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QUANTUM DOTS (NANOPARTICLES) BENIFICIAL FOR EARLY DETECTION OF CANCER.

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ABSTRACT

Quantum dots (QDs) are a kind of nanoparticles that are used in Imaging, Detection and Targeting. They are nanometer-size luminescent semiconductor crystals and have unique chemical and physical properties. The research of the quantum dots has lived for about two decades. Now, there are many kinds of quantum dots. And due to the technology improvement, we know how to control some defects during the application, such as reducing the blinking. Recently, the new generations of the quantum dots achieved the goal for the single molecule application under the intracellular process. Compared with the conventional organic dyes we use in the biophysics, quantum dot has some attractive advantages: long-term photo stability, higher fluorescent outcome, narrower fluorescence emission, sensitivity to the electric and magnetic field. These advantages give a broad prospect for quantum dot to be applied in the biophysics field. Also, they emit different wavelengths over a broad range of the light spectrum from visible to infrared, depending on their size and chemical composition. Eventually, the use of quantum dots has been improved dramatically to improve clinical diagnostic tests for the early detection of cancer.

Keywords: Quantum dot, Nano-particle, Imaging, Targeting

INTRODUCTION

Quantum dot is a brand new development from the nano particle science. Now the most useful quantum dot is semiconductor QDs, such as ZnS(zinc selenide)-capped CdSe (cadmium selenide) nano-crystals. This will give a composition and size dependent optical property both for the absorption and emission process. When excited by the photon, the electron in the semiconductor energy band gap of the core region will jump over the band and leave a positive hole in the lower energy band (electron-hole pair). According to the

semiconductor knowledge for the band energy, the probability of the absorption will increase as the excitation energy increases. This will create a broadband absorption. The typical QD comprises by two main parts. The middle part is a single crystal, which is the heart of the structure. The diameter of it is about few nano-meters and the size and the shape can be controlled by appropriate growing environment. [1]

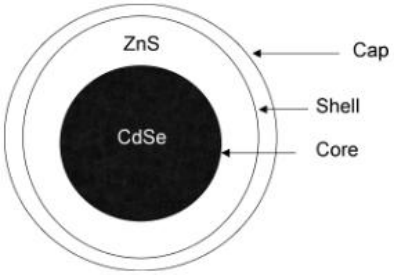

Fig 1. A sketch map for the structure of the semiconductor QDs.

Working of Quantum Dots:

When Quantum Dots (essentially nanocrystals of certain semiconductors) are excited, the wavelength of light emitted is controlled by the relationship between the size of the nanocrystal and the level of confinement of the electrons within the particle. Thus, Quantum Dots have the unique ability to emit light representing the entire rainbow of colors from the same elemental material based solely on the size of the particles of that material being excited. The smaller the particle, the more the inter band gap is blue shifted. By narrowly controlling the particles distribution (PSD) of the quantum dot crystals to within 10 nanometers, discreet colors can be emitted with wave lengths representing the entire visible spectra.

Prior to quantum dots, light emitting semiconductors, such as light emitting diodes (LED), could not emit white light. With the development of quantum dots with particle size distributions less than 500 nanometers (nm), LED emissions in the blue range can be achieved which may allow for the commercial use of solid state semiconductors to generate luminescent light.[4]

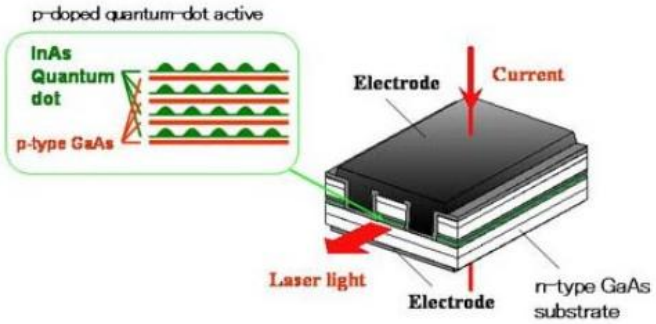

Fig 2. Structure of New Quantum-Dot Laser

Fabrication Techniques of Quantum Dots:

1. Core-Shell Quantum Structures

QDs are small regions of one material buried in another with a larger band gap.

