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Optical Properties of Carbon Quantum Dots for AI-enhanced Flexible Bioelectronics and Nanomedicine

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Abstract

Carbon nanodots are the emerging nanomaterials of 20th century. Carbon nanodots is the family of carbon based material with distinguished bio-physical properties. In this paper, the optical properties of carbon nanodots are presented. One of the developments Nanoscale physics and nanotechnology is the ability of converting optical signals into meaning full information. This innovation is accelerated and improved by incorporating nanoscale materials including carbon quantum dot, carbon nanotube, and graphene quantum dots due to their pronounced optical properties. These properties enable generation of electrical signal in device such as optoelectronics, photodiodes, photoconductors, and photo detectors. Moreover, the effect of doping and AI on improving the optical properties of carbon quantum dot is visualized. This research therefore, presents the optical properties and role of carbon quantum dots as nanoelectronics and nanomedicine. In this regard, emphasis is given to the essentials of carbon quantum dot in fluorescent electronic devices, flexible electronics, and optoelectronics, power electronics, bioelectronics, and biomedicine.

Keywords: Emerging technology, green nanotechnology, green hydrogen, nanocomposite, Nano polymers

INTRODUCTION

Research and innovations in Nanotechnology is growing in an unpredictable manner. The wise use of emerging nanomaterials such as carbon quantum dots has enhanced the growth rate in at an alarming rate. As Xu et al. 2004 [1], Youfu Wang & Aiguo Hu, 2014 [**2**], and Azam, N. et al. 2021 [**3**] discussed, Carbon quantum dots was discovered by Xu and his coworker in 2004. Since then it is studied for its fascinating optical, fluorescent, and electrical properties.

A carbon quantum dot is is a concern of nanotechnology. Nanotechnology provides a means to engineer, manipulate, simulate, and analyzing big data with the aid of AI. As Anne L. Clunan et al. 2014 [4] nanotechnology involves imaging, measuring, modeling, and manipulating matter at nanoscale. Nanomaterials comprises of nanoparticles, nanowire, nano composites, nano discs, Nanostar, nano flowers, nano rods, and quantum dots. The focus of this research is carbon quantum dots, which has a size of less than 10nm. Carbon nanomaterials such as carbon nanotube and carbon nanofiber are made from sp^2 carbon atoms. These nanostructures have one dimension (1D) while carbon quantum dots have 0D. Carbon quantum dots are nanomaterials whose sole properties are determined by its size, crystal structures, and energy band gap. As the size of

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carbon quantum dots increases, their energy band gap decrease. As Mengli Liu, 2020 [**5**] stated, the optical band gap of graphene quantum dots decrease as their size increase. Hence, their optical properties are greatly dependent on their size, shape, surface morphology, synthesis method, and surface area to volume ratio.

Carbon quantum dots (CQD) is non-crystalline solid core with sp^2 configuration. As Jing Zhu et al. 2019 [**6**] defined Carbon quantum dots (CQDs) are quasi zero-dimensional carbon nanoparticles with an average particle size of less than 10 nm. According to H. Ye. 2022 [**7**], it has spherical structure suitable for fluorescent probing. Carbon quantum dots are spherical shaped nanostructures. It is less toxic compared to other semiconductor quantum dots. As Paola Lagonegro et al. *2020 [8* revealed, depending on the synthesis methods, height of carbon quantum dot is 0.5nm – 5nm. It has a lattice spacing of graphite and organic functional group. CQD is popular carbon nanomaterials due to its excellent biocompatibility, high chemical stability, excellent water solubility, ability to form a wide range of wavelength in the visible electromagnetic spectrum. As E. and Nurlaela, A. *2023 [9]* demonstrates, CQDs solution emits yellow-green light.

Carbon quantum dots are the need of modern electronics due to their moderate electrical conductivity and semiconducting properties. Carbon quantum dots or carbon nano lights are strong candidates in optronics, Photocatalysis, and nanosensors due to their strong luminescence. Carbon quantum dot is a versatile nanomaterial in bioelectronics, nano devices, fluorescence, and optical sensors. *Z. A Qureshi et al. 2024 [10]* attracted a lot of attentions in biomedicine. More importantly, it is used in drug delivery, theranostics, and bio imaging. L Zhao et al. 2018 [11] realized that Carbon dots are used for antifouling, organic solvent nanofiltration, and water treatment by membrane technology.

