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Applications of Quantum Dots

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Abstract- Quantum dots are also called fluorescent nanocrystals that play an important role in biologi- cal and bio-medical fields. They are well-known for their drug-delivering capabilities and cellular imaging. In electronics perspective, quantum dots act as semiconductor nanoparticles that ex- hibit unique optical properties such as size- controlled fluorescence that is being used in quantum dot televisions, high quantum yields, and stability against photo bleaching. Carbon being a very important element in chemistry has an important role in the applications of quantum dots as well. Graphene, a carbon compound, is introduced with the concept of Graphene Quantum Dot or GQD.

Keywords- Quantum Dots (QD), Fluorescent Nanocrystals, Nanomaterials, Drug Delivery, Cellular Imaging, Semiconductor Nanoparticles, Size-Controlled Fluorescence, QLED, High Quantum Yield, GQDs.

I. INTRODUCTION

There has been an immense advancement in nanoparticle surface chemistry with the help of many fluorescent polymer-encapsulated probes that are stable. Quantum Dots (semiconductor nanocrystals) are treated as an important tool in biomedical research fields. The base rule for working with quantum dots is related to their unique properties that are not associated with other semiconductor solids.

As per Taylor and Francis, "Quantum dots are currently limited to cell and small animal uses due to its probable long-term in vivo toxicity and degradation." Since the sensitivity of optical imaging is very high, Quantum Dots can act as an ideal prototype to make use of biocompatible carriers for clinical purposes.

Quantum Dots have many characteristics like controllable fluorescence emission, very high bright- ness, a good quality of electronic properties, etc. In addition, they are a good choice for organic dyes in terms of photo bleaching stability and chemical degradation stability. The spectral overlapping is much reduced due to the narrow spectra of Quantum Dots

II. METHODOLOGY

The classic definition according to ISO is a "nanoparticle or region that exhibits quantum confinement in all three spatial directions." [1]. The quantum dots exhibit various properties like –

1. Physical Properties

Since the quantum dot has confinement in all directions, the Graphene Quantum Dots are said to have the properties of Quantum Dots. The graphene and graphene oxide atoms have the sp-2 hybridized carbon atom of one hexagonal array, they also have the functional group that contains oxygen with some latter containing defects throughout the edges of the lattice. The property that differentiates the GQDs from other quantum dots is their crystalline structure. We can evaluate the composition of the complex GQDs with the help of XPS (X-ray Photo electron Spectroscopy). The desired properties of the GQDs are obtained by altering the chemical composition as well.

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2. Electronic Properties

The GQDs exhibit electronic properties based on the arrangements of the electrons within them. They have a unique electronic structure as compared to other quantum dots. The bandgap formed by the valence electrons is zero hence, graphene is known as a zero-energy bandgap substance. These properties can also be altered with the help of different functional groups.

The GQDs also have several properties like Photoluminescence, Magnetic Properties, Biological Properties,

There are different methods of synthesis of quantum dots

Hydrothermal Cutting

A high amount of temperature and pressure is used to convert the precursors into GQDs after a strong amount of oxidation with suitable chemicals. This method is used to synthesize the size and changeable color properties of the GQDs.

Solvothermal Cutting

This method consists of organic solvents such as benzene, DMF, dimethylsulfoxide, etc instead of water. Each type of solvent determines the size of GQDs.

Microwave-Assisted Method

This method is quick as compared to the above two methods. The GQDs have the initial greenish-yellow glow with the help of this method in which they are cleaved under specific microwave conditions

Oxidative Cleavage

According to T.K. Henna, and K. Pramod "The principle of oxidative cleavage is the breaking of carbon-carbon linkage present in precursors such as graphene, graphene oxide or carbon nanotube by acid treatment." This involves different oxygen functional groups with GQDs.[2]

Functionalization

This is a concept that involves the transfer of charge between the functional groups that leads to the luminescence of the GQDs. Functionalization involves several methods such as Heteroatom doping, Functionalization with polymers/organic molecules, Carboxylated GQDs, etc [2] Functionalization can be achieved by Heteroatom doping, with polymeric molecules

Heteroatom Doping The fluorinated graphene contributes to generating the fluorinated GQDs. They are also called F-GQDs which have remarkable optoelectronic properties. The major ad- vantage of F-GQDs is that in acidic as well as alkaline medium, they show stable luminescence regardless of the pH level. They are 4 to 5 times more paramagnetic as compared to traditional GQDs.

Along with Fluorine, Nitrogen, and Sulphur GQDs are also there that support better catalytic properties

The polymer GQDs obtained by doping the primary amines. They contribute towards the tunable photoluminescence of GQDs.

The carboxylated GQDs are mostly multi-colored and help to produce a higher yield of the quantum well. It is achieved by some Solvothermal methods. They are highly soluble in water as compared to traditional and other GQDs. The colors they hold are primarily red, green, blue, fluorescent yellow, and indigo.

Biocompatibility and Toxicity of GQDs

To satisfy the compatibility with the body, every organic material should be checked to work as a biological application. Such materials should be non-toxic.