2. Self-Assembled QDs & Stranski-Krastanov growth

Self-assembled QDs nucleate spontaneously under certain conditions during molecular beam epitaxy (MBE) and metalorganics vapor phase epitaxy (MOVPE), when a material is grown on a substrate to which it is not lattice matched. The resulting strain produces coherently strained islands on top of a two-dimensional "wetting-layer". This growth mode is known as Stranski-Krastanov growth. The islands can be subsequently buried to form the QD. The main limitations of this method are the cost of fabrication and the lack of control over positioning of individual dots.

3. MBE (Molecular Beam Epitaxy)

A technique that grows atomic-sized layers on a chip rather than creating layers by diffusion.

4. MOVPE (Metalorganics Vapor Phase Epitaxy)

It is a chemical vapor deposition method of epitaxial growth of materials, especially compound semiconductors from the surface reaction of organic compounds or metal-organics and metal hydrides containing the required chemical elements. In contrast to molecular beam epitaxy (MBE) the growth of crystals is by chemical reaction and not physical deposition. This takes place noting a vacuum, but from the gas phase at moderate pressures (2 to 100 kPa).

5. Monolayer fluctuations

QDs can occur spontaneously in QW structures due to monolayer fluctuations in the well's thickness.

6. Individual QDs

It can be created from two-dimensional electron or whole gases present in remotely doped quantum wells or semiconductor hetero-structures. The sample surface is coated with a thin layer of resist. A lateral pattern is then defined in the resist by electron beam lithography. This pattern can then be transferred to the electron or whole gas by etching, or by depositing metal electrodes (lift-off process) that allow the application of external voltages between the electron gas and the electrodes. Such QDs are mainly of interest for experiments and applications involving electron or hole transport, i.e., an electrical current.[5], [6], [7]

Fabrication Procedure:

Fabrication of quantum dots proceeds through a series of masking and etching steps. First, an electron beam scans the surface of a semiconductor containing a buried layer of quantum-well material. Resist is removed where the beam has drawn a pattern. A metal layer is deposited on the resulting surface, and then a solvent removes the remaining resist, leaving metal only where the electron beam exposed the resist. Reactive ions etch away the

chip except where it is protected by metal, leaving a quantum dot.

Synthesis of Quantum dots:

Colloidal synthesis

In large numbers, quantum dots may be synthesized by means of a colloidal synthesis. It is the cheapest and has the advantage of being able to occur at bench-top conditions. It is acknowledged to be the least toxic of all the different forms of synthesis. Highly ordered arrays of quantum dots may also be self assembled by electrochemical techniques. A template is created by causing an ionic reaction at an electrolyte-metal interface which results in the spontaneous assembly of nanostructures, including quantum dots, on the metal which is then used as a mask for mesa-etching these nanostructures on a chosen substrate.

Pyrolytic synthesis

Pyrolytic synthesis produces large numbers of quantum dots that self-assemble into preferential crystal sizes.[8]

The most common method of synthesis can be explained in three steps.

Step 1: Add silicon alkoxide (1) to an organic solvent containing CdSe/ZnS QDs. Partly hydrolyze silicon alkoxide (1) and coat the QDs with the hydrolysate (organic solution A). Generally, the PL efficiency of a QD is significantly affected by the surface condition of the QD. This coating prevents a decrease in the PL efficiency of the CdSe/ZnS QD.

Step 2: Prepare an aqueous solution containing partly hydrolyzed silicon alkoxide (2). Mix this with organic solution A prepared in step 1 to form a layer of alkoxide (2) on the surface of the QDs coated with alkoxide (1). The silicon alkoxides on the surface of the QDs are further hydrolyzed upon contact with water. The QDs become hydrophilic and move to the aqueous phase, forming assemblies. Select appropriate species and concentrations of silicon alkoxides to make the hydrolysis of alkoxide (2) slower than that of alkoxide (1) and thereby prevent the formation of large aggregates of the QDs. As a result, a decrease in PL efficiency due to imperfect chemical bonds between the QDs can be prevented.