Due to their biocompatibility, carbon quantum dots are used as coating materials for non-organic quantum dots like CdSe, ZnS, ZnO, GaAs etc. As Aswathi MK et al. 2018 [12] verified, QDs exhibits size-tunable light emission, improved signal brightness, and simultaneous excitation of multiple fluorescence colors compared to organic dyes and fluorescent proteins.

CQD has high thermal stability, low cytotoxicity, and tunable fluorescence emission. Consequently, CQD is widely applicable in optoelectronic as light-emitting diodes, semiconductor laser, solar cells, and photo detectors. Currently, quantum dots are an active area of research in bioelectronics, biochips, and nanomedicine. Bioelectronics medicine is a seemingly separate field that involves electrical stimulation in the nervous system (neurostimulation) with the primary goal of treating disease related to organ and immune system. In additions, due to its high dielectric constant, green synthesized CQDs have good commitment to design a broad range of photoelectric materials for application in bioscience and storing energy for long.

One innovation in bioelectronics technology is biochips. Biochip is a kind of micro reactor that contains millions of biosensors that detect biological organism. R Singh, 2014 [13] realized that biochip is a type of bio-security device and which translates human information. A biochip is designed to perform biochemical procedures for biomedical applications rapidly with least cost.

Nano fillers enhance carbon fibers and carbon quantum dots in order to improve its elastic properties and flexibility. As C Zhao et al. 2020 [14] introduced, bottom up and top down synthesis methods improves the optical and magnetic properties of Fe_3O_4 /GQDs nanocomposite. Such novel hybrid nanocrystal (NCs) is suitable for delivering nanocarriers to the tumor sites for imaging. The optical feature of this NC can be used as photo thermal therapy agents to kill cancer cells.

The primary goal of bioelectronics in nanomedicine is clinical translation of bio information. With the aid of AI, Carbon quantum dot plays a central role in transporting disease information and translating meaningful data. Bioelectronics technologies enable a personalized medicine system to monitor an individual's wellness, detect disease at the earliest stage, and measure the effectiveness of therapies. Bioelectronics technologies facilitate a method of identification and analysis of abnormal electrophysiological conditions. It is also used for modulating epileptic neuronal activities and the treatment of neurological disorder.

The advantages of fabricating carbon quantum dots are low cost, its abundance, and physical structures that can be modified to different structure by varying Rheology. Carbon quantum dots have remarkable excitonic states and emission spectrum. Carbon quantum dots have better stability compared to organic dyes, amino acids, metal nanocomposite. Singh et al. 2017 [15] illustrated that the biological compatibility as hydrophobic, low toxicity, and chemical stability, makes carbon quantum dots useful for biosensor, drug delivery, and bio imaging. By doping with suitable impurity such as nitrogen, the photoluminescence of CQDs can be quenched. As model workshop, the synthesis of carbon quantum dot is briefly presented.

METHODS

Synthesis Methods

Materials

The optical properties of carbon quantum dots are influenced by many factors. These properties are greatly impacted by synthesis methods, doping conditions, and sizes. Different materials have been used in the synthesis procedures. Some of the most important material used in the synthesis procedure are citric acid monohydrate (CA), urea, aqueous ammonia (NH_4OH, 25%), glycine, and ethylenediamine (EDA), Sodium dodecyl benzene sulfonate (SDBS), acrylic acid (AA), stearyl methacrylate (SMA), acrylamide (AM), potassium per sulfate (KPS), $CuSo_4$, $MgCl_2$, $FeCl_2$, BaC_2, CoC_2, $Pb(NO_3)_2$, $CaCl_2$, $CdCl_2$, $ZnCl_2$, and $HgCl_2$. These materials are as useful ingredient for the synthesis of carbon quantum dots. The research also reveals that compared to other quantum dots; green synthesized CQDs exhibit excellent water solubility and fluorescence emission. However, in this project, $FeCl_2$ is preferred. This is due to the fact that incorporation of $FeCl_2$ in the synthesis process increases the optical efficiency of carbon quantum dot 70-75% on average. Chitosan is treated with $FeCl_2$, and then annealed at moderate temperature.

Synthesis of Carbon Quantum Dots

Green Synthesis of Carbon Quantum Dots

A green synthesis method is one-step method and used for the synthesis of fluorescent carbon quantum dots from natural and mostly green medical plants. These methods of synthesis enable extractions of not only C-dots but also metal and semiconductor nanoparticles such as Ag, Fe, Al, Cu, ZnO, Fe_2O_3 etc. By using ginkgo leaves as carbon source, Q. Zhang, 2019 [16] had prepared cost effective, eco-friendly and blue fluorescent CQDs by hydrothermal method. Moreover, R. Meena et al. 2019 [17] were able to synthesis photo stable, biocompatible, affordable, and green fluorescent CQDs from Ayurveda medicinal plant. K Dehvari et al. 2019 [18] synthesized highly fluorescent carbon quantum dots from crab with a quantum yield of 14.5%. However, in my work, Chitosan is preferred due to its ability to form stable conformations, biocompatibility, enzymatic biodegradability and use in various field of medicine.

