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Review of green synthesis of carbon quantum dots and its applications in biosensing

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Abstract

Carbon quantum dots are carbon nanotubes of 6-10 nm in size. They play a role in early disease detection, increasing treatment success, and reducing healthcare costs. Therefore, they are highly sensitive and essential for developing biosensors globally for improved health outcomes. This opens up opportunities for future development of high-quality carbon dots and applications. Green dots are converted from waste materials like fruits, flowers, and vegetables. Bottom-up and top-down synthesis are commonly used.

These methods are not environmentally friendly, which is why there is a growing interest in green dots. Synthesizing carbon dots through various techniques is an area of interest. Why nanotechnology is a promising approach to transforming organic matter from natural materials? Finally, nanotechnology is also discussed. Environmental concerns of carbon dot soil sensors are described.

Keywords: CDs; synthesis; optical properties; Characterization; applications

Introduction

The field of nanoscience and nanotechnology is rapidly evolving, drawing interest from diverse disciplines such as chemistry, biology, and engineering. These technologies hold great promise for reducing healthcare costs by enabling the early detection and treatment of diseases, thereby playing a crucial role in modern medicine[.1] Carbon quantum dots represent a novel form of carbon in this context. In 2004, Xu et al. identified colloidal semiconducting carbon nanocrystals—with dimensions smaller than 10 nanometers—during the purification of carbon nanotubes. Nanomaterials are attracting significant attention due to their unique properties, and the development of various associated technologies has spurred extensive research[.2]

In recent years, considerable research has been conducted to enhance the efficiency of biosensors, paving the way for future applications in this domain[.3] Consequently, the focus has shifted to exploring their utility in areas such as biological labeling, bio-imaging, and drug delivery; notably, these materials are water-soluble. They are widely used in applications ranging from monitoring water quality to drug delivery. Furthermore, the "green synthesis" approach used to produce them minimizes pollution, converts waste materials into useful products, and ensures environmental friendliness.[4]

Synthesis methods for carbon dots

Carbon Dot is divided into two parts: the first, a bottomup approach, and the second, a top-down approach. Carbon Dot represents the challenges of this process, which involves the need to maintain uniform shapes during processing. Several innovative techniques have been developed to create carbon dots, including those from floral science and what we call synthesis.[5] Today, natural materials like fruits and vegetables are being used, which are eco-friendly.[6] This process involves curving, shaping, and purification. Carbon dots are widely used today, and their original material is widely used.[7] The top-down approach, which is achieved due to its specific properties, is the bottom-up approach. It is created by combining small components[8,9]. It exhibits very different properties at high temperatures, and this is the largest part of this process, and many other synthesis techniques are used.[10,11] For example, it is very easy to make them using microwaves, and this process involves causal purification. [12,]

The bottom-up process involves the ability to adjust the size and shape of a particular material, and this technology involves using ultrasonic treatments to electrochemically break it down into smaller particles, as you can see in this diagram.[15]