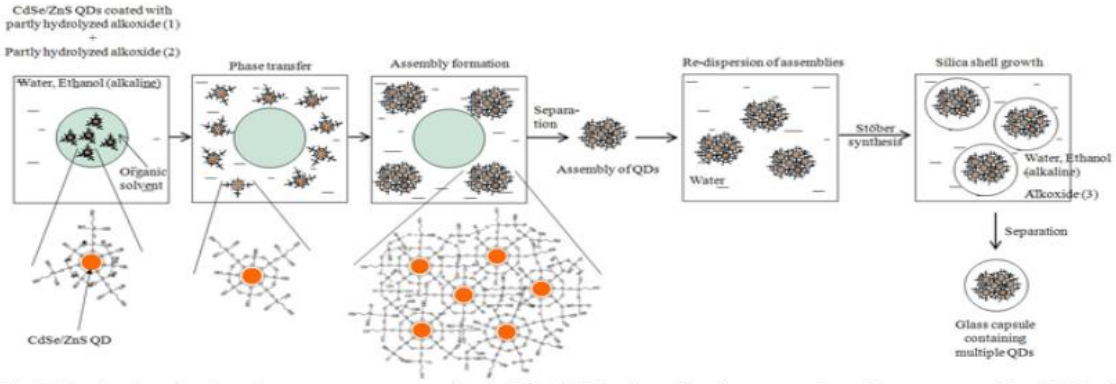

Fig 3. Production by the three-step process of a bright, highly durable glass capsule with an assembly of CdSe/ZnS QDs as the core

Step 3: Deposit a silica (glass) layer on the surface of the QD assembly to produce a QD-dispersed photoluminescent glass capsule. This can be done by hydrolyzing silicon alkoxide (3) in an alkaline solvent by the Stober synthesis and then depositing the alkoxide around the QD assembly. In this step, a dense silica layer is deposited to coat the QD assembly, making the produced photoluminescent glass capsule highly durable.

A 20- to 100-nm photo-luminescent glass capsule is obtained by depositing highly networked silica around densely assembled CdSe/ZnS core/shell QDs using the three-step synthesis. This glass capsule contains more than ten CdSe/ZnS QDs. Capsules of different diameters (e.g. 40 and 95 nm) can be produced by changing the concentration of silicon alkoxide (1) and (2) used in the steps 1 and 2. The PL efficiency of the encapsulated QD is similar (20% to 35%) to that of the non-encapsulated QD.

Properties:

Optical properties

An immediate optical feature of colloidal quantum dots is their coloration. While the material which makes up a quantum dot defines its intrinsic energy signature, the nanocrystal's quantum confined size is more significant at energies near the band gap. Thus quantum dots of the same material, but with different sizes, can emit light of different colors. The physical reason is the quantum confinement effect.

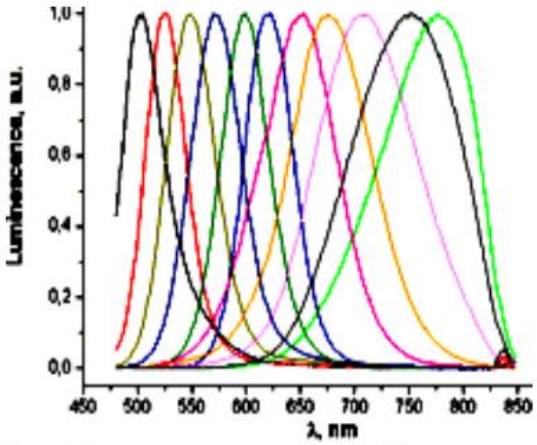

Fig 4. Fluorescence spectra of CdTe quantum dots of various sizes.[9]

The larger the dot, the redder (lower energy) its fluorescence spectrum. Conversely, smaller dots emit bluer (higher energy) light. The coloration is directly related to the energy levels of the quantum dot. Quantitatively speaking, the band-gap energy that determines the energy (and hence color) of the fluorescent light is inversely proportional to the size of the quantum dot. Larger quantum dots have more energy levels which are also more closely spaced. This allows the quantum dot to absorb photons containing less energy, i.e., those closer to the red end of the spectrum. Recent articles in nanotechnology have begun to suggest that the shape of the quantum dot may be a factor in the coloration as well, but as yet not enough information is available. Furthermore, it was shown[20] that the lifetime of fluorescence is determined by the size of the quantum dot. Larger dots have more closely

spaced energy levels in which the electron-hole pair can be trapped. Therefore, electron-hole pairs in larger dots live longer causing larger dots to show a longer lifetime.