In the synthesis process above, Chitosan is preferred since it is biocompatible, biodegradable and by itself used for bioelectronics. C P. Jiménezet al. 2020 [**19**] demonstrated, Chitosan is obtained by deacetylation of chitin exhibiting physio chemical properties that are suitable for conformations and structures. R. K. Mishra et al. 2018 [**20**] revealed that Chitosan is excellent film-forming biopolymer, which is used as drug carrier, coating agent, gel former etc. In addition, its high strain and modulus make it useful for the synthesis of CQDs for flexible bioelectronics and biochips Figure 1.

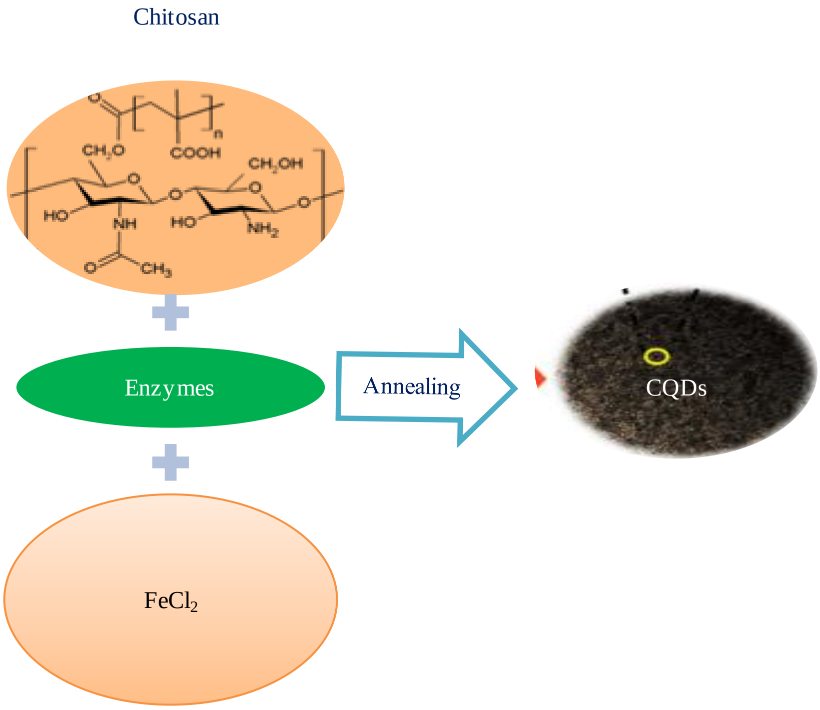

Figure 1. Green Synthesis of Carbon quantum dot.

Carbon quantum dots can also be prepared from leaves. CQDs synthesised from leaves have a quantum yield more than 50%. However, as Z. Wang et al 2021 [**21**] determined N doped CQDs prepared from the roots of Moringa oleifera via hydrothermal method exhibits a quantum yield nearly, 43% with acid treatment.

