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Analytical applications of quantum dots: Their utilization in sensors, diagnostics and environmental monitoring

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Abstract

Quantum dots are very small particles, about one nanometer across. They are made up of a heavy metal core, like cadmium selenium or cadmium telluride, an unreactive zinc sulfide shell, and a customizable outer coating of different bioactive molecules made for a certain use. Due to their unique chemical make-up and very small size, quantum dots have very stable fluorescent optical qualities that can be easily changed by changing their size or chemical make-up. If quantum dots are excited, they can give off light. The lighter the dot, the stronger the light it sends out. Since dots can be made to give off a range of colors, it seems likely that they could be used as biosensors. Quantum dots don't break down as quickly as the dyes that are currently used as biosensors.

Keywords: Quantum dots; Fluorescence; FRET; Magnetic nanocomposites

1 Introduction

The three-dimensional shape of quantum dots (QDs) is constrained to that of a roughly spherical nanoparticle, usually with a diameter ranging from 2 to 8 nanometers. The number of atoms in a particle might range from a few dozen to several thousand. Quantum dots exhibit unique electrical and optical characteristics due to their microscopic size. "Artificial atoms" describe these particles because of their atomic-level behavior. One property of quantum dots (QDs) is their composition-dependent band gap energy, which varies with nanoparticle size. A wide Stokes shift, great brightness, long fluorescence time, resistance to photobleaching, and a wavelength that may be adjusted are some of the unique optical qualities. Due to these characteristics, QDs have recently garnered a lot of attention from the medical and biological communities.

2 Analytical Application of quantum dots

2.1 Fluorescence

Recall that quantum dots (QDs) have recently come into their own as outstanding fluorescent materials for use in a wide variety of biological applications, offering significant benefits over similar organic molecular probes. In fact, from a chemical analysis standpoint, QDs' photoluminescence properties are their most important characteristic. Fluorescent analytical methodologies have taken advantage of quantum dots' (QDs') ability to absorb light across a wide bandwidth while emitting light across a narrow spectrum; the intensity of the emission is dependent on the quantum yield, which is influenced by the surface interactions formed between the QDs and the target analyte.

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2.2 FRET

Forster resonance energy transfer (FRET) has grown in importance over the last few decades as a powerful tool in physical chemistry and biology. Perrin and Forster were the first to describe conceptually how energy can be transferred from an excited electron state of a donor (or sensitizer) chromophore to an acceptor chromophore over distances of up to 10 nm. FRET works best when the orientation factor, the overlap between the donor and acceptor's emission and absorption patterns, and the distance (r) between them are all taken into account. Because their photoluminescence changes depending on their size, QDs are great providers in this way (Fig. 1). Being able to change the size of the QDs during synthesis basically lets you change this parameter (r). It also lets you match the QDs' emission wavelength with the acceptor's absorption maximum, which lets you make and tweak sensing systems that are more sensitive. A lot of studies that have used QD-based nanosensors have shown that organic colors can act as acceptors and QDs can act as FRET donors. However, the opposite situation, in which organic colors act as donors and QDs as acceptors, has not been used very often. While quantum dots have been used with continuous flow analysis systems and other automated analysis methods for FRET-based tests, not much attention has been paid to those studies. in chemistry and biology. There aren't even many examples of using QDs-based FRET with microfluidic systems that have been written down.