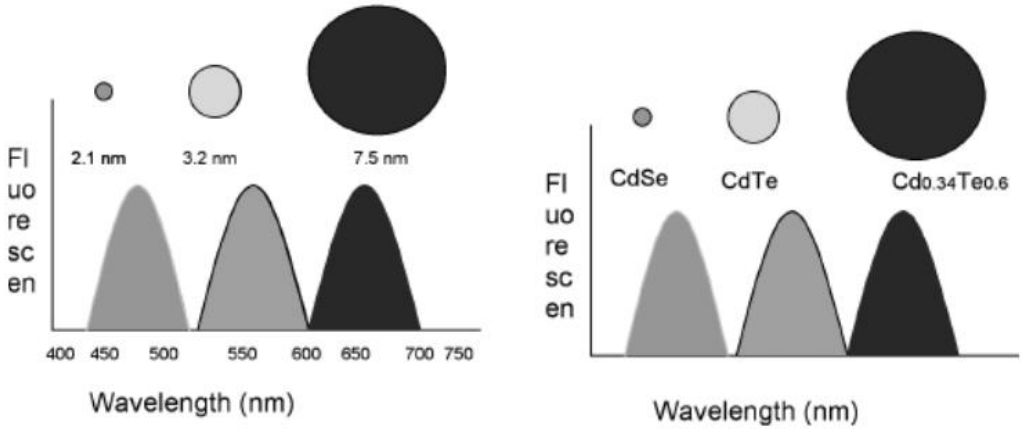

Fig 5.Optical properties of binary and alloyed quantum dots. Schematic drawings of three CdSe quantum dots with different diameters (a) and three quantum dots (mean diameter ~5nm) with different composition (b) and their corresponding fluorescence emission spectra.[3]

As with any crystalline semiconductor, a quantum dot's electronic wave functions extend over the crystal lattice. Similar to a molecule, a quantum dot has both a quantized energy spectrum and a quantized density of electronic states near the edge of the band gap.[10]

Nanocrystals:

A nanocrystal (NC) is a single crystal having a diameter of a few nanometers. A NCQD is a nanocrystal that has a smaller band gap than the surrounding material. The easiest way to produce NCQDs is to mechanically grind a macroscopic crystal. Currently NCQDs are very attractive for optical applications because their color is directly determined by their dimensions. The size of the NCQDs can be selected by filtering a larger collection of NCQDs or by tuning the parameters of a chemical fabrication process.

CdSe nanocrystals

Cadmium selenide (CdSe) and zinc selenide (ZnSe) NCQDs are approximately spherical crystallites with either wurtzite or zinc-blend structure. The diameter ranges usually between 10 and 100 Å. CdSe NCQDs are prepared by standard processing methods. $Cd(CH3)_2$ is added to a stock solution of selenium (Se) powder dissolved in tributyl phosphine (TBP). This stock solution is prepared under N_2 in a refrigerator, while tri-*n*-octylphosphine oxide (TOPO) is heated in a reaction flask to 360◦C under argon (Ar) flow. The stock solution is then quickly injected into the hot TOPO, and the reaction flask is cooled when the NCQDs of the desired size is achieved. The final powder is obtained after precipitating

the NCQDs with methanol, centrifugation, and drying under nitrogen flow. The room-temperature quantum yield and photo-stability can be improved by covering the CdSe NCQDs with, e.g., cadmium sulphide (CdS). By further covering the CdSe NCQDs by CdS, for example, the room temperature quantum yield and photo-stability can be increased. The almost ideal crystal structure of a NCQD can be seen very clearly in the TEMs.

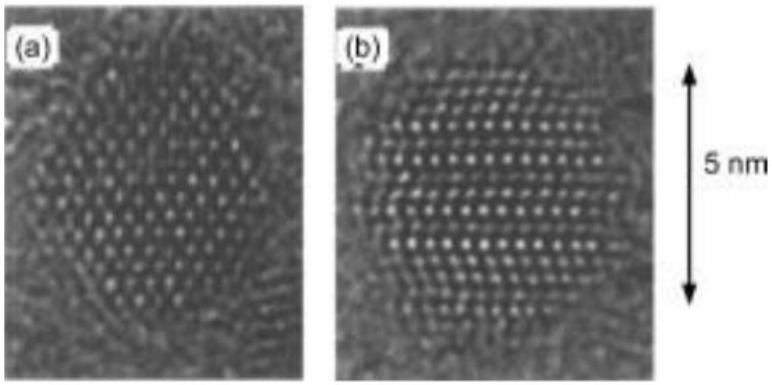

Fig 6. TEM images of CdSe/CdS core/shell NCQDs on a carbon substrate in (a) [001] projection and (b) [100] projection. Dark areas correspond to atom positions.