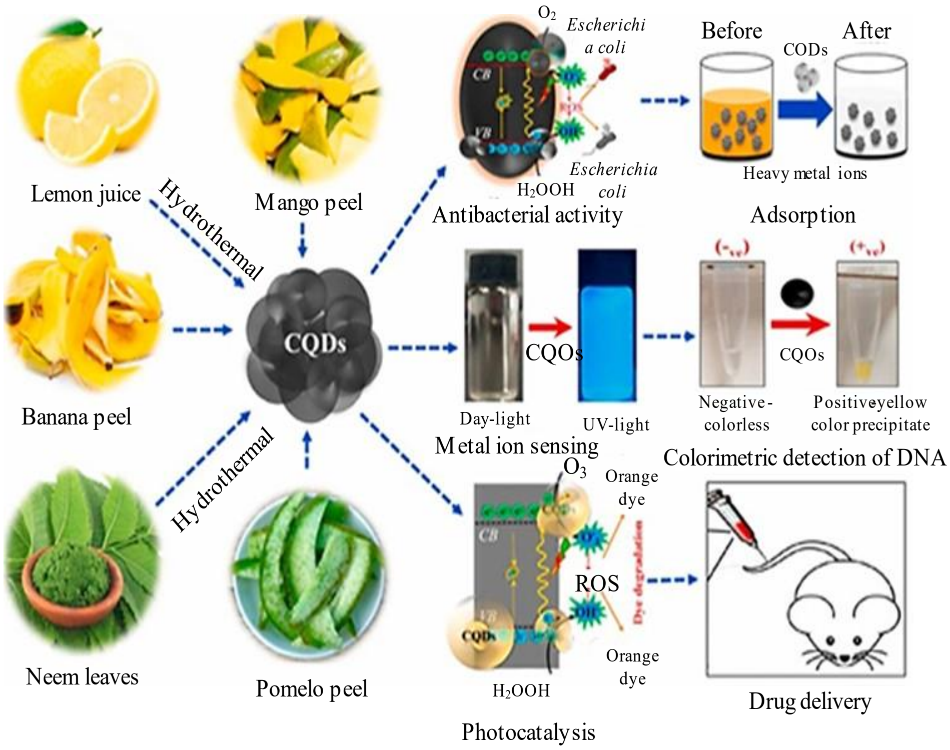

Figure 2. Green synthesis of carbon quantum dots from Kitchen green peels, leaves, & fruits, Velu Manikandan Nae Yoon Lee, 2022 [22].

As shown in the Figure 2 the precursor can be glucose, citric acid, Chitosan or proteins. The effect of precursor is to improve the shape, size, morphology, and its optical character. In addition to green synthesis method, carbon nano dots can be synthesized from Kitchen Waste. Carbon quantum dots synthesized from kitchen waste are versatile and amendable. Besides, food waste like rice, maize and others are used as a carbon precursor for the synthesis of CQD. The size and size-distribution of the CQDs produced in this way are dictated by the texture parameters of the nano - reactors.

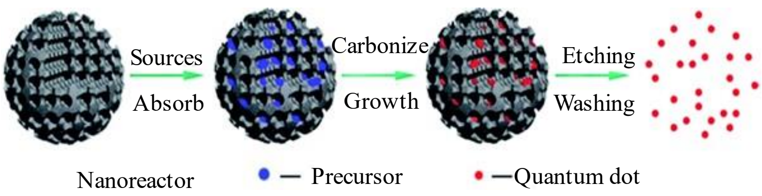

Figure 3. Schematic representation of green synthesis of CQDs via confined pyrolysis of an organic precursor in Nano reactor, J. Shen et al. 2012 [23].

The steps followed in the synthesis of carbon quantum dots used three steps as follows (i) Absorbing the organic precursor into porous nonreactors via capillary force,(ii) Pyrolysis of the organic precursor confined in the nonreactors into carbonaceous matter, (iii) Release of the as-synthesized CQDs by removing the nonreactors Figure 3.

Despite enormous research on CDs synthesis and its modifications, the real mechanism of CDs formation is not understood fully until date. Furthermore, simple and controllable surface modifications are still crucial problems, which may help for designing CQDs with excellent photoluminescence property and other applications with high efficiency. The selected methods may produce another toxic effect including production of carbon mono oxides and nitrogen di oxides. Searching an alternative might be essential. Hence, its energy gap is on average equal to the photon energy, $\hbar\omega$. The Intensity distributions,

$$I_f = \frac{\sigma_c V^2}{r} \tag{1}$$

Where, I_c is fluorescent intensity, σ_c is electrical conductivity of quantum dots, v is the potential difference between electrodes, and r is the separation between electrodes. In the derivation of equation (1), the electric field between electrodes is assumed uniform. Carbon quantum dots produced in this way have high dielectric constant, which enable them useful in electronic elements such as super capacitor.

Characterization/Instruments

X-ray photoelectron spectroscopy (XPS) is preferred instrument for characterizing the quantum dots. It is enable determination of elemental composition, the bond between molecules and binding energy and its optical properties. This technique is quite useful for characterizing organic and non-organic molecules. Carbon quantum dots, graphene quantum dots, and most carbon nanomaterials including nano diamonds can be characterized by this technique. A studies by T. Yu et al. 2018 [**25**] also show that CQDs synthesized by rapid microwave method can characterized by transmission electron microscopy, X-ray photoelectron spectroscopy and Fourier transform infrared spectroscopy.