The GQDs' cells and tissues can be tested to determine their toxicity. A study was conducted to check the toxicity of N-doped GQDs. It involved the prolonged exposure of nematode strains of "Caenorhabditis elegans"[2]. In conclusion to this, the N-GQDs came out to be non-toxic and safe for offspring as well. This study mainly included the difference in the levels of toxicity of the GQDs and graphene oxides.

Synthesis

There are two approaches to the synthesis of GQDs. One is top-down and another is bottom-up. The top-down methods include Hydrothermal Cutting, Solvo thermal Cutting, Methods assisted by Microwave, Oxidative Cleavage, and Electrochemical Exfoliation whereas the bottom-up methods are Pyrolysis of the Precursor and Cage-opening method of the catalyzed Fullerene [2]

Graphite, Graphene Oxide, Carbon Fiber, etc are the primary contributors to the oxidative cleavage method. Except for these carbon compounds, some strong acids are used as well. The cheapest among all is coal. Coal is much more beneficial because it can be easily cleaved due to its weak amorphous carbon chains.

On the other hand, bottom-up methods involve the use of smaller precursors. The synthesis is carried out with the help of focused morphological techniques as well as some singly dispersed particles. It involves stepwise organic synthesis, precursor pyrolysis, and hydrothermal synthesis carried out using microwaves.

III. APPLICATIONS

1. As Drug

Some special features and tasks of GQD are used in medical applications. We know the transport capacity of the drug GQDs and other carbon nanostructures. In addition to the courier, she too works as a good therapeutic agent in some pathological conditions. Low offer The toxicity and good biocompatibility of make it suitable for biomedical applications questions. This opens a new window in therapy and treatment. In some cases when GQD acts simultaneously as a therapeutic agent and drug carrier.

2. GQDs in Neuro-Degenerative Disorders

With the different types of chemical bonding of GQDs and functional groups on different positions of the structure of GQD, it can be very useful in the treatment of neurodegenerative disorders like Alzheimer's. [3]

3. GQD against Diabetes

The identification of Diabetes is in the levels like type 1, type 2, etc. GQDs help to cure type 2 diabetes with its peptide aggregation. For such cases, we can make use of a highly electronegative compound of GQD which is fluorinated GQD.

4. GQD against Cancer Cells

The combination of different cancer therapies that involve GQD, makes this treatment a bit more rapid as compared to chemotherapy. GQDs have a remarkable helping spot in terms of oncology.

5. Bio Imaging

Bio imaging is an important method used in both cases research stations and clinics that enable bio observation logical processes such as targeted delivery, cellular uptake bio distribution of therapeutic agents isolated and detailed using different parts of the electromagnetic spectrum.[10,57,101]The role of imaging techniques is particularly important in the diagnosis of cancer, as sensitive imaging enables early diagnosis of cancer, as well as the identification of metastases and recurrence tumors. The inter- nal PL of GQDs allows their use as optical probes in fluorescence imaging without further restrictions of fluorescent dye, as required for other nanosteamerstile platforms. Recent developments have ex- panded the scope of application of GQDs in bioimaging because they have demonstrated their ability billion for NIR fluorescence imaging and MRI imaging. Combined with excellent biocompatibility are GQD simaging probes ideal for use in various modalities images.

Fluorescence Imaging

Fluorescence imaging is an important tool in biomedicine, which use visible light and NIR spectra for analysis. Distribution of molecules of interest in cells, tissues and whole animals. Use specific molecules indicated PL as probes, in both cases fluorescence imaging is often used laboratory environments and clinical practices for such applications as cell tracking, monitoring subcellular therapies. Imaging and disease diagnosis. The most commonly used in vitro fluorescent probes are fluorophores, in vivo and ex vivo. An important

determining factor in Whether the material can be used in the body depends on its solubility. Very often fluorophores are poorly soluble in water and often require water solubility additional bio conjugation steps to make it soluble in the body fluids. When substances that are not soluble in water get into the water. The bodies will likely be bundled and marked for disposal the body's own immune system or, if supplied in sufficient quantities, can cause catastrophic damage such as blockages. Blood flow after entering the vascular system. fur In addition, organic fluorophores have been shown to be toxic.in large doses.Interest in semiconductor QDs such as halogens The number ofcent probes is increasing due to their optical properties. Bonds like CdSe, these QDs require a surface coating Polymers or ligands that become soluble in water.The quality of semiconductor QDs and their quality has long been a problem. The ingredients of were found to be toxic and not completely transparent. Toxins in the body can cause chronic tissue damage.In the case of GQDs, their intrinsic solubility in water is low The placement toxicity of, GQDs has been widely reported as a viable fluorescence imaging platform.