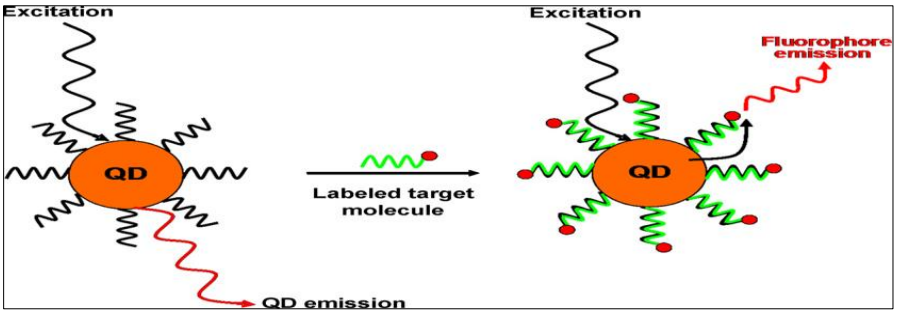

Figure 1 FRET process for QDs

In 2006, Zhang and Johnson (2) wrote about a new way to make quantum dots (QD)-based nanosensors more sensitive so they can pick out single molecules moving through a capillary flow. We used QDs to make biosensors that can find DNA quickly and correctly. Streptavidin-coated QDs are used as FRET donors in these biosensors, and cyanine dye (Cy5) is used as an acceptor. Cy5-labeled 25-mer DNA (ssDNA) and double-stranded Cy5-labeled 25-mer DNA (dsDNA) were attached to the 605QD surface to get it ready. Together with 605QD, DNA, and Cy5, the enzyme bound to dsDNA and ssDNA. They showed FRET between 605QD and Cy5s when excited at 488 nm. They proved that the FRET rate went up as the DNA-to-605QD ratio went up in both the 605QD/dsDNA/Cy5 and 605QD/ssDNA/Cy5 complexes. This is because many groups of dsDNA or ssDNA were marked with Cy5 on each 605QD. ssDNA could twist and turn into a random coil shape because it was easier to breakdown in water. The Cy5 acceptor was moved closer to the 605QD. This made the 605QD/ssDNA/Cy5 complex work better for FRET than the other complex. It worked better for FRET of 605QD/DNA/Cy5 complexes in the capillary stream because the DNA was bent there more than in bulk tests. We quickly combined microfluidics and QD-FRET to see how chitosan/DNA polyplexes put themselves together in a laminar flow. The same conjugates QDs (605QD) were used for this (3). At 488 nm, the 605QD is active and is used as a FRET donor. The Cy5 is used as an acceptor. They were then tagged with chitosan and plasmid DNA (pDNA). To see how the pDNA and chitosan reacted with each other, FRET signs were used. When QD-FRET and microfluidics work together, scientists say they could make a new platform that lets them watch basic processes very accurately and in great detail down to the millisecond level. Biosensors on QDs that are fixed in a microfluidic device driven by electrokinetics were used in a solid-phase nucleic acid test that was shown not long ago. One set of oligonucleotides held other sets of oligonucleotides in place on a microfluidic tube, and the other set of oligonucleotides worked as a probe to connect with the target nucleic acid in the sample solution. A CdSe/ZnS quantum dots (QDs) that gives off green light was added to each line. To keep an eye on the signal during hybridization detection, the target oligonucleotide sequences were marked with Cy3 and CdSe/ZnS QDs were used as a FRET donor. A common way to describe chemiluminescence (CL) is as the process by which a molecule gives off light when chemicals mix with it. Recently, researchers have switched their attention from molecules to CL of nanomaterials systems in order to find more uses for this mode of detection and make it more sensitive and stable. This is mostly because nanoparticles have a large surface area and a unique structure. Basically, most CL processes have weak luminescence because they don't use quantum wells very well. To get around this problem, sensitizers made of fluorescent materials with high quantum yields can be used. A lot of people are interested in these QDs because they are bright, reactive, and can be tuned to a continuous band gap. When you use QDs as chemiluminescence emitters with CL tools that can tell the difference between wavelengths, you can label things in more

than one color over a wide range of frequencies without the need for an excitation light source (4). It might also be possible to use nanocrystals of different sizes that target different molecules together for multi-parametric tracking. There are three main ways that QDs can be useful in a CL reaction: (i) as an emitter species after direct oxidation; (ii) as a catalyst for a reaction with other luminophores; or (iii) as an emitter species after CRET. It might be hard to figure out what the QDs in a CL discharge are used for. When QDs are the last emitters, for example, it's hard to tell if the CL generation process is linked to the direct oxidation of QDs or a CRET event. There are times when both methods may work at the same time. On the other hand, when QDs are the only glowing chemicals in a CL system, it is likely that direct oxidation took place in the big picture. When a luminophore is added to the reaction plan, the process can be either CL catalysis by the QDs when the luminophore is the last emitter or CRET when the QDs are the last emitters.