Hemerson P. S. Castro et al. 2017 [**26**] has reported the optical characterization techniques such as photoluminesces, and spectral absorption coefficient for carbon quantum dots. Dinesh Kumar et al., 2014 [**27**] and Yin Cheng Yen et al. 2017 [**28**] have revealed that various techniques have been invented to characterize carbon quantum dots (CQDs). Some of them are UV-VIS., FT-IR, PL, XRD, NMR, TEM, FEEM HR-TEM TGA, XPS and Raman analysis. These devices help to analysis Crystallographic, topographic, and morphology of carbon quantum dots. Carbon nanodots produced by photo ablation have the advantage of synthesis control with good reproducibility to further investigate the optical properties of carbon dots, C-dots.

DISCUSSIONS

Carbon dots are superior materials for application in bio imaging, bio sensing, drug delivery, optoelectronics, solar cells, and optical lights. Due to their unique optical properties like photoluminescence, high quantum yield, high water solubility, chemical inertness, and less toxicity, it is used in optical sensors, nanomedicine, and environmental monitor applications. They are used in optical fibers, Ozone detectors, Antimicrobial and sensing organic molecules.

Sensitivity of CQDs

The sensitivity of Carbon quantum dots is affected by electric parameters. Specially, the luminescence, fluorescence and quantum yield are influenced by electric potential. The PL study of K K. Chan et al. 2018 [29] revealed that an applied voltage of 3V produce PL QY of 9.5%, which is 4.6% at 7V. F. Lisdat et al. 2013 [30] revealed that the quantum dot electrode can be modified by a specific recognition element (DNA, aptamers, and antibody. The research by Renée St. Amant et al., 2018 [31] shows that 1D & 2D structure as graphene layer, silicon nanowire, and carbon nanotube are essential in bioelectronics medicine and biosensing and offer better sensitivity. Hazal Gergeroglu et al. 2020 [32] realized that CNT-doped Chitosan film produce immunosensors which have high-sensitivity. Researches of Haitao Lin, et al. 2019 [33] indicate that the precursor immobilization of carbon dots increase its solubility.

Optical properties

A typical nanomaterial with recognized optical and electric property is quantum dots. An ordinary carbon dots have low quantum yield but it can be improved by doping and coating with organic molecules such as citric acid and Chitosan. Different method has been employed to improve the optical characteristics of CQDs. One of the major mechanisms is doping with variety of metals and non-metals. Most importantly, doping CQDs with chalcogens such as N and S increase the optical absorption and emission intensities greatly. Moreover, artificial intelligence (AI) and deep learning can help to detect, process high quality and big date to improve the optical property of CQDs.

The optical and electrical properties of carbon quantum dots depend on the synthesis methods. The photoluminescence study of J Liu et al. 2020 [34] reveals that carbon dots prepared by bottom up techniques exhibits higher quantum yield than grown in top down approach. The reports of D Yoo et al. 2019 [35] also show that optical properties of CDs can be easily tuned by the surface passivation of the organic layer and Functionalization of the CDs.

Table 1. The effects of metal and non metal doping of Carbon quantum dots (CQD).

Elements	Categories	Crystal structure	Effects
Ag	Metal	FCC	Improve Photocatalytic activity
Au	Metal	FCC	Enhance fluorescence
Dy	Metal	HCP	Nanocarriers
Fe	Metal	BCC/FCC	Quenching of fluorescence intensity
La	Metals	HCP	Luminescence performance and fluorescence intensity
Na	Metals	BCC	Enhance emissions (blue)
Mn	Metal	BCC Bravaise lattice	Quantum yield and fluorescence intensity
Sn	Metal	Tetragonal	Increase activation energy, produce energy quantization and light emission
Zn	Metal	HCP	Fluorescent intensity
F	Non metal	Monoclinic	Quantum yield and light emission
N	Non metal	HCP	Improves optical characteristic enabling efficient nanosensor
S	Non metal	Orthorhombic	Fluorescent intensity

The following table demonstrates some of the selected metals and nonmetals used for doping in order to enhance its optical properties.

As the table demonstrates, both metal doping and non-metal doping can improve the optical properties of carbon quantum dots, Most importantly, metals such as transition metals such as Mn, Sn and Zn can greatly enhance the optical properties of CQDs such as activation energy, fluorescence, and quantum yield. However, Fe^{+2}/Fe^{+3} produce quenching in absorption intensity. More, almost all non metals of Halogen families increase quantum yield, optical emissions, and fluorescent intensity.