Electron confinement in CdSe NCQDs is due to the interface between CdSe and the surrounding material. The potential barrier is very steep and at most equal to the electron affinity of CdSe. Even if the growth technique is fairly easy, it is very difficult to integrate single NCQDs into semiconductor chips in a controlled way, whereas the possibility to use them as biological labels or markers is more promising.

Silicon nanocrystals

Silicon/silicon dioxide (Si/SiO2) NCQDs are Si clusters completely embedded in insulating SiO_2. They are fabricated by ion-implanting Si atoms into either ultrapure quartz or thermally grown SiO_2. The NCs are then formed from the implanted atoms under thermal annealing. The exact structure of the resulting NCQDs is not known. Pavesi et al. reported successful fabrication of NCQDs with a diameter around 3 nm and a NCQD density of 2 × 1019 cm−3. The high-density results in an even higher light wave amplification (100cm−1) than for seven stacks of InAs QDs (70 to 85 cm−1). The main photoluminescence peak was measured at λ = 800 nm. The radiative recombination in these QDs is not very well understood, but Pavesi et al. suggested that the radiative recombinations take place through interface states. Despite the very high modal gain, it is very difficult to fabricate an electrically pumped laser structure of Si NCQD due to the insulating SiO_2.[11]

Quantum Dots-Based Optical Imaging:

Fixed cells and tissue imaging

The feasibility of using quantum dots for antigen detection in fixed cellular

monolayers was first demonstrated in 1998.[12] By labelling nuclear antigens with green silica-coated CdSe/ZnS quantum dots and F-actin filaments with red quantum dots in fixed mouse fibroblasts, these two spatially distinct intracellular antigens were simultaneously detected. For cellular labelling quantum dots are ~20 times brighter and dramatically more photo stable over many weeks after injection than organic fluorophores.[13] Recently, specific genomic sequences and antigens in tissue sections have been labelled.[14]

Live cell bio imaging

Live cell imaging is a more difficult task compared to fixed cells and tissues due to the care that must be taken to keep cells alive and due to the challenge of delivering probes across the plasma membrane for studying intracellular targets. In vivo applications of quantum dots have been demonstrated for labelling cellular surface antigens [13]. By covalently conjugating mercapto acetic acid-coated CdSe/ZnS quantum dots to the transferrin protein, quantum dots were spontaneously endocytosed by cancer cells and retained their bright fluorescence, indicating that quantum dots can be used as intracellular labels.

For intracellular staining of cells poly(ethylene glycol)- coated CdSe/ZnS quantum dots with green emission were injected into single cells of a *Xenopuslaevis* embryo.[15] Microscopic fluorescence imaging allowed real-time monitoring of cell lineage and differentiation.

Remarkably, most of the embryos exhibited normal development, and there was no evidence of toxicity, even with the injection of over one thousand million quantum dot particles per cell. Recently, the true advantages of quantum dots for live cell imaging have been demonstrated by labelling plasma membrane receptors, such as glycine receptors[16] and erbB/HER receptors[17] enabling real-time tracking of biomarkers and imaging single molecules. The data provide new insights into the mechanism of ligand-receptor interactions.

In vivo imaging

In order to benefit from the advantageous optical properties of quantum dots as *in vivo* labels, a number of issues must be addressed. First, the relatively large size and surface area of quantum dots allow the attachment of multiple targeting probes to each label of enhanced binding specificity. However, this size (~4-20 nm in diameter following bioconjugation) has the disadvantage of being too large to penetrate through the vascular endothelium, and too large to be excreted in the urine. The accessible targets for systemically administrated quantum dot probes could be limited to those of vascular exposure, such as endothelial receptors. Also, nanoparticles are non-specifically taken up by phagocytic cells in the organs of the reticulo-endothelial system (most notably by the liver

and spleen). This non-specific targeting can be reduced by coating nanoparticles with hydrophilic polymers such as poly(ethyleneglycol) to allow greater vascular circulation time, but non-specific uptake cannot be eliminated completely.

