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Progress in Innovations Based on Synthesis of Carbon Dot's: Review

Dr. Nikhilesh Bajaj [a]*, Anil Bodke [a], Mr. Gajanan Bhise [a], Dr. Rajesh Joshi [a], Dr. Rupali Korpe [b]

[a] *Department of Physics, Toshniwal Arts, Commerce & Science College, Sengaon, Dist; Hingoli, MH, India*
[b] *Department of Physics, Shri Shivaji Arts, Commerce & Science College, Amravati, MH, India*
[*] nikhileshbajaj@yahoo.com

A B S T R A C T

From Ancient era carbon is always a choice of materials for innovators due to its availability and it is a ease to process materials. day by day the researcher modified its forms likewise Diamond, Graphite, etc by changes its structure and its processing. it is evidenced that after the discovery of Carbon dots C-QDs in 2004, a number of simple, low-cost and efficient routes for the synthesis of C-QDs have been developed and their applications are explored thoroughly. In Recent Years, Carbon and carbon materials nano materials such as carbon dots, nanotubes and nano sheets (Graphene))attracted many researcher due to their eye catching properties and their utilization in variety of applications. Literature survey revealed that macroscopic carbon materials have less abilities those as compared to nano scale materials due to low band gap and poor stability. In current review we have made an attempt to summarize the properties and application of one such nano scale product of carbon known as carbon dots.

Keywords: Carbon Materials, Carbon Dots, Fluorescent Material, Nanotechnology

Introduction

Carbon-based materials are essential to the progress of material science innovations. Nevertheless, carbon-based materials in their macroscopic state demonstrate an insufficient band gap. As a result, their utility as semiconductor materials or as efficient fluorescent agents in optical systems is constrained. This issue can be resolved by reducing the size and behavior of carbon. A multitude of researchers has sought to achieve the sought-after properties of materials, uncovering innovative carbon-based compounds such as carbon dots, fullerenes, and graphene, with further investigation in this field [1-3].

Nevertheless, it has been shown that the synthesis and separation of nano-diamond can be achieved at the laboratory scale; nevertheless, reproducing these results on a wider scale presents difficulties. Carbon nanotubes (CNT), fullerenes, and graphene demonstrate restricted water solubility and reduced fluorescence in the visible range, hence limiting their utility. Carbon quantum dots (CQDs) are innovative zero-dimensional carbon-based nanomaterials distinguished by their small size and remarkable fluorescence characteristics. Within the realm of carbon quantum dots (CQDs), graphene quantum dots (GQDs), carbon nanodots (CNDs), and polymer dots (PDs) are the principal focus of research [5].

Carbon dots feature a carbon-rich core substantially functionalized with nitrogen and oxygen surface groups, demonstrating strong optical absorption and tunable emission transitions in the visible range [6]. Carbon dots are a unique class of emitters distinguished by size-tunable emission wavelengths, vibrant emission colors, near-unity brightness efficiency, inherent photo and thermal stability, and remarkable solution processability. Carbon dots have attracted significant research attention due to their diverse physicochemical properties and beneficial attributes, such as superior biocompatibility, unique optical characteristics, affordability, small size, eco-friendliness, plentiful functional groups (e.g., amino, hydroxyl, carboxyl), high stability, and improved electron mobility, as depicted in Figure 1.

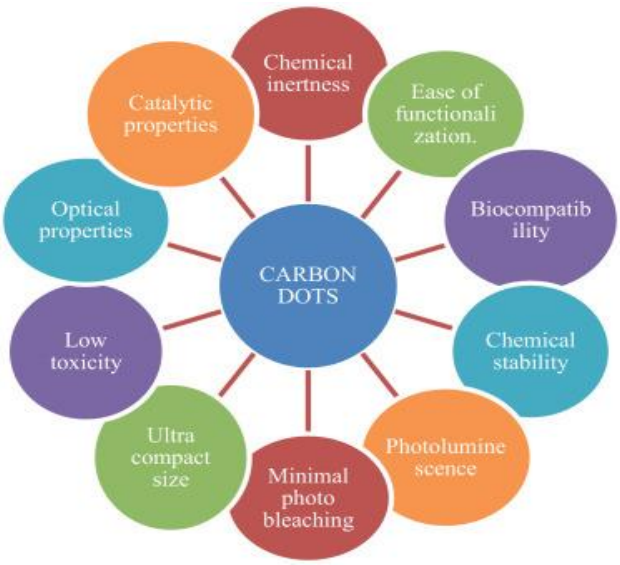

Fig. 1 - Properties governed by Carbon Dots

[Source: Manju Kurian, Anju Paul, Recent trends in the use of green sources for carbon dot synthesis–A short review, Carbon Trends, 3 (2021) 100032]