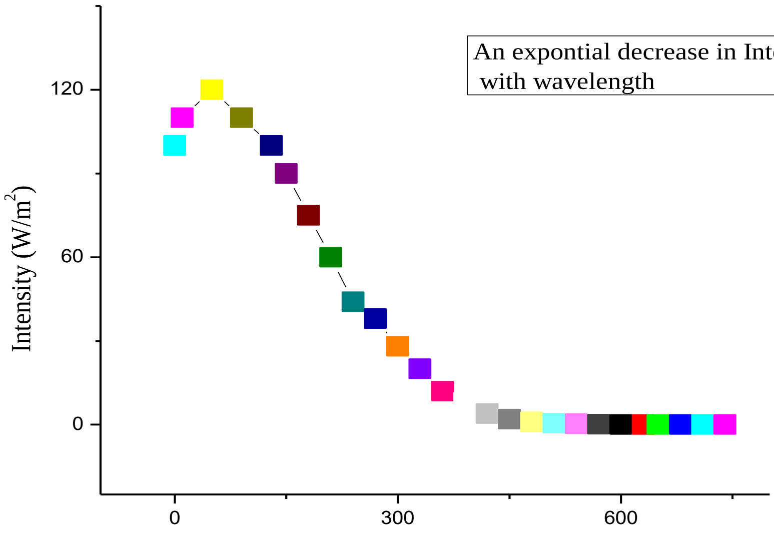

Figure 4. The change of absorption intensity with wavelength.

The graph is obtained by simulating intensity as a function of wavelength in the visible spectrum by using the Gaussian distribution. From the diagram, different color emissions are noticed describing the optical properties of carbon quantum dots. This color emission is observed in the electromagnetic wave spectrum. The wavelengths are an ideal for estimating the optical properties and its applications in optoelectronics, optical sensors, and nanomedicine. Investigation on the relation between, intensity and electrode potential reveals that for uniform electric field, intensity is directly proportional to square of potential difference Figure 4.

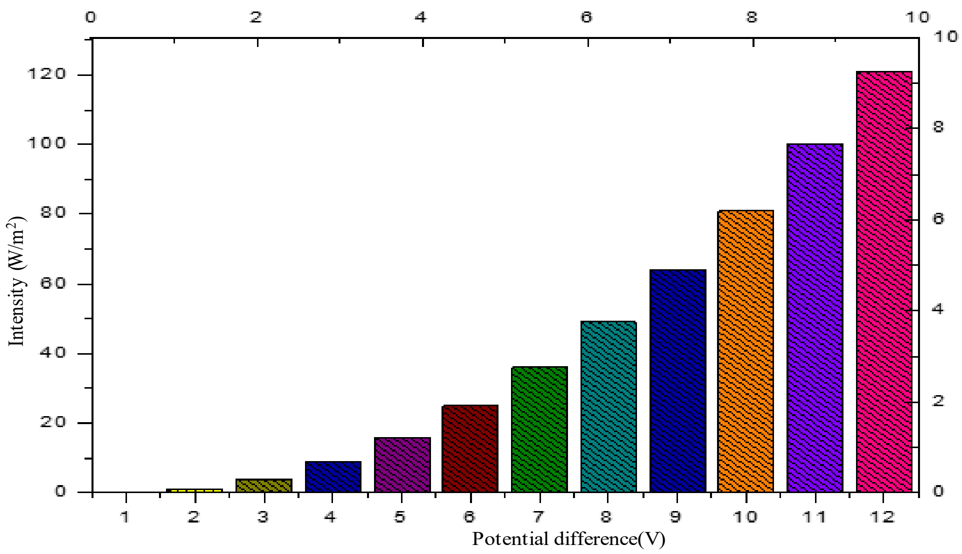

Figure 5. The relation between potential difference and Intensity of fluorescent CQDs.

Hence, increase the potential difference between electrons enlarges the fluorescent intensity by four fold. However, in real conditions, the intensity of quantum dots might vary depending on doping materials, nature of dielectric between electrodes; synthesize method, and substrate conditions. Thus, by controlling doping conditions, surface engineering and passivation, both electrical and optical properties of green synthesized carbon quantum dots can be modified Figure 5.

CQD as Detectors

The potential of carbon quantum dots as detector nanomaterials is greatly observed in nanomedicine and electronics. It is essentially use in combined applications of biomedicine and electronic s referred to as bioelectronics. Nanomedicine has been considered as an emerging technology of 20th century. It is an advanced application of nanotechnology and nanomaterials including carbon quantum dots in medicine for the purpose of improving efficiency, efficacy, biodegradations, biocompatibility, theragnostic and drug delivery system. As analytics of bioelectronics, CQDs enhance sensitivity and amplifications of biosensors and in vivo imaging. As Radwan, FAA 2018 [**36**] stated, nanomedicine involves at least three major fields, nano diagnosis, controlling the drug delivery (Nano therapy) and remedial and renovated medicine.