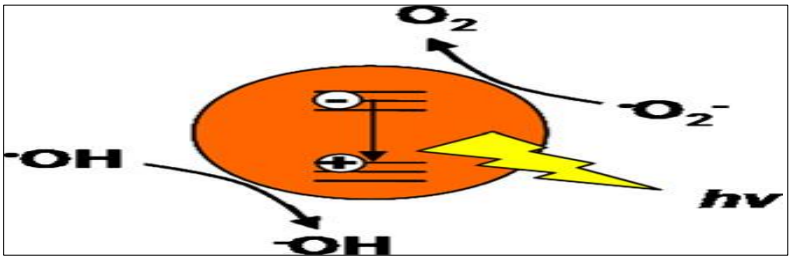

Figure 2 Chemiluminescence emission process for QDs

2.3 Electrogenerated chemiluminescence (ECL)

In electrochemiluminescence, also called electrogenerated chemiluminescence, there is an electrochemical process that happens before the reaction that gives off light. Electricity moves from one place on an electrode to another, creating excited states as energy is released. Then, these species go through a process that lowers their energy and gives off light (Fig. 3). ECL not only shows the good things about chemiluminescence detection, like its high sensitivity and wide concentration range, but it also promises extra benefits. These include better selectivity, wider analytical use by changing the electrochemistry of the analyte, and better spatial clarity for detection because the time and place of the light-emitting reaction can be controlled. Quantum dots can make light when an electric potential is applied, first in a non-aqueous medium and then in water. This is in addition to their photoluminescent and chemiluminescent properties. Even though a lot of success has been made in these areas, a lot of people still don't know the basics of ECL systems based on QDs. The three main types of ECL processes used to describe quantum dots are annihilation, core actant ECL, and cathodic luminescence. In annihilation ECL, electrons are transferred between oxidized and reduced species to make cation and anion quantum dots radicals. This process doesn't need any extra chemicals for emission. It's important that the chemicals stay stable and that the negatively charged radicals that are made can keep their charges until they combine and destroy each other, making the excited species that give off light. A process called cathodic luminescence happens when heated electrons are pumped into water-based electrolyte solutions during electrolysis. Core actant ECL is the most common method. It uses a one-way potential to start a reaction between a luminophore and an extra chemical (core actant), which usually makes luminescence work better. Electrons can only move between the core actant and the QDs species that are made electrochemically. Chemicals like oxalate, hydrogen peroxide, peroxydisulfate, tri-n-propylamine, and others have been used as core actants. Only a few studies, all of which came out in 2011, use automatic methods, even though there are many ECL analytical programs that use QDs nanotechnology (7, 8). The work of Wan et al. (9) suggested using TGA-capped CdTe quantum dots to make a flow injection electrochemiluminescence (FI-ECL) sensor that could find durabolin in food samples. For ECL tests, the QDs were put together by themselves layer by layer on ITO glass, and the slide was crammed into a makeshift flow cell. The amount of layers used affected how well the system worked; 4 layers were found to have the highest ECL intensity. As the main drug, durabolin increased the ECL emission linearly at concentrations between 1.0×10−8 and 1.0×10−5 gmL-1.

It was possible to identify up to 2.5×10−9 mL−1. The newly made FIECL had high sensitivity and sample output, and it was also very cheap. Jinjin et al. (10) came up with a different way to measure dopamine very accurately in cerebrospinal fluid by using flow injection analysis ECL. The authors made the ECL working electrode by sticking a mix of carbon nanotubes, chitosan, and CdTe QDs with a TGA cap on ITO glass slides. This electrode was then used to build a 300-nL flow-cell. Triethylamine was used as a coreactant to boost the ECL emission up to a value of 40 mM. It was proven that the excited CdTe QDs transferred energy to the oxidized dopamine products during sample tests, which proved that the QDs had an ECL quenching effect. The lowest concentration that could be found was 3.6 pM, and the measured range for it was 10 pM to 4 nM. The flow-cell that was made is expected to be used in microfluidic devices.