In vivo tumour targeting

Targeted molecular imaging of tumours was first demonstrated in nude mice using quantum dots.[18] Nude mice lack a thymus and a functional immune system. Therefore, a human xenograft of tumour cells will be accepted and grow in nude mice. This xenograft tumour model is therefore an excellent model to study in vivo targeting of therapeutics to human cancer cells. Subdermal tumours require only a shallow penetration depth for imaging. Moreover, the vasculature of most cancer tissue is highly disordered, causing exposed interstitial tissue, so that tumour antigens are in direct contact with blood. Nude mice with human prostate tumours were injected intravenously with poly(ethylene glycol)-conjugated quantum dots functionalised with anti-bodies against the prostate-specific membrane antigen. Quantum dot accumulation in the tumour was primarily due to antibody-antigen binding, but was also aided by the enhanced permeability and retention effect characteristic for tumor vasculature. The permeability and retention effect is due to the inherent vasculature permeability of the microenvironment of cancerous tissue, combined with the lack of lymphatic drainage.[19] Due to the permeability and retention effect alone, it was found that nonconjugated poly(ethyleneglycol) quantum dots accumulated in induced mouse tumours, demonstrating tumour contrast, but much less efficiently than actively targeted probes. Recently, an intraoperative highly sensitive technique for pulmonary sentinel lymph node mapping using near-infrared fluorescent quantum dots has been developed.

The study showed the feasibility of the method for mapping pulmonary lymphatic drainage and guiding excision of the sentinel lymph node in a porcine model. In addition, the application of quantum dots in multiphoton intravital microscopy shows great versatility for studying tumour pathophysiology. Intravital microscopy is a powerful imaging technique that allows continuous non-invasive monitoring of molecular and cellular processes in intact living tissue with 1-10 µm resolution. Quantum dots can be customized to concurrently image and differentiate tumour vessels from both perivascular cells and matrix and to monitor the trafficking of bone marrow-derived precursor cells to the tumour vasculature allowing to investigate the degree to which the vascular and perivascular structures are formed or remodelled in response to cell homing. Gao et al.[20] created QD conjugates containing a special polymer coating (including a QD capping ligand) for in vivo protection, targeting ligands for tumour recognition, and several molecules

(poly ethyleneglycol) for improved biocompatibility and circulation (Fig 7). By attaching a targeting ligand, high affinity binding of QD-antibody conjugates to tumour antigens occurs (Fig 8).

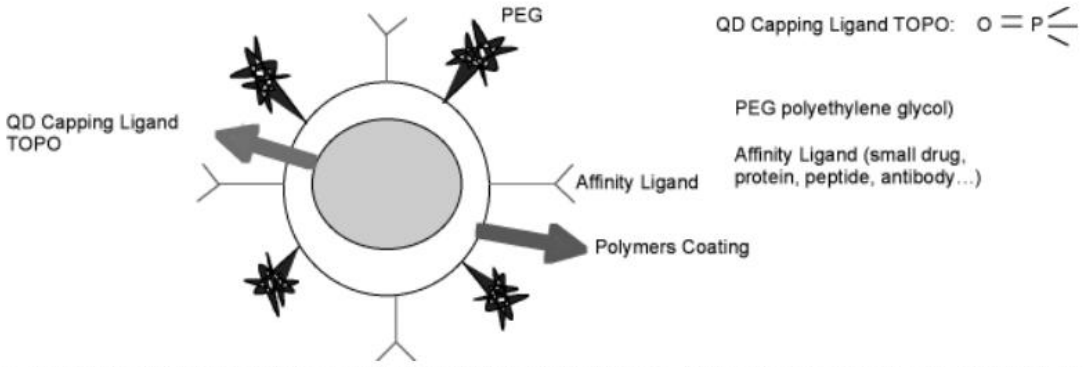

Fig 7. Structure of a Multifunctional Quantum Dot Probe** PEG, polyethylene glycol; QD, quantum dot; TOPO, tri-n-octylphosphine oxide[21]

