Versatile Applications of Carbon Nanoparticles

Synopsis

Under the supervision of

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Chapter 1

Introduction and Literature Review

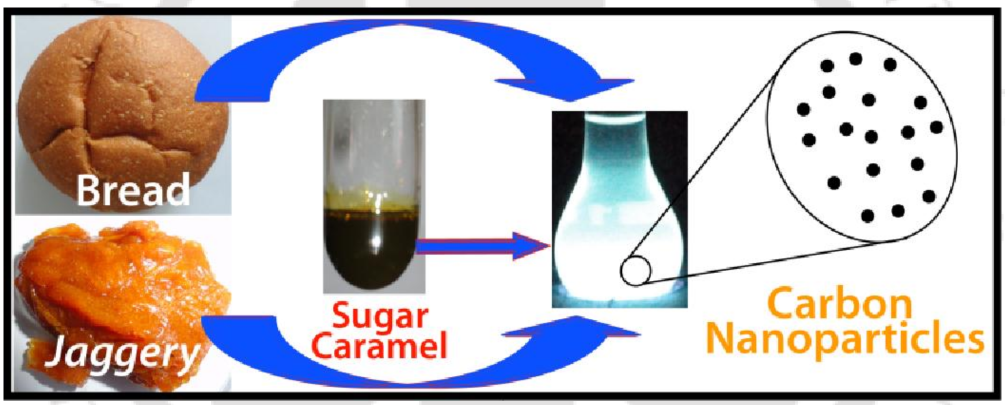
The first chapter of this thesis briefly reviews the emergence of carbon nanoparticles (CNPs) and their general importance. Then, advantages of CNP as an alternative promising candidate over fluorophore like quantum dot have been discussed. A brief account of various aspects, such as advancement of synthetic methods to achieve high quality luminescent CNP, composition, photolumience property, cytotoxicity has also been included. Finally, diverse applications of CNP in bioimaging, drug delivery, sensing, photocatalysis, electrocatalysis and optoelectronics have been briefly illustrated.

Chapter 2

Presence of Amorphous Carbon Nanoparticles in Food Caramels

In this chapter, we have demonstrated the findings of the presence of carbon nanoparticles (CNPs) in regular carbohydrate based food caramels, such as bread, *jaggery*, sugar caramel, corn flakes and biscuits. The CNPs have been found to be present in those samples, where the preparation of food mainly involves heating of the starting ingredients in absence of water, leading to formation of caramels. The

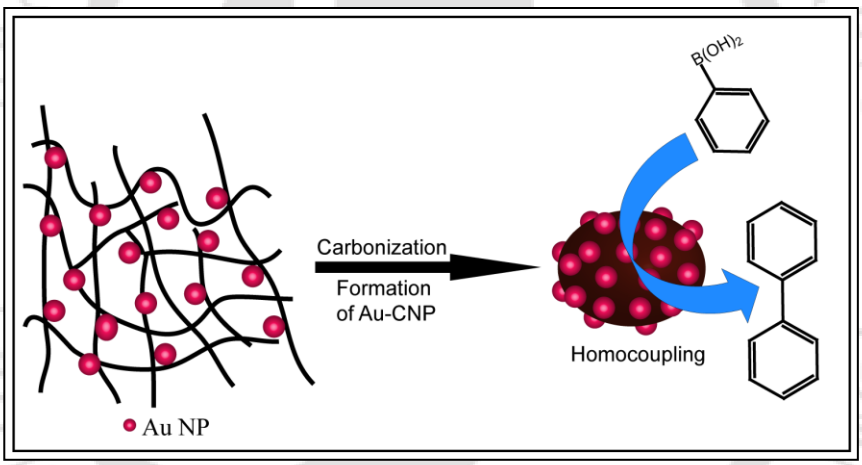
CNPs were amorphous in nature; the particles were spherical having sizes in the range of 4-30 nm, depending upon the source of extraction. The results also indicated that the particles formed at higher temperatures were smaller than those formed at lower temperatures. Excitation tunable photoluminescence was observed for all the samples with quantum yield (QY) 1.2, 0.55 and 0.63%, for CNPs from bread, *jaggery* and sugar caramels, respectively. The surface-characterization of CNPs, by ^{13}C NMR, indicated that the CNPs were coated with hydrophilic carbohydrate units. The present discovery suggests potential usefulness of CNPs for various biological applications, as the sources of extraction are regular food items, some of which have been consumed by humans for centuries, and thus they can be considered as safe.