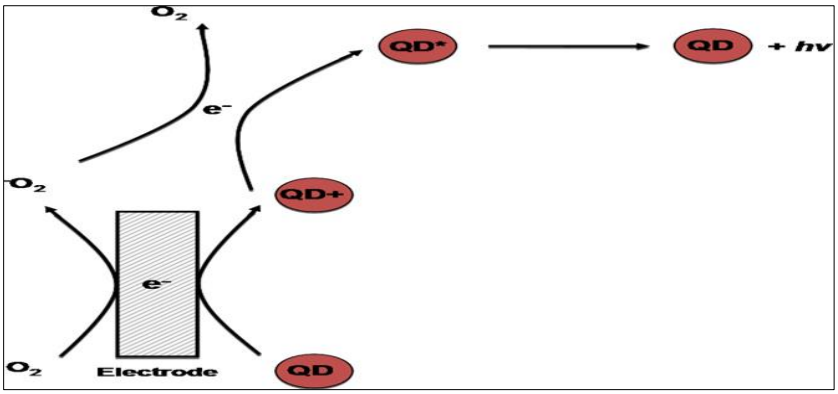

Figure 3 Electrochemiluminescence of QDs

2.4 Liquid chromatography

Liquid chromatography is a well-known way to physically separate mixes. It uses the analyte's movement between a stationary phase, which is usually a solid, and a liquid mobile phase. The amount of separation that can be done depends on the interactions (ion exchange, adsorption, partitioning, affinity, size exclusion, etc.) that happen between the sample and the fixed or mobile phases. High performance liquid chromatography is now the standard for current chemical analysis and many other fields. It may also separate the mixture into its individual elements in a single step, in addition to giving a quantitative estimate of each part.For a liquid chromatography method to work well for analysis, it needs to be able to separate things correctly and measure and identify them in real time. The main things that LC detectors do are electrochemical readings, mass spectrometry, UV/vis spectroscopy, and fluorescence spectroscopy. There should be little noise in an LC detector, and it should be very sensitive, respond quickly, and have a large linear dynamic range. Fluorescence has become an important way to identify things in liquid chromatography (LC) because it is selective, sensitive, and doesn't cause instrument instability because it has a very low light background. One big problem is that there aren't any substances that glow over a range of wavelengths that can be used. With this in mind, QDs can be used as LC labels to help with signaling and identifying analytes in a way that is similar to capillary electrophoresis 11–17. Adding different biomolecules, like proteins and immunoglobulins, to QDs gives them the specificity and sensitivity they need to find a particular analyte in a multiparametric array analysis. This makes it possible to quickly identify multiple analytes at the same time. Quantum dots (QDs) have a huge analytical potential, but they have not been used as labels for compounds in standard liquid chromatography methods. It has been suggested that size exclusion chromatography (SEC) could be used to separate QDs and QDs-conjugates from sources. The first study in this area (18) used HPSEC to separate the waste products that were made when cohesin and dockerin protein chains were bound to CdSe and ZnS. There were two main types of bioconjugate species that could be told apart: clusters of cohesin/dockerin-QDs, which had the biggest molecular mass, and clusters of single QDs with protein conjugate, which were found later in the elution process. The study also showed that recombinant protein polymers that put themselves together have strong interactions with CdSe/ZnS quantum dots. An SEC method was suggested by Wang et al. (19) to measure how much polymer is attached to the QDs' surface and to get rid of any free polymers from the QDs during the conjugation process. Using nanocrystals as fluorescent markers, we measured how many polymeric ligands were attached to each QD. The free conjugation polymer was easy to elute, which made it easy to separate the conjugated QDs from the free ones. A silica monolithic column was also brushed with a concentrated poly (methyl methacrylate) (PMMA) surface that repels QDs so that an SEC method could be used to sort QDs of different sizes (20). Chouhan et al. (21), using a Fluor immunochromatographic method, which is one of the few useful analytical tools, found the picogram amount of methyl parathion. Part of the flow-injection analysis device was an immunoreactor column that had anti-MP IgY antibodies attached to it. Instead of normal chromatographic equipment, thiol-stabilized CdTe QDs were used as fluorescent probes. Capillary electrophoresis

Because each analyte has a different charge-to-size ratio, capillary electrophoresis (CE) uses the difference in how mobile they are in reaction to a uniform electric field to separate them. In CE, a narrow-fused tube filled with an electrolyte solution is used to separate the charged analytes. With the capillary ends under water, the BGE and electrodes are put in bottles. Putting the sample solution into the capillary can be done in a number of ways, such as by applying pressure, using gravity, or applying a voltage. The analyte moves toward the exit side after forming zones when a high voltage is applied because it has different electrophoretic mobility. There was an in-line monitor put in front of the outflow that could find the analyte. Quantum dots have an electric charge on their surface that makes them perfect for photoelectron spectroscopy (CE). This is why CE has recently become a powerful way to characterize and separate QDs (26–29) and to use their photoluminescent properties as fluorescent labels in different analytical methods (30–