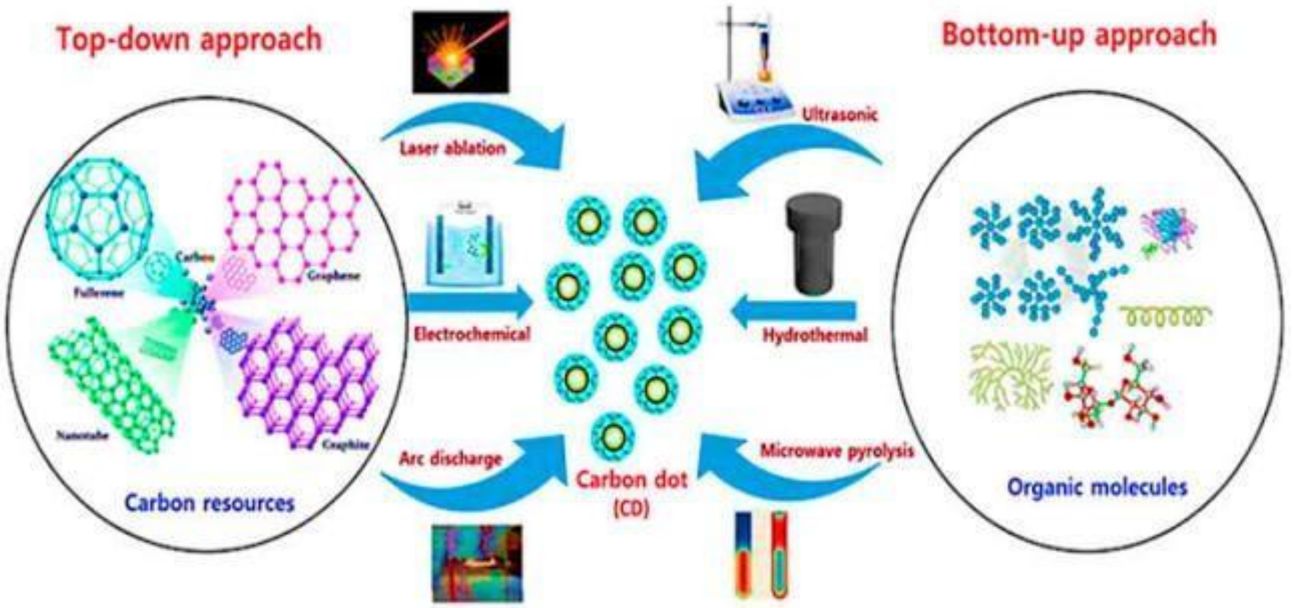

Figure 1 ; Bottom up and top down approaches for carbon dots synthesis .

Ultrasonic approaches

The ultrasonic method has attracted attention due to its advantages, including its low cost, robustness, and environmental friendliness[16]. In top-down applications, various types of carbon dot materials, such as graphene oxide, carbon nanotubes, and carbon fibers, are chemically assembled[17,18]. Ultrasonic treatment involves breaking the carbon into smaller particles using technologies such as lasers and electron beams.

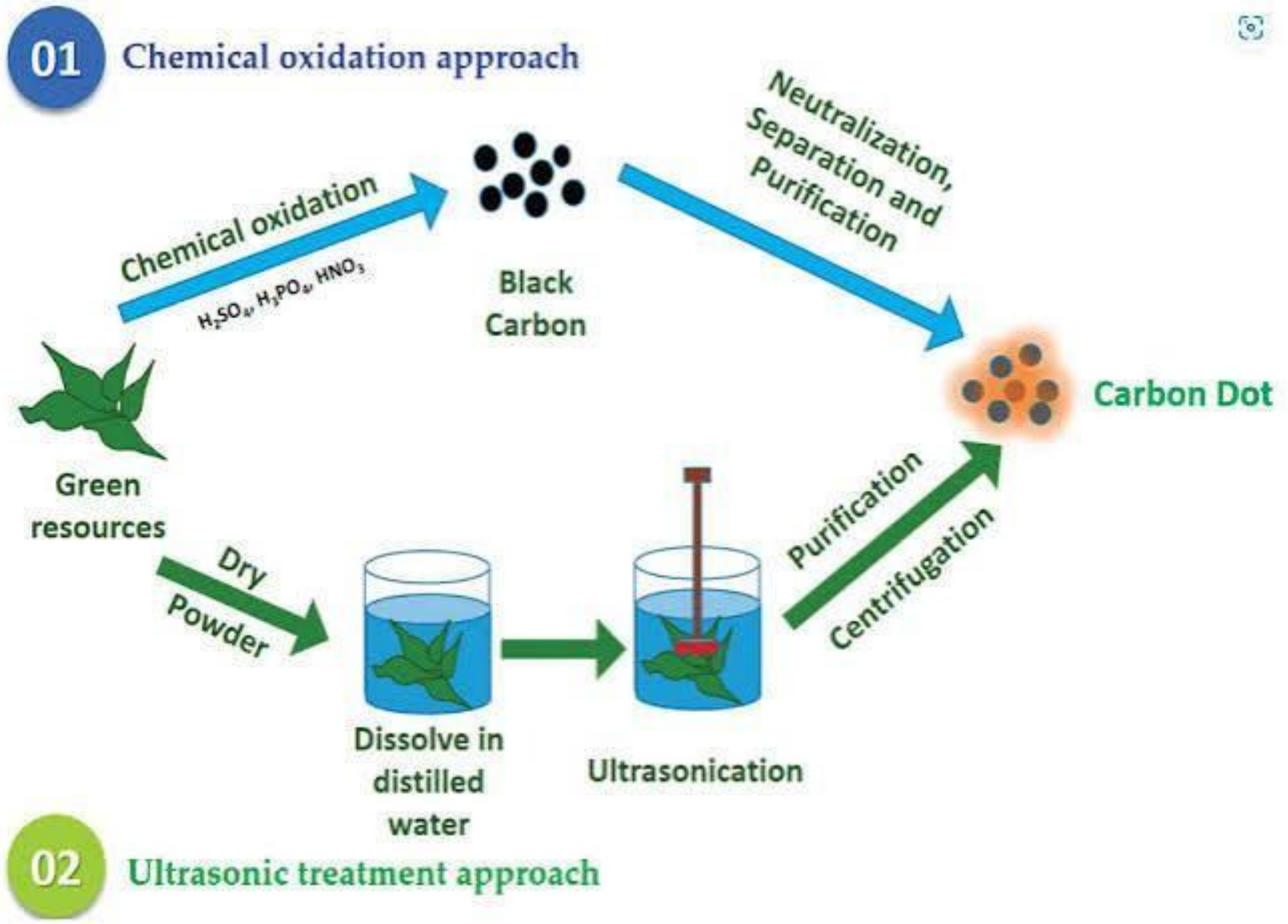

Figure 2 ; Top down approaches in the green synthesis of carbon dots reproduce with permission .