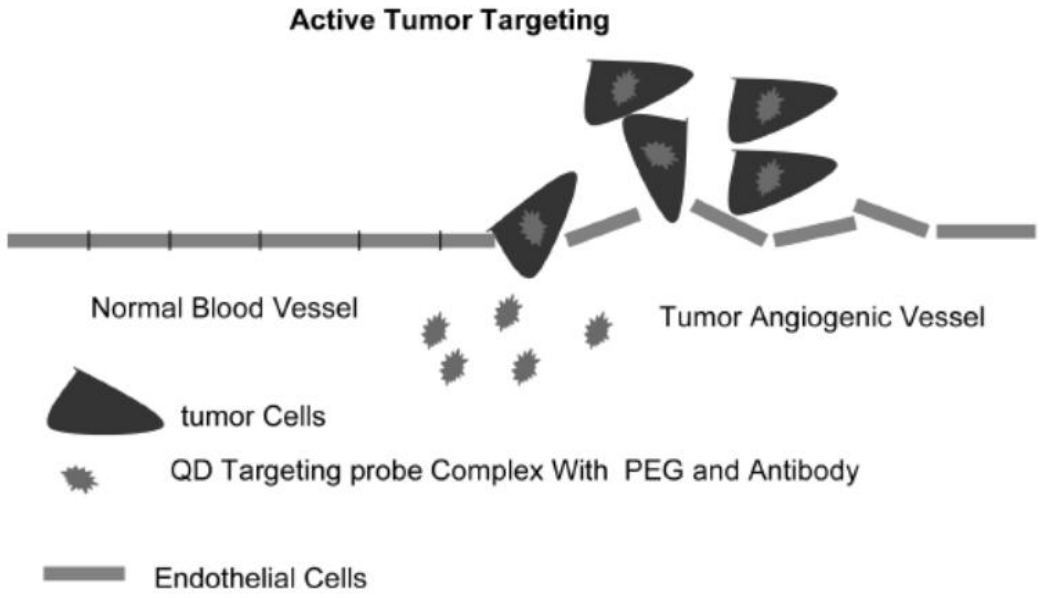

Fig 8. Structure of a Multifunctional Quantum Dot Probe** PEG, polyethylene glycol; QD, quantum dot; TOPO, tri-n-octylphosphine oxide.[22]

Objective &Future of QD:

It is very important that develop a biocompatible quantum dot as a potential probe for many disease such as: neurological disorders. The starting material is a commercially available CdSe-ZnS core-shell quantum dot having surface ligands of tri-n-octyl phosphine oxide (TOPO). The quantum dots will be solubilized following the exchange of a thiol-containing molecule for the TOPO ligands. One such strategy involves the replacement of TOPO with either

mercaptosulfonic acid or D, L cysteine.[23] Subsequently, a layer of the conductive polymer, polypyrrole will be attached through an electrostatic interaction. At this stage scientists have the option to also incorporate polyethylene glycol for enhanced circulation time should the quantum dots be tested later in vivo. The polymer polypyrrole will be the key to studies of the electrochemical stimulus that occurs between neurotransmitters and their corresponding receptors. The amine functionality of polypyrrole provides a favourable site for further addition reactions.

Polypyrrole was chosen because of its electrically conducting properties, ease of preparation and its ability to conjugate with many amino acids. Most neurotransmitters derive from amino acids (as related compounds such as choline). Some neurons modify amino acids to form the "amine" transmitters, e.g. norepinephrine, serotonin and acetylcholine others combine amino acids to form "peptide" transmitters while still others neurons use amino acids unchanged or synthesized as transmitters.[24] Preliminary investigations will begin with the binding of the amino acid tyrosine to the polypyrrole-coated quantum dots. Tyrosine is the precursor to the neurotransmitters dopamine (DA) and norepinephrine (NE). Subsequent studies will involve the conjugation of dopamine to polypyrrole-coated quantum dots. The loss of neurons and the accompanying decrease in levels of dopamine are associated with Parkinson's disease.[24] Also dopamine is a good candidate as it is electroactive.[25] Active laboratory preparation of materials will start with the solubilization of the quantum dots whereby a thiol-containing molecule is to be exchanged for TOPO. A measure of the completeness for the occurrence of this exchange will be determined by mass spectrometry (MALDI-TOF) and infrared spectroscopy. Absorption and emission spectra will be recorded throughout to monitor for any changes during the stepwise, surface modification of the quantum dots. Morphology and size determination will be completed using transmission electron microscopy and dynamic light scattering (DLS).

Light scattering is the best estimator of the actual particle size as it measures the hydrodynamic radius. As an indication of potential toxicity, free Cd^{2+} will be measured by inductively coupled plasma (ICP) according to the methods of Derfus et al.[26] Whereas the binding of appropriately modified quantum dots to specific target cells can be followed and observed by fluorescence microscopy the interaction of chemicals comprising a neurotransmitter and receptor may prove difficult to confirm. This attachment between neurotransmitter and receptor not be brief it may be possible to verify using 1H NMR (nuclear magnetic resonance).