31). Here are the most important of the different ways that CE could work with QDs nanotechnology and were set up by different separate mechanisms:

- Capillary zone electrophoresis (CZE) (32-33,34,35,36,37 ,38).
- Micellar electro kinetic chromatography (MEKC) (39,40,41, ,42).
- Capillary gel electrophoresis (CGE) (43).
- Microchip electrophoresis (MCE) (44,45).

In the beginning, CE methods were mostly used to figure out what QDs were made of and how their sizes were distributed. They used these techniques to separate QDs and figure out how dangerous they might be to the world. The reason for this is that CE is the best way to separate things because it is easy to use, doesn't need many samples, works very well, and can be done quickly. People started using and throwing away these nanoparticles more, though, and it became clear that they could be bad for the world (46–47). A groundbreaking study by Song et al. (43) used capillary gel electrophoresis (CGE) technology and a laser-induced fluorescence (LIF) monitor to separate CdTe-MPA quantum dots. Linear polyacrylamide (PAA) was used as the screening medium to make quantum dots of different sizes very clear. Peak widening made it harder to tell the difference between quantum dots of similar sizes because they had more polydispersity, and the increased photoluminescence emission at higher pH levels had big effects. It was Pyell (25) who was the first person to use the CZE method to separate and measure CdSe/ZnS/SiO2 quantum dots. The size, pH, and ionic strength of the separation solution affected how the quantum dots moved along the electrophoretic gradient (48). It was found that the electrophoretic movement didn't depend on the electric field force that was applied. The results were in line with the size range seen with TEM. When Li et al. (34) used PEG (4%), they got the same results. We were able to separate three core/shell CdSe/ZnS quantum dots of different sizes. This showed that size and electrophoretic mobility were negatively related in the nanocrystals we were studying. Carrillo-Carrion et al. (40), who recently published their results, used micellar electrokinetic chromatography to find the best resolution level for quantum dots, which was 0.5 nm. Previous studies mostly focused on finding quantum dots that had the same make-up but different sizes. Dimensions are just one of many important factors. Surface charge can change how electrophoretic motion works, so the type of QD coating, capping, or bioconjugation is very important. Huang et al. (32) used the CE method to tell the difference between CdTe QDs that were attached to bovine serum albumin (BSA) and those that had MPA on top of them. Zhang et al. (50) did a full study on CdTe quantum dots that were all the same size and had mercaptopropionic acid (MPA), methacrylic acid (MAA), and glutathione (GSH) added to the top of them using micellar electrokinetic chromatography (MEKC). In their study, Pereira et al. (49) looked at what net charge means when there are several capping agents in CZE. By adding SDS, a micellar environment was made that improved selectivity because of the specific ways that the organic caps being studied interacted with each other. In their study, Oszwałdowski et al. (51) looked at a micellar plug that had QDs and either TX-100 or DOSS using CZE.The traditional method made QD preconcentration easier and improved the separation ratio. The way the nanoparticles are spread out in the micellar and micellar-free zones depends on how well the quantum dots stick to them. This is a very important part of the separation process. Based on previous work, Vicente and Colon (48) used capillary electrophoresis with polyethylene oxide as a sieving agent to successfully sort a number of CdSe/ZnS conjugate quantum dots. They looked at what happened when they mixed two bioconjugated quantum dots together. Because of this, a third peak that was hard to tell apart appeared. One big problem with capillary electrophoresis clarity of bioconjugates is that the results aren't always the same. Pereira and Lai (52) were the first to explain how peak widening can happen when proteins and immunoglobulins selectively or non-selectively attach to QDs.