Chapter-3

A Gold-Carbon Nanoparticle Composite as an Efficient Catalyst for Homocoupling Reaction

Chapter 3 delineates synthesis of CNP supported Au nanoparticle starting with Au nanoparticle-chitosan composite and its catalytic activity. The formation of smaller Au NPs embedded in the larger amorphous CNP composite was established using UV-visible spectroscopy, fluorescence spectroscopy, powder X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and transmission electron microscopy (TEM) studies. In the composite, the size of Au NPs was 4.9 ±1.4 nm, while that of CNPs varied from 50 nm to 350 nm. Also, the absence of any oxidation states other than Au(0) makes the Au-CNP composite ideal for studying the efficacy of Au NP catalyzed coupling reactions. The composite nanoparticles efficiently converted phehylboronic acid to biphenyl through homocoupling in tolune/water solvents. In addition, a plausible mechanism relying on the role of Au-NPs as the active site was proposed which rationalizes the solvent dependent reactivity and selectivity of the reaction. It was observed that dissolved oxygen and carbon NPs played important role to catalyse the reaction. The catalyst was stable and could be recycled. This reaction may open new doors to produce metal-CNP composites for coupling reaction and production of fine chemicals and pharmaceuticals of industrial importance.



Chapter-4

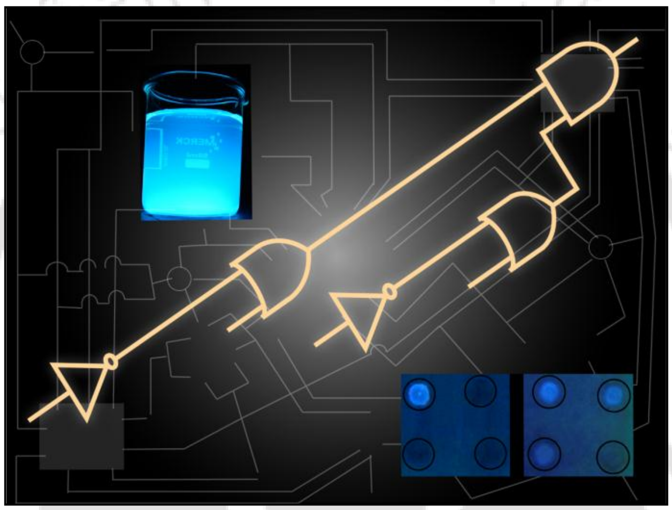
Highly Fluorescent Carbon Dots as Invisible Ink and Explosive Sensor

Chapter 4 describes a new and facile method of synthesizing highly fluorescent carbon dots (Cdots) using a commercially available induction coil heater. The Cdots were produced when an aqueous solution of citric acid and a diamine compound was heated at 100 ^{o}C for 12-15 min. The formation of Cdots was confirmed by various techniques such as UV-visible spectroscopy, fluorescence spectroscopy, powder X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), electron paramagnetic resonance (EPR) and transmission electron microscopy (TEM). The Cdots, with an average size of less than 5 nm (being produced when ethylenediamine was used), emitted blue light with high quantum yield, when excited by UV light. The quantum yield was dependent on the nature of diamine and was as high as 73.5% for ethylenediamine. Interestingly, EPR spectroscopy studies indicated the presence of one or more singly occupied electron orbitals in the ground state (with g = 2.012451), suggesting the electron donation and acceptance properties of Cdots. The as-prepared Cdots could easily be converted into gel by mixing with chitosan biopolymer. The gel could be used for filling up the refill of a ball-point pen and be used for UV-active marking, for sensing of explosive compounds (such as picric acid and 2,4 –dinitrophenol) with high efficiency and for other fluorescence based applications. The use of commercial induction coil heater, scalability and high chance of commercial viability make the method especially appealing.

