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Carbon quantum dots

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Abstract

Carbon Quantum dots are a class of materials studied under Nanotechnology. We know that nanotechnology is a wide research topic as it has wide range of applications in various fields. This review is about carbon quantum dots which is the carbon material in the range 1-10 nm. Carbon Quantum dots with unique optical properties, low toxicity, low cost and simple synthetic routes are very important research topic in coming decades. CQDs have 2 approaches for fabrication top-down and bottom-up. CQDs are also known as fluorescent carbon nanoparticles. In this review we have discussed the information about carbon quantum dots, their synthesis, properties and also their wide range of applications in various fields like optronics, bio medicine, and sensors etc. which are helpful for future generations. This review summarizes the research, application and brief study of carbon quantum dots.

Key Words: *CQDs, Properties, Fluorescence, Synthesis, Applications.*

Introduction:

As we earlier mentioned carbon quantum dots are based on nanotechnology. Nanotechnology is the science, Engineering and technology conducted at nanoscale which is about 1 to 100 Nanometer. Nanotechnology is invented by Physicist **Richard Feynman** who is also known as father of nanotechnology. Nanotechnology has applications in various fields. Due to this nanotechnology is the study of synthesis and application of extremely small things and can be used across all fields such as chemistry, biology, physics, material science, and engineering. Nanotechnology is started as The idea and concept behind nanotechnolog is started with a talk entitled "There's plenty of Room at the bottom" by physicist Richard Feynman of California institute of technology on December 29, 1959, and before term nanotechnology was long used.

Fundamental concepts of nanotechnology is its hard to imagine how small nanotechnology is one nanometer is billionth of a meter or 10^{-9} of a meter.

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Nano examples: an inch= 24,400,000 Nanometer.

Sheet of newspaper is about 100, 000 Nanometers thick.

Carbon quantum dots (CQD) is a class of carbon nanomaterials with sizes 1-10 nm.[1]They were first obtained during purification of single walled carbon nanotubes through preparative electrophoresis in 2004, and then via ablation of graphite powder and cement in 2006. [2]Carbon Quantum dots are essential in modern life and also need to grow in future. They are firstly discovered by 'Xu' et al in 2004.[9] Since the CQDs have been area of interest due to excellent optoelectronic properties, simple synthetic routes, facile surface functionalization, large specific surface area, good bio compatibility and less toxic etc. [10-12] The experiments have proved less toxicity of CQDs than GO sheets and hence safe for in vivo biological research. [13-14] Apart from energy applications CQDs are widely used for water and waste water treatement.[15-16] This discovery triggered extensive Studies to exploit the fluorescence properties of carbon quantum dots much & progress has been achieved in synthesis properties and application of carbon quantum dots. Carbon quantum dots have been extensively investigated especially due to their strong and Tunable fluorescence emission properties which enable their application in biomedicine, optronics, catalysis and sensing.

The specifically synthesized and selected carbon dots of relatively High Fluorescence quantum yields were evaluated in their Fluorescence labelling of cell is also for cancer cells 1ines. The cellular uptake of carbon dots was generally efficient resulting in labelling cells with bright fluorescence emission for both one and two-photon excitations from predominantly the cell membrane and cytoplasm.

Research has shown that carbon quantum dots can resist temperature as high as 800 degree Celsius. Paving way for application carbon quantum dots in High temperature environment based on carbon quantum dots possess such properties as good conductivity begin chemical composition, Photochemical and Thermal stability. Carbon quantum dots have emerged as a potential material in diverse fields of biomedical applications due to their numerous advantages properties including. the fluorescence, water Solubility, low toxicity, and small size of modification, inexpensive scale up production and versatility.

Wide attention is focused on CQDs because of their good solubility and strong luminescence for which they are known as carbon nanolights.[2]

CQDs are novel zero dimensional carbon based nanomaterials known for their small size and relatively strong fluorescence characteristics. CQDs are also known as carbon dot (CDs). GQDs, CNDs and PDs have similar size and photo electrochemical properties but differ in the internal structure and chemical groups on the surface. These are mono disperse spherical nanoparticles with a carbon based skeleton and a large amount of oxygen-containing groups on the surface.[4]

CQDs have attracted attention of researchers due to unique properties like large surface to volume ratio, low toxicity, stable photoluminescence, bio compatibility, good solubility in water and electrical conductivity. Due to these properties the

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varied application areas are energy conversion, sensors, photo catalyst, bio imaging and tissue engineering.[7]

Properties

A. Fluorescence properties of carbon quantum dots:

1) Fluorescence emissions from band gap transitions of conjugated pi-domains :

This is the first property of carbon quantum dots in fluorescence field. This type of pi-domain is isolated by creating sp^2 hybridised islands which are rich in the pi-electron by reduction of graphene oxide which are obtained by humans methods like oxidising and also exfoliating graphite flakes.