Carbon CQDs have high biocompatibility and moderate resistance to photo bleaching, and photoluminescence. These properties enable generation of electrical signal in device such as optoelectronics, photodiodes, photoconductors, and photo detectors.

As Siacheshm P. and Heiden P, 2022 [**37**] revealed, Carbon quantum dots exhibits 75% quantum yield with effective turn of fluorescent probe for Fe/Fe ion detection. Quantum dots (QDs) are nanoparticles that are emerging as promising probes for ultrasensitive detection of cancer biomarkers. Quantum dots including Carbon quantum dots and Graphene quantum dots are widely used as biomarkers, cell labels and detectors of virus. Their high refractive index, permittivity, and optically tunable frequency enable sensing organic solvents, like glyphosate and cancero us cells.

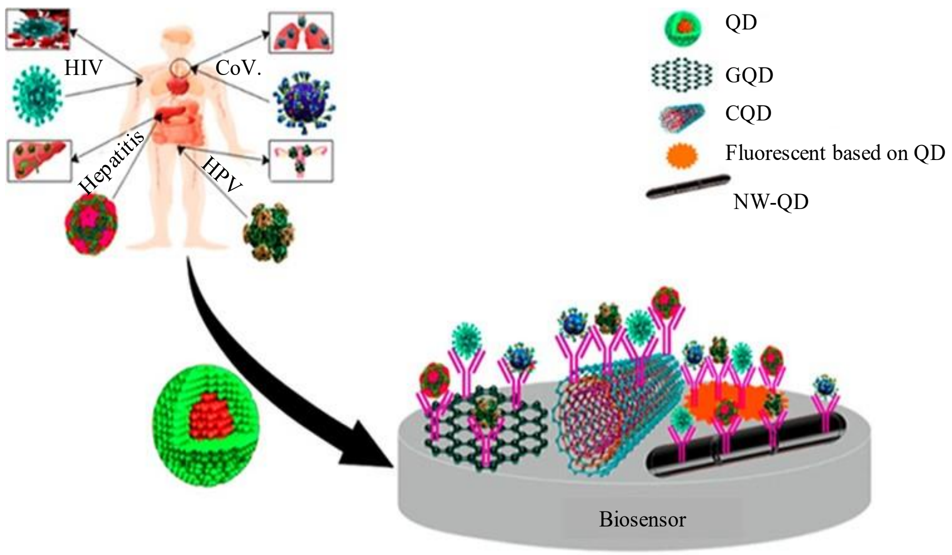

Figure 6. Quantum dots based nanosensor for detecting pathogen, virus, bacteria, etc., Mousavi, S. M et al. 2022 [38]

Carbon quantum dots are inevitably used in optical sensors and used for detection of heavy ions, biomolecules such as DNA, organic polymers, food safety, and biomedical diagnosis. In addition, Ying Chen et al. 2020 [28] flexible acoustic electronics serves as an acoustic signals detector. Biochips are designed for gene diagnosis and detecting organic solvents like glucose and organic semiconductors. Invention of bioelectronics technologies enables a personalized medicine to monitor an individual's feelings, detect disease at the earliest stage, and measure the effectiveness of therapies. CQDs synthesized from Chitosan precursor/wafer are used for tough sensor to detect locadyne hydrochloride, cell-imaging tool and as corrosion inhibitor Figure 6.

Bioelectronics in Medicine

Carbon nanotube, graphene, and carbon quantum dots are filler nanomaterials for conductive hydrogel. Carbon quantum dots are enhanced by Nano fillers increases the flexibility and softness of bioelectronics. Reviews of Moon Kee Choi et al. 2018 [39] indicate that flexible quantum light emitting diodes (QLEDs) is integrated as electronic components of sensors, memories, controllers, smart pressure-sensitive display, and Bluetooth units for the next-generation portable optoelectronic systems. Sung Hyuk Sunwoo et al. 2020 [40] the penetration of ions into the conducting polymers increases the volumetric capacitance of conducting polymers. This effect lowers electrical impedance and enhances charge-injecting capacity of bioelectronics.