Microwave synthesize approach

Microwave synthesis is a new method. To prepare it, carbon dots are mixed with flowers, tomatoes, onions, and roses, a reaction that proceeds at low temperatures. [19]These carbon dots can be used to load and release medicines.

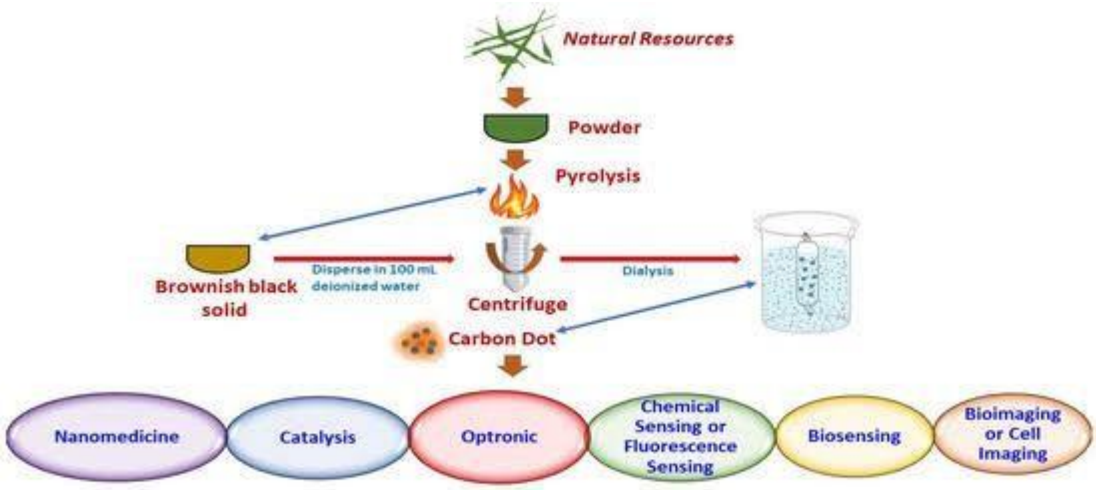

Figure 3; Preparation produce of reduce carbon dots via the microwave synthesize approaches .

Application of carbon dots

These modern fluorescent nanomaterials exhibit properties of carbon dots such as environmental friendliness, water solubility, light scattering, and many more. Due to these green chemistry concepts, carbon dots can be easily prepared.[20,21,23] Due to these properties, carbon dots find applications in many areas including bias imaging, nanomedicine, medicine, delivery and solar cell energy storage, photocatalysis and many more.

Biomass

Biomass-derived carbon dots from natural biomass have attracted considerable attention due to their potential use in bioresource cells. This is primarily due to their nanoscale properties, which offer significant advantages. The carbon source involves heating organic matter at high temperatures, dehydrating it, and converting it into carbon dots. The pyrolysis method uses highly concentrated acids to break down the carbon into nanodots. Several biomass resources, such as watermelon peels, sago, coffee waste, and plant leaves, can be used as remotely produced carbon source.[22] The reaction system involves temperature and pH values. The pyrolysis of litchi seeds yielded carbon dots with an intrinsic density of 10.6% per capita, which can be used for living organisms. A simple and cost-effective technique for producing carbon dots from peanut shells was presented.