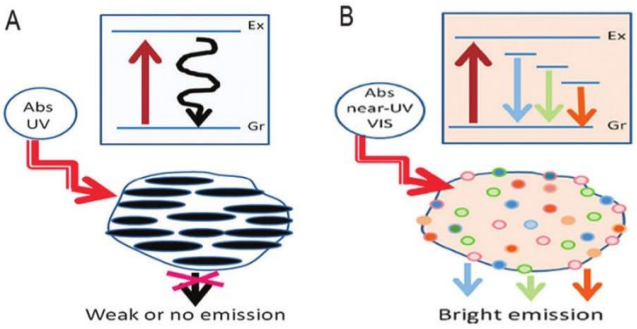

Fig 1[3]: A) CQD with strong absorption in UV region and weak emissions

B) CQD with weak absorption near UV but strong multicolour emissions in the visible regions

2) fluorescence emissions of surface defect-derived origin :

The second class of the fluorescence mechanism arises from surface-related defective sites - generally any sites which contain non perfect sp^2 domains whichare results in surface energy traps. Both sp^2 and sp^3 hybridised carbons and other functionalised surface defects such as carbonyl-related localised electronic states present in CQDs contribute to their multicolour emissions that are concentrated in the blue and green regions of the visible light spectrum. These surface defects behave like aromatic molecules that are individually incorporated into solid hosts, exhibiting multiple colour emissions due to existence of multiple surface defects with different excitations and emission properties.

3) **Tunable Fluorescence emissions of carbon quantum dots:**

One of unique property of carbon quantum dots is their tunable florescence emissions. Generally carbon quantum dots possess tunable emissions without any surface passivation but they usually contain very low quantum yields because of the unstable surface defects. leading to reduced radiative recombination.

4) **Up-conversion fluorescence :**

In addition to conventional down conversion florescence conversions, CQDs have up-conversion fluorescence emission properties. Up-conversion fluorescence is

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optical phenomenon where in fluorescence wavelength is shorter than the used excitation wavelength. Up-conversion fluorescence is important fluorescence related property of carbon quantum. dots up- conversion fluorescenceIn this type of property wavelength of fluorescent emissions is short than the excited wavelength which are attractive for in vivo bioimaging since bioimoging at longer wavelengths especially in NTR region is Which is preferred improve tissue penetration and also helps in to reduce auto fluorescence also on the other hand. Up-conversion fluorescence emissions are originating are from conventional down-conversion emissions which have been excited by leaking component from second diffraction in monochromator of spectrofluorameter. These are well-known important properties of carbon quantum dots in fluorescence field which Useful are future research field.

B) Phosphorescence

The Phosphorescence properties on CQDs were discovered recently. A pure organic room temperature Phosphorescent (RTP) material was obtained based on water soluble CQDs and its life time was lengthened to the order 30ms. [2]

C) Chemiluminesence

Chemiluminesent properties of CQDs were first discovered when CQDs co-existed with some oxidants like KMnO4 and Cerium (IV). The EPR reveals that these chemicals inject holes into the CQDs. The process increases the population of the holes in the CQDs and accelerates electron-hole annihilation. [2]

Synthesis of carbon quantum dots

Various synthetic methods for the preparation of CQDs are available and used widely. These are chemical ablation, electrochemical carbonisation, laser ablation, microwave irridation, hydrothermal treatment.[2]

Synthesis of CQDs is broadly classified into top-down and bottom-up approaches. [17-18] In the top-down approach, CQDs are synthesized by breaking the large carbon materials into smaller ones by employing arc discharge, laser ablation and chemical oxidation where as in bottom-up approach, CQDs are synthesized via molecular carbon precursors using methods like hydrothermal microwave etc. [5] There are many green synthesis roués devised for synthesis of CQDs by employing natural materials as starting carbon source like chytosan, orange juice, lemon peel, humic substances, peanut shell, garlic etc. Major hindrance with these natural carbon sources is that they undergo seasonal fluctuation based on geographical location of plant cultivation. This affects reproducibility, size distribution and shape of CQDs.[5]