Chapter-5

Dual Phase Logic Operations using luminescent Carbon Dots

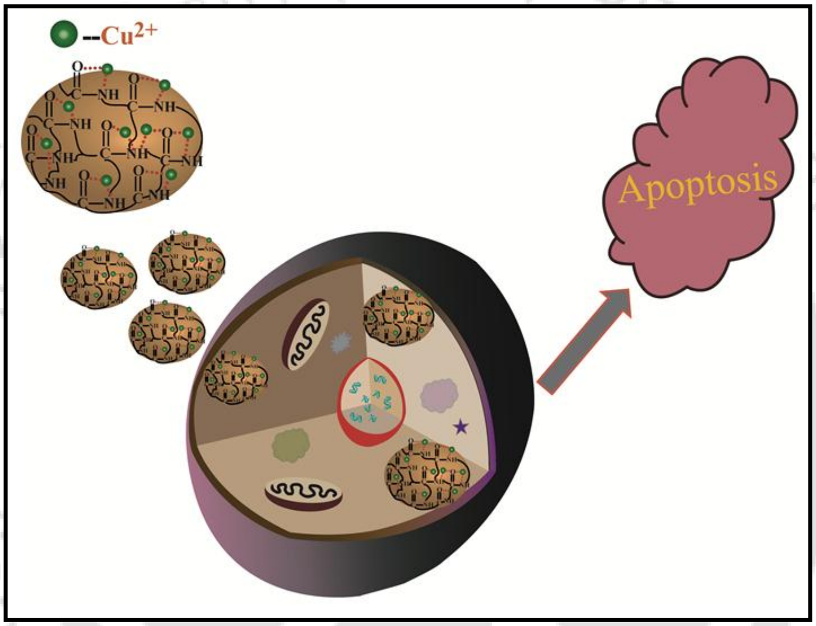
Chapter 5 deals with the application of luminescent Cdots (mentioned in chapter 4) in pursuing cascade logic operations in two different phases. In this chapter, basic, universal and higher integrated logic operations were achieved based on the changes of photoluminescence of Cdots through interactions with metal ions and organic molecules in liquid dispersion as well as in the solid phase. For example, in the presence of Fe^{3+} ions, quenching of emission of Cdots was observed. The emission could be recovered following treatment with ascorbic acid or cysteine. On the other hand, emission quenched by picric acid could be recovered by using a phase transfer process. We have also established a logic system using Fe^{2+} and H_2O_2 which could distinguish Fe^{3+} from Fe^{2+} ions. Overall, the simple and complex logic systems, being capable of operating in dual phases, offer applications in various analytical purposes as well as detection of important elements in diverse environment.



Chapter-6

Cu^{2+}- embedded Carbon Nanoparticle as an Anticancer Agent

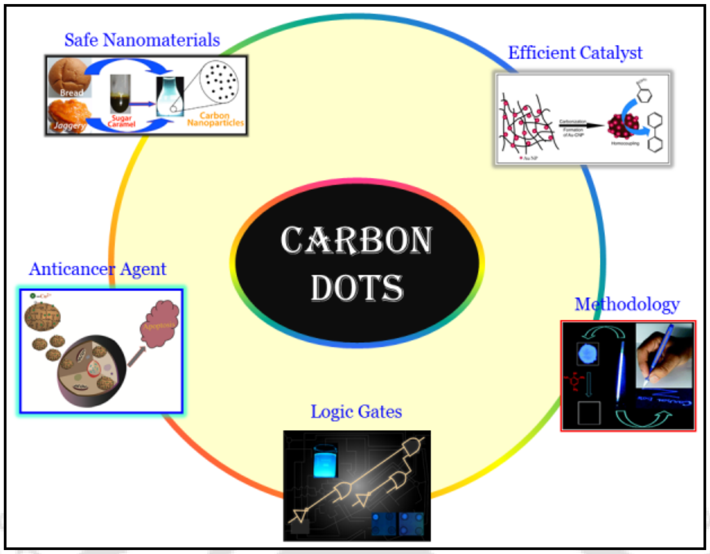
Chapter 6 demonstrates that Cu^{2+} embedded carbon nanoparticles (Cu-CNP) acts as an anticancer agent. The fluorescent Cu-CNP was synthesized by using carbon nanoparticles and copper salt at 50 °C (pH=9-11). The formation of Cu-CNP was established using UV-visible spectroscopy, fluorescence spectroscopy, IR spectroscopy, powder X-ray diffraction (XRD) and transmission electron microscopy (TEM) studies. The average size of the Cu-CNP was found to be 92.7 ± 49.8 nm. The cell viability study in presence of Cu-CNP was carried out by standard MTT assay followed by cell cycle analysis, where the cells have been found to undergo apoptosis. Also, generation of reactive oxygen species in the cell, in the presence of the composite nanoparticles, has been attributed to their killing. In this regard, the blue emission of Cu-CNP could be used to monitor the cellular uptake by confocal microscopy. Overall, good biocompatibility, bright emission, cellular imaging application, and anticancer effect of Cu-CNP will make it a promising candidate for future theranostic applications.



Chapter-7

Overview and Future Prospects of the Thesis

The last chapter (**Chapter 7**) deal with the future prospects of the key findings of the research works carried out in this thesis.



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