powder was used as a precursor to synthesize boron nitride quantum dots (BNQDs) through hydrothermal treatment. The synthesized BNQDs were characterized using X-ray diffraction (XRD), transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS) for their structural and elemental characterizations. The photophysical properties of the BNQDs were investigated using UV-Visible and photoluminescence (PL) spectroscopy. The sensing behaviour of the BNQDs towards the organic pollutant p-nitrophenol (PNP) was studied, and it was found that the BNQDs exhibited remarkable sensing behaviour with high selectivity towards PNP. The quenching constant Ka was found to be 2.325 M^{-1}, which is 14.49% of the collision quenching phenomena derived constant, indicating a defined way of quenching by the quencher towards the BNQDs PL intensity, as revealed by the modified Stern-Volmer (S-V) plot. Time-resolved PL (TRPL) studies suggest high selectivity ($K_q = 4.95 \times 10^5 M^{-1}s^{-1}$) and sensitivity of the BNQDs towards PNP sensing. The developed probe showed a very low limit of detection (LOD) of approximately 7.91pM in a linearity range from 100pM to 1μM. Overall, this study demonstrates a cost-effective and eco-friendly approach to synthesize BNQDs, which can be used as an efficient, reliable, and feasible sensing probe for the detection of PNP in real water systems and pesticides. This study contributes to the advancement of nanomaterial-based sensing technologies and provides insights for further development of sensing probes with high selectivity and sensitivity towards target analyt