Vivo Optical Imaging

In contrast, in vitro imaging serves as the primary demonstration of the fluorescent probe's capabilities in optical imaging.In vivo imaging is challenging in comparison. Because several factors such as in vivo biology need to be taken into account, biotoxicity and dynamic metabolismorganisms tested. May be an indicator of a young professional points in GQD studies, so many studies use GQDs for in vivo applications such as cell tracking and nuclear energy Directions to. Annexin V modified GQDs (A5) were used for the demonstration. Ability to track apoptotic cells in zebrafish. Fluorescents of the GQDs synthesized from neem leaf extract were conjugated to A5, which is commonly used to detect apoptosis with other fluorescent probes. Modified green fluorescent protein (EGFP) (A5-EGFP), transgenic, enhanced A5 fusion zebrafish and zebrafish were treated with A5-GQD.EGFP and A5- GQD illuminated a similar area of zebrafish, suggesting that A5-GQDs were capable of targeting apoptotic cells. Although there is much more research must be run before obtaining results in the zebrafish model can be translated and reproduced in a mammalian model, This study implicates the feasibility of monitoring apoptotic cells in vivo using a GQD-based probe.In another study GQD cells synthesized from graphite were used to trace human adipose stem cells (hADSCs) in a mouse model Two-photon fluorescence microscopy. Two-photon fluorescence microscopy The spectra ofPL showed emission wavelengths from 400 to 520 nm with and without excitation from 680 to 860 nm Cytotoxicity or inhibition of cell function. hADSCs were treated with GQD, encapsulated in hyaluronic methacrylate acid hydrogel injected and injected into the back areaathymic mice. When irradiated at 670 nm, a clear fluorescence signal was observed after just 24 hours. In these two studies, GQDs retained their PL properties without significant photo bleaching and did not show significant toxicity or insolubility in aqueous media in vivo. These studies indicate that GQD-based systems can be used as fluorescent probes for cell tracking, unlike traditional organic dyes. In addition to optical imaging in the visible region, GQDs are also used for NIR window imaging and MRI imaging The extraordinary versatility of GQDs as a bio imaging platform. By increasing the signal intensity of GQDs, such as monitoring metastasis cells or immune cell stagging using GQDs could be within reach.

MR Imaging

MRI imaging uses radiofrequency signals to change rotation protons are present throughout the body to maintain anatomy images and observe physiological processes. MRI imaging is the preferred modality for clinical imaging due to its lack of invasion vivid characters, high spatial resolution, and virtually unlimited Tissue penetration depth. Contrast media (CA) can be used for this purpose. Highlight the studied biological properties by creating brighter (T1 CA) or darker (T2 CA). Even if there is progress was prepared on T2 CA using safe super paramagnetic iron oxide, CA T1 are generally limited to transition metals ionic chelates, especially those based on gadolinium (Gd). AsIt is well

known that transition metals are toxic to the body. Recently, Gd- and-based ACs have been shown to cause nephropathy. systemic fibrosis genes and accumulate in tissue after chronicity. [119-121] Various modules are used to solve toxicity problems. doped graphene nanomaterials have been tested as safe,metal-free alternatives to transition metal-based alternating current

Bio-sensing

In addition to bioimaging, the optical properties of GQDs for use in biosensors. Both in bioimaging and biosensing applications use PL-GQDs and require discovery photons are emitted, allowing the use of GQDs in bioimaging isolated views of specific cells and tissues of interest and increased contrast in MRI images. On the other hand, the role GQDs in biosensor systems enable presence detection and display biomolecules. As already mentioned, an exchange of electrons The structure of the edge groups can change the optical properties GQD. GQD-based biosensors exploit the affinity between specific functional groups within the GQD and the biology of the analyte molecule. If the functional group to which it is conjugatedGQD binds to the analyte, the relationship between the pair can offer different electronic states. Changing the electronicsGQD the analyte can then be detected measured as change in PL intensity. Based on biosensor systems It was found that on GQDs are capable of producing ions, DNA, and various other metabolites.[99,123] Biosensing requires high dosesSelectivity, Sensitivity and Simplicity – PhotostabilityGQD and rapid response of PL-based systems set GQDwill be a promising biosensor platform.

Therapeutic Applications

The physicochemical and biological properties of GQDs have led to this for their use in therapeutic applications. Variety of functions The groups available on the periphery of the GQD can be combined targeted ligands and therapeutic agents. In addition to the Edge functionion groups, presence of sp2 hybridized carbon in GQDs The grid allows the use of therapeutic molecules, which often also contain aromatic cycles to be associated with the basic plans of the GQD, increases drug loading capacity and allows for more effective active ingredient release. In addition to chemotherapy drugs GQDs have been reported to provide DNA for gene therapy. Furthermore, GQDs can improve ROS generation incident radiation, which enables use in PDT.

IV. CONCLUSION

Quantum Dots play an important role in the fields of biology as well as technology. It serves as a matter that helps the treatment of harmful diseases as well as has an application like Quantum TV in the field of electronics. The randomness of the electrons of the same structure can have an impactful spectrum of uses in almost every industry. The Graphene Quantum Dots exhibiting the properties of quantum dots provide us with a variety of applications in the biological world. We cannot just forget about the amount of ease it serves for various complex problems.

Scope

The future scope of quantum dots includes the vast scaling of photoluminescence properties on different devices, the advancements in bioimaging for cell treatments, drug delivery abilities and biosensor fabrications.

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