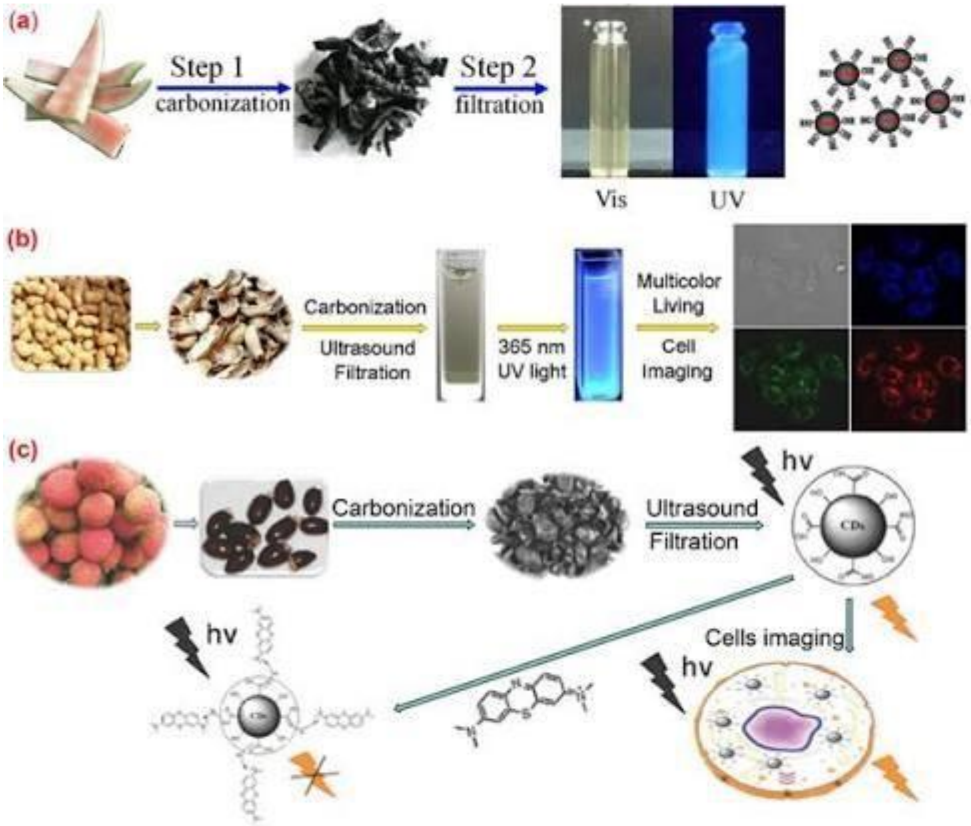

Figure 4; Preparation of fluorescence carbon dots from agricultural waste is the pyrroles method (a) synthetic the water melon (b) the preparation and flurorescent cdsfrom lychee seeds (c) the preparation and application of cds of peanuts shell .

Biomedical

Carbon dots exhibit excellent properties, including high chemical inertness and dispersibility in both organic and gel media. Carbon dots are commonly used in concentric laser scanning, which measures the rapidity of cell growth in response to microscopic red, blue, and green wavelengths[24]. For example, zebra fish have been used extensively in medical fields such as disease progression because they are well-developed and amenable to optical imaging. Zebra fish were chosen as a model. This model demonstrated that carbon dots rapidly accumulate in the eye and eye. Using carbon dots to detect heavy metals in bacterial DNA is a simple technique and is useful in biomedical applications. Carbon quantum dots are useful because they act as toxins and are only proven to be toxic to our bodies, and carbon dots are very effective in killing bacteria.

Challenges and future perspectives

Carbon dot synthesis is a promising field for various nanomaterials due to its versatility. Furthermore, a variety of methods exist for carbon dot synthesis, including many biological approaches and chemical approaches. However, due to their environmental friendliness and cost effectiveness, biological approaches have been preferred. Over the past few years, carbon dot synthesis has attracted significant attention for its potential applications in biomedicine, auto-electronics, bio-imaging, and energy storage and back-catalysis. [25]Syntheses are lab-based processes for fabricating materials, and auto-electronics are IC technologies that operate on the interaction of light and electricity, and are used for drug delivery to treat diseases like cancer. Scientists are exploring various methods, but controlling their size and surface area remains a challenge.[26].

If we want carbon dots to be used everywhere in the future, scientists will need to develop standard protocols for their production. This includes element analysis and stability when carbon dots are exposed to environmental factors such as heat, light, and moisture. It is essential to increase the photostability of carbon dots and first, before using them in humans or animals, we must ensure that they are not toxic. In the future, carbon dots hold potential for advanced applications in solar cell catalysis and sunlight harvesting.[27]. Carbon dots act as light absorbers during sunlight harvesting.

Advantages

- **Enviornmental friendlines and sustainblity:**
  Green sources such as leaves, biomass, and fruit waste are used. This helps our environment, reduces waste, and is in line with green chemistry principles.

- **Low cost and abundance:** Raw materials are inexpensive and readily available, making them less expensive and easier to manufacture than synthetic chemicals.

- **Non toxicity :** They are non-toxic and safer for use in living systems, such as drug delivery, bioimaging, and environmental sensing.

Efficient production methods

- **Hydrothermal synthesis**
- **Microwave – assisted synthesis**
- **Ultrasonication**

Conclusion

Carbon dots (cds) have transitioned from lab scale research into a versatile, sustainable nano material, with advancement in green synthesis – chracterizatio,and wide spread applications in opto electronic , bio imaging , catalysis . Researches , focusing on precise control and scalable methods such as hydro thermal and microwave – assisted synthesis , aims to drive industrial – scale adoption in field like led production and medical diagnostics .

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