History

In 2004, Xu et al. unintentionally discovered luminous carbon nanoparticles while conducting electrophoretic purification of single-walled carbon nanotubes. Two years later, Sun et al. produced carbon dots from graphite powder and cement using the laser ablation technique [8-9].

Carbon dots are often produced through two primary methodologies: top-down and bottom-up approaches. In top-down methodologies, the macromolecule is either destroyed or broken into diminutive carbon dots through physical or chemical processes. The bottom-up process essentially involves the polymerization and carbonization of a series of small molecules into carbon dots through chemical reactions. Figure 2, derived from the study conducted by Anirudh Sharma and Joydeep Das, visually represents both methodologies.

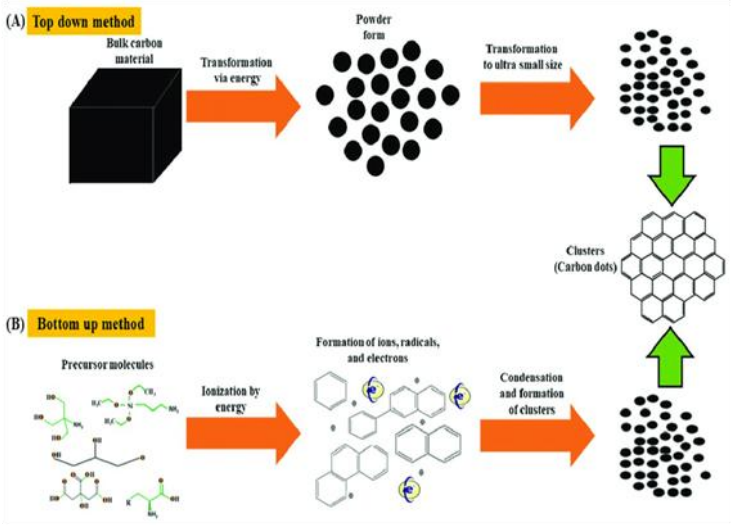

Fig. 2 - Different Approaches for Synthesis of Carbon Dots.

[Source: C. Sakdaronnarong, A. Sangjan, S. Boonsith, S. Boonsith, H. Suk Shin, Recent Developments in Synthesis and Photocatalytic Applications of Carbon Dots, Catalysts 10(3):320, 10.3390/catal10030320] [8]]

The researchers also summarized the details of many different methods were reported through different platforms for synthesis of carbon dots, Those are Electrochemical /chemical oxidation, Ultrasonic treatment, Hydrothermal /Solvothermal synthesis, Microwave assisted synthesis, Thermal decomposition, Laser ablation, Microwave irradiation methods [11] .

Evolution of Carbon Dot As Technology

Nanotechnology is a rapidly progressing domain within materials science. The foundational idea of nanotechnology is believed to have originated from a lecture given by a scientist in 1959. Nanotechnology is an extensive field encompassing organic chemistry, inorganic chemistry, surface science, molecular biology, semiconductor physics, and energy storage.

In the last twenty years, a variety of novel nanomaterials have been developed, including gold particles, silver particles, palladium nanoparticles, silica hollow spheres, carbon nanotubes, graphene, and quantum dots, among others. Quantum dots (QDs) are a material type of considerable interest. Quantum dots are nanoscale semiconductors that exhibit unique optical and electrical properties. When quantum dots are exposed to UV light, they absorb energy, causing an electron to be excited to a higher energy state. The energized electron may then go to a lower energy state, releasing energy in the form of light through a process known as fluorescence. The color of the emitted light depends on the difference between two energy levels, which is converted into carbon dots based on the size of the crystal.