1) Add 50 ml of ethanol and 0.5 ml deionised water and then this mixture is pour in round bottom flask Put the magnetic stirrer in flask in the middle.
2) Weigh approximately 0.3 gram NaOH. And add this NaOH to flask of 50 ml mixture. Stir This solution at 750 RPM until NaOH dissolves. Pour NaOH solution 50 ml in 100 ml beaker.
3) Mounted graphite rods connected to power supply which carbon rods separate by 1 inch which are submerged 30 ml in solution.

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4) Turn on power supply and multimeter. Adjust current with voltage knob in this case 30 mA will be used. Keep adjusting until current is stabilized. Let reaction run for 2hr and then remove beaker and off power supply and multimeter.

5) Pour resulting solutions in 25 ml vials, then label and close them and age solutions for couple of days. Until they turn into yellow-organish colour.

6) Chromatographic column with cotton in bottom is used to filtering for this measure 30 ml of silica gel in small beaker and 30 ml of diethyl ether slowly pour due to exothermic reaction and also measure petroleum ether it is also add to solution of silica and then pour in column which is closed. Put small beaker below column. Ether start to drainpour ether in column.

7) Pour aged quantum dot solution and wait until column is become completely orange and switch small beaker to new vials to recover the filtered quantum dots. Finally carbon quantum dots in vials are fumerhood for 1 day to evaporate ether and we get carbon quantum dots.

Applications:

There are many applications of carbon quantum dots in Various fields which are as follows :

Biomedicine: there are number of application of carbon quantum dots in Biomedicine field such as

Bioimaging, Biosensor, Biomedicine delivery system

Bioimaging: CQDs have comparable optical properties and good chemical and photochemical stability. Carbon is non toxic and is environment friendly so CQDs are desirable as alternatives to semi conductor quantum loss to visualise biological systems.

Biosensors: CQDs are used in bio-sensing based on the use of antibodies and their gene recombinant fragments. CQDs are mainly applied in immune assays as fluorescent labels. CQDs are less costly, more stable, more sensitive and hence are chosen over other commonly used fluorescent labels for this study[19-21].

Optronics: There are no of application of carbon quantum dots in also optronics field such as

solar cell ,Supercapacitor ,Light emitting devices are the application of carbon quantum dots in optronics field.

Photocatalysis: Photocatalytic processes have gained tremendous momentum as greener alternatives in organic synthesis. Recent study has proved that smaller CQDs (1 to 4 nm) are effective near infrared light-driven photocatalyst for selective oxidation of alcohols to benzaldehydes with good conversion efficiency and selectivity. On the other hand larger CQDs (5 to 10nm) can be used as acid catalysts to catalyse a series of organic transformations in aqueous medium under visible light.

Biological Applications:

*Carbon quantum dots are mainly used in cancer treatment. The major application of carbon quantum dots is they target at single organ such as liver and much more precisely than conventional drug to reduce side effects in cancer treatment.

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* Also carbon quantum dots are used in place of organic dyes in biological research. For example they can used like nanoscopic light bulbs to light up and colour specific cells. That need to studied under microscope. Also as we know carbon quantum dots have wide range of application in biological field also such as low toxicity, excellent water solubility, environmental friendliness.

Conclusion:

Since the discovery of CQDs in 2004, the physicochemical properties including fluorescence, tunability and chemical stability have been studied thoroughly. The CQD research has heralded a new chapter in biomedicine. Carbon quantum dots have already shown immense potential to play an important role in nanotechnology for development of assays, Sensors, bioimaging agents, during carriers phototherapy, photocatalysis and electrolysis. Fact that many optional and electronic properties of carbon quantum dots are not well understood yet, there is no doubt that CQDS will play huge role in bioimaging and biomedical research in near future open upon furthur development. Although in the midst of development, CQDs have immense potential in nanotechnology for assays, phototherapy, photocatalysis, sensors etc. many properties of CQDs like optical and electronic are not well understood yet. Due to its versatility CQDs can be modified as per the requirement.

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Ethical issue

No

Conflict of interest

no

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