The higher polydispersity was caused by the bioconjugation method, which used multiple linkage sites on the molecules. This made different numbers of proteins able to connect with a single quantum dot. These results were confirmed by a careful study of products made using different bioconjugation methods and capillary zone electrophoresis (CZE), which allowed for high resolution without the need for a sifting medium (Liskova et al., 53). In the past two years, electrochemistry (EC) and quantum dots (QDs) have been combined to create new analysis methods that use EC's ability to separate things along with QDs' optical properties and sensitivity. Chen et al. (54) showed a good way to find 7-aminoclonazepam (7-ACZP) in pee by using a microfluidic chip-based immunoassay and laser-induced fluorescence (LIF) detection. After being covered in denatured bovine serum albumin (dBSA), the CdTe-TGA quantum dots were joined to an anti-7-ACZP antibody. It is the goal of 7-ACZP and 7-ACZP-OVA (ovalbumin) to connect with the antibody that is connected to the CdTe quantum dots. The difference in movement between the antibody and the antibody-antigen complex was used to tell them apart. Using quantum dots as sensors made it possible to find drug residues on a pictogram scale. The first study to look into this problem used microchip electrophoresis along with a CRET-based method (55).

The nanocrystals were found to be the end acceptor and emitter entities in a luminol-NaBrO-QDs chemiluminescence system. Our method for isolating and identifying amino acids in the same cell was carefully tested and found to be useful

for a wide range of chemicals. To separate and measure dopamine and epinephrine, an EC-CL method (Zhao et al.) was used. With the addition of a QDs-luminol-H2O2 system to the running buffer, it became easier to get a much higher CL power. The two catecholamines, which are known for their ability to remove radicals, had a big effect on the CL signal by stopping the catalytic activity. Neurotransmitters were found in samples of human pee using this method. A way to find organophosphorus herbicides was suggested by Chen and Fung [61]. Researchers made a MEKC-LIF system better so they could separate and identify these compounds in vegetables because they can combine with QDs. It was shown that CdTe/CdS quantum dots stuck to the inside of the LIF window were stable in a borate buffer (pH 8–10), 5% methanol, and for a long time. It was possible for EC to find both single-base and double-base changes in DNA when CdTe was wrapped in glutathione or l-cysteine and linked to molecular beacons (MBs) (57). The nanocrystal and the quencher on the MBs worked together to lower the emission of QDs using field-effect resonance transfer (FRET). When the target DNA attached to the MBs, it messed up the FRET process, which made the QDs glow brighter. Because the form of the MB changed, the transfer time was sped up. The two QDs-MBs conjugates enabled us to distinguish between single-base mutations and other mutation types, as single-base mutations do not bind to MBs and do not alter migration time. CdTe-MPA quantum dots were included as a buffer in MECK with LIF detection to detect acrylamide (58). The background photoluminescence was deactivated in a manner contingent upon the concentration of the quantum dots. The research conducted by Celiz et al. examined the influence of fluvic acid interactions with QDCOOH and QDNH2 on motion and fluorescence (59). The electrophoretic mobility and photoluminescence emission both decreased as the concentration of fulvic acid increased.

3 Prospects and trends

While quantum dots are mostly used as glowing labels, they are also being used in new analytical ways, such as to make chemosensors that are sensitive and selective, to use their high reactivity for different online reactional schemes, and to immobilize and/or encapsulate substances in solid supports. If you use automatic analytical methods with QDs, you might be able to use them to separate and recognize analytes. This makes it easier to find different kinds of substances, like drugs, xenobiotics, dangerous chemicals, and pollution in the environment. Most of the time, these chemicals are present in small amounts or can't be found using normal methods, like a step for preconcentration or interference removal. You can also use QDs to speed up redox processes or make species that are metastable or have a short half-life, which makes them perfect for measuring quickly. Automated methods, on the other hand, can cut down on the need for reagents and the waste they create. This is good news for chemists who care about the environment because it means operators will be less exposed to toxic materials and maybe even do better with semiconductor materials that contain heavy metals. It's also easy to connect ideas like automated flow-based techniques to quantum dots nanotechnology. These are great for putting complicated reactional schemes or multiparametric results into practice..