With the rapid advancement of science and technology, environmental degradation and energy scarcity are becoming increasingly critical issues. Photocatalytic technology is regarded as one of the most efficacious methods for pollution degradation and energy conversion.

The emergence of carbon dots has captivated materials scientists due to their remarkable photophysical characteristics and extended colloidal stability [12-14].

Current Innovations

Figure 3 depicts the prospective applications of carbon dots. Pathogenic bacterial infections present a significant threat to humanity. Recent studies on the application of nanoparticles as imaging and detecting agents have revealed their considerable potential for the management of infectious diseases. Carbon dots have attracted considerable attention as a novel nanoparticle owing to its unique optical and physicochemical properties, as well as their enhanced biosafety. .

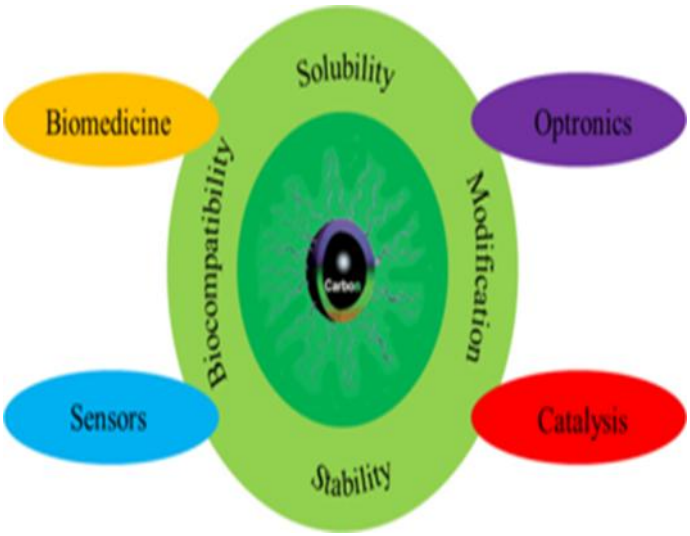

Fig. 3. Applications of Carbon Dots

[Source: https://en.wikipedia.org/wiki/Carbon_quantum_dots]

Carbon dots are now a days used as sensors in fingerprint imaging. Latent fingerprints, or those hidden from eye, have been widely used in forensic investigation, since the friction skin ridges pattern is unique to an individual. Latent fingerprint, in a typical investigation, need to be recovered and preserved. Wang and coworkers showed that carbon dots imbedded in a film of polyvinyl (PVA) could be used to get a highly detailed image of the fingerprint and that the films had long term stability.

In biomedicine carbon dots used as bioimaging and low biotoxicity, CQDs shows great potential for fluorescent bioimaging and multimodal bioimaging of cell and tissues, which have been reviewed elsewhere. It is attractive to integrate multi-imaging technology for one agent comprehensive understanding of the illness. Carbon dots is used as biomedicine delivery system, it is an attractive prospect to combine medical therapy and bioimaging diagnostics for visual drug distribution and monitoring of their effects.

Carbon dots used in Dye synthesized solar cells, organic solar cell, superconductors and in light emitting diodes, to increase the properties of this materials. Carbon recently used as a photocatalysis, sensors (Solid phase sensors, test paper sensor, electron nanofibrous film sensing, hydrogel sensing, fingerprint sensing, small molecules and macromolecules sensor). Carbon dots also used to check the food quality. [15-17]

Conclusion

Since the discovery of carbon and carbon based materials, it is evidenced that these materials attracted at most researchers' attentions because of their good chemical and physical properties. However, after the discovery of Carbon dots C-QDs in 2004, a number of simple, low-cost and efficient routes for the synthesis of C-QDs have been developed and their applications are explored thoroughly. The current article emphasis on the all these simple and low cost processing of C-QDs and their possible applications in biomedical fields. After thorough review it is observed that the advantages of CQDs are being acknowledged by researchers with concern in areas as diverse as of materials science this suggests that research on CQDs will continue to grow in synergistic relationship with intellectually adjacent fields. It seems clear that the future of CQDs remains promising.

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