Bioelectronics has revolutionalized nanomedicine. Patrick D. Gallagher et al. 2009 [**41**] electronic technologies have already revolutionized medicine with X-ray and MRI imaging technologies. Before the invention of print technology, the drug failure rate was very high. However, the invention of nanobased biochips, bioelectronics and optical sensors decrease the rate at a great percent. However, Atheer Award et al. 2018 [42] revealed, due to its flexibility, 3D print technology has revolutionized rapid identification of suitable drug, creates "organ – on-chip" designed to mimic the structure and functions of both human and disease tissue. As Conal Timoney and Robin Felder [43] researched, biochip technology can be adapted for detecting immunology, clinical chemistry, DNA profiling, fertility markers, drugs of abuse and antibiotic residues.

Carbon quantum dots can be used in bioelectronics cell electrode. In the blue wavelength spectrum, CQDs is employed for cell imaging. Fluorescent carbon quantum dots with green fluorescent protein, blue fluorescent protein, and yellow fluorescent protein is part of biochips.

The medical applications of bioelectronics include blood pressure measurements, electrocardiograms, and brain activity monitoring. Bioelectronics enable detection, characterization, and measurement of biological materials at molecular and particle level which make interaction of carbon quantum dots easier for drug delivery and kinesis. In order to enhance its kinesis 1) a little change in temperature, 2) activating the QD crystal by photon and decreasing the particle size to strengthen particle confinement, and 3) doping with metals and non metals to enhance fluorescence and quantum yield is greatly advised.

As Chad Bouton, 2015 [44 discussed, bioelectronics medicine involves electrical stimulation in the nervous system (neurostimulation) targeted for diagnosis, lowering blood pressure, promoting nerve and bone growth, wound healing and treating Alzheimer and cancer.

Carbon quantum dot have high quantum yield and fluorescent at wide range of optical wavelength spectrum. Hence, it has extremely low optical flicker. It is essential nanomaterials in cancer therapy, cell imaging, and targeted drug delivery. QDs attached to antibodies, aptamers, Oligonucleotides, or peptides can be used to target cancer markers. Currently Anuja Vibhute et al. 2022 [45] reported that CQDs can penetrate cancer cells, due to its biocompatibility & stable optical properties. Cancer cells can be detected by fluorescence imaging of CQDs. Although carbon quantum dots are valuable nanomaterials, its quantum yield is low. Moreover, it has ability to form poison gases like CO and CO_2 which have capacity to cause inflammations at the walls of lung, kidneys, and weakens the breathing rate by producing bronchitis. For this reason, its effect on cell imaging is weak. Hence, optimum doping with transition metals, halogens, and some inert metals is advisable. Besides, coating with magnetic oxides such as Fe_2O_3, ZnO, TiO_2, and natural polymer such as Chitosan will is predominantly improve its optical and biomedical application. Moreover, the composites of these materials improve it in treating skin disease, neural disease, bone imaging, tissue engineering, and wound healing.

Finally, upgrading the optical properties of CQDs such as fluorescence in the UV- near to infrared region, its biomedical applications can be universalized.

CONCLUSION

Carbon Quantum dots (CQDs) are versatile material in bioelectronics and nanomedicine. They are recognized for the optical properties. They can be synthesized in many ways. In this research, green synthesis is given attentions due to its ecofriendly, cost effective, and best fit for photoluminescence applications. In the synthesis processes, Chitosan is used as a source of carbon. This is because Chitosan plays principal role in improving the optical properties of carbon quantum dots. Different techniques have been proven for the characterization of carbon nano dots (CQDs). These techniques are UV-VIS, FT-IR, PL, XRD, NMR, FEEM, HR-TEM, TEM, TGA, XPS and Raman analysis. The study of optical property reveals that CQDs emits light in visible electromagnetic spectrum. The analysis of optical property reveals that the absorption intensity is directly proportional to the square of potential difference between electrodes. Due to its tunable band gap, wavelength, and frequency, carbon quantum dots are proven useful nanomaterials in flexible bioelectronics, biochips, nanomedicine, cell imaging, drug delivery & kinesis, photo catalyst and spectroscopic studies. The study reveals that carbon quantum dots have great promise for detecting microorganisms such as viruses, bacteria, antimicrobial, and organic solvents. They are also designed for optical sensor for the detection of heavy metal ions, biomolecules, human feeling, and disease. As biomedical applications, optical sensors made of CQDs are used in measuring blood pressure, diagnosis, bio imaging, and theranostics applications. Although green synthesized carbon quantum dots are multifunctional nanomaterials, they have low quantum yield and produce poison gases like CO_2. This limits the biomedical applications of CQDs. Moreover, optimum doping with metals, and chalcogen & halogen families, surface passivation, coating with magnetic oxides, and the use of AI moderating optical properties and disease treatment at the point of care is encouraged.

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