4 Solid phase reactors

As a way to do green chemistry and protect the environment, reactions that use solid-state reagents are becoming more and more common (60). It is common for solid phase reactors to be used in redox reactions. They have shown amazing benefits for many reasons, such as the chemical instability of wet reagents, higher utilization, lower consumption, ease of reaction application, and online reagent derivatization. Solid-phase reactors can easily be used with automated flow-based and related methods for redox derivatization, chromatographic separations, sorptive preconcentration and/or matrix removal, and other similar tasks. This makes it easier to handle samples, combine multi-parametric analysis, shorten analysis times and reduces the need for operator help, fix samples, get rid of carry-over issues, and more. Many different solid-phase methods are possible, such as using low-pressure chromatographic columns for pre-concentration and interference removal, photoreactors, photoinduced chemiluminescence reactors, and electrogenerated chemiluminescence units. These can be used to couple, encapsulate, or coat quantum dots with silica, polymeric matrices, glass spheres or sheets, and porous materials. Different-sized QDs could be put into polymeric microbeads, which would allow for multiplexed sensing. Functionalized QDs-SiO2 beads could be used to make solid-phase extraction (SPE) and detection devices better. Mixing QDs with molecularly imprinted polymers could be a low-cost option to enzyme reactors that lets you find targets or selectively use different types of catalysis.

5 Magnetic nanocomposites

Recently, there has been talk of multimodal probes that combine luminous and superparamagnetic powers. These would allow both optical and magnetic monitoring, which would make it easier to diagnose diseases and keep an eye on them. Luminous nanocrystals can be joined with magnetic nanoparticles, like Fe3O4, in analytical chemistry to make it possible to identify events or analytes and separate them quickly and effectively using a magnetic field. It would be easier to find molecules that have been tagged if they could be separated or concentrated ahead of time. Magnetic

luminescent nanocomposites could be used in biology to separate cells or improve drug delivery methods, for example. They could be magnetically changed, though, to work as two-in-one probes that specifically bind analytes and hold them at the flow cell of a detector. This lets measurements be taken in areas like fluorescence enhancement or quenching. The flow cell is either emptied so that a new sample can be analyzed or sent to an automatic cleaning unit as part of the process. This is done after the magnetic field is turned off. This machine can fix the magnetic nanocomposite's surface, making sure it can keep being used. You can make these multipurpose nanoparticles brighter, more durable, more stable, and more flexible in how they are functionalized by covering them with a silica shell, a polymeric coating, or a bilipid layer, or by encasing them in a silica or polymer matrix (61). So, they could be used as solid supports in in-line flow columns, in reactions with other materials or in different situations, or even as a way to heat the reaction to make it hotter. Soon, it's easy to see them being used as magnetic handlers to move, place, and direct the sample zone inside the flow manifold, as well as to make physical barriers, apply mechanical forces, and do other things without touching anything.

6 Bead injection

Bead injection is an automatic flow method that seems to work well with quantum dots technology and other technologies. Bead injection is a type of FIA that involves putting microspheres (microbeads) of different materials into a tube. This lets the analyte sample react with the functional groups on the beads' surfaces. Some detectors elute the analyte downstream to find it from microbeads that are kept at a certain spot, but most use a flow cell that traps microbeads. Some of the best things about this flow technique are that it is very sensitive (target molecules can be collected on microbead surfaces from a large sample volume and found in situ without elution), the reactive solid phase can be replaced quickly and automatically, there is no carryover, and the beads are delivered very precisely. From a quick look at the literature, it looks like the two ways will work well together because they both involve adding something to the surface of QDs and polysaccharide microspheres that are used in bead injection. Quantum dots also have a more adaptable surface chemistry that lets them be used in a wider range of targeting methods and analyte recognition functions. This makes it possible for bead-based sensing and flow analysis methods to work in new ways.Many types of polymers are used to make microspheres that glow. Some examples are polystyrene, N-isopropylacrylamide, and 4-vinylpyridine. Silica colloidal crystal beads and quantum dots (QDs), which can detect a wide range of analytes, are some of the other materials used to make them. However, a single bead made of silica, polymeric, or magnetic material could act as a solid base for several layers of identical quantum dots (QDs); QDs could also be enclosed in polymeric materials or attached to beads to create a multi-layer signal enhancement; or, multiplexed signals could be made possible by putting together several QDs on a single bead. To sum up, quantum dots are nanoparticles that have a lot of potential for use in analytical chemistry and related fields because they can be used in a lot of different ways and are very easy to modify. Analytical scientists can use automation tools, mostly flow-based or similar methods, to help them deal with some of the problems that come up when they use them the old way. However, these tools are not perfect.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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