Further, electrochemical stimulus to drive the interaction between neurotransmitter and receptor will be investigated using

individual electrolytic solutions in which there is an excess of Na+, K+ and Ca++ ions. These ions are involved in the process of neurotransmission.

Applications of Quantum Dots in various fields:

Pharmaceutical field

In the field of diagnosis, magnetic resonance imaging is one of the first and up to now the most developed application of metallic particles. But beside this application, a very new generation of biosensors based on the optical properties of colloidal gold and fluorescent nanocrystals, called quantum dots seems to be ready to be implemented in diagnosis and medical imaging. Concerning therapeutic applications, the potentialities of metal nanoparticles to help fulfilling the need of time and space controlled release of drugs has been intuited for a long time. It should also be used for the detection of active ingredients with fluorescence.[27]

In-vivo imaging

Non-targeted near infrared emitting quantum dot core T2-MP EviTags were tested in tumor bearing mice. Optical image was acquired after intravenous injection of 100pmol of T2-MP EviTags (left) or of physiological buffer as a control (right) into the tail vein of tumor bearing mice. In this preliminary experiment, T2-MP EviTags were shown to be capable of generating a reasonable signal to noise image when compared to the control. Further, the biodistribution pattern as determined from the optical image shows favorable clearance of the non-targeted T2-MP EviTags through the lymphatics, kidneys and bladder. The development of T2-MP EviTags as non-invasive optical molecular imaging probes will have a great impact on the early detection, diagnosis and treatment monitoring of cancer.[28]

Cancer Application

Quantum dots, which range from about 2 to 10 nanometers across (roughly equivalent to a medium-sized protein), have distinct advantages over conventional fluorescent dyes. By simply varying the crystal size, scientists can produce dots that emit light in a wide range of wavelengths, or colors, that are less prone to overlap than those of organic dyes. And whereas each organic dye must be excited with a specific wavelength of light, a single light source can excite quantum dots of many colors, so scientists can use the dots to label and detect multiple targets simultaneously. In addition to this "multiplexing" capability, quantum dots are much brighter than organic dyes and retain their glow much longer.[29]

Computation

Quantum dot technology is one of the most promising candidates for use in solid-state quantum computation. By applying small voltages to the leads, the flow of electrons through the quantum dot can be controlled and

thereby precise measurements of the spin and other properties therein can be made. With several entangled quantum dots, or qubits, plus a way of performing operations, quantum calculations and the computers that would perform them might be possible.

Photo-detector devices

Quantum dot photo-detectors (QDPs) can be fabricated either via solution-processing [30] or from conventional single-crystalline semiconductors.[31] Conventional single-crystalline semiconductor QDPs are precluded from integration with flexible organic electronics due to the incompatibility of their growth conditions with the process windows required by organic semiconductors. On the other hand, solution-processed QDPs can be readily integrated with an almost infinite variety of substrates, and also postprocessed atop other integrated circuits. Such colloidal QDPs have potential applications in surveillance, machine vision, industrial inspection, spectroscopy and fluorescent biomedical imaging.

Photo-voltaic devices

Quantum dots may be able to increase the efficiency and reduce the cost of today's typical silicon photovoltaic cells. According to an experimental proof from 2006 (controversial results [32]), quantum dots of lead selenide can produce as many as seven excitons from one high energy photon of sunlight (7.8 times the bandgap energy).[33] This compares favorably to today's photovoltaic cells which can only manage one exciton per high-energy photon, with high kinetic energy carriers losing their energy as heat. This would not result in a 7-fold increase in final output however, but could boost the maximum theoretical efficiency from 31% to 42%. Quantum dot photovoltaics would theoretically be cheaper to manufacture, as they can be made "using simple chemical reactions.[33] The generation of more than one exciton by a single photon is called multiple exciton generation (MEG) or carrier multiplication.

Light emitting devices

There are several inquiries into using quantum dots as light-emitting diodes to make displays and other light sources, such as "QD-LED" displays, and "QD-WLED" (White LED). In June, 2006, QD Vision announced technical success in making a proof-of-concept quantum dot display and shows a bright emission in the visible and near infra-red region of the spectrum. Quantum dots are valued for displays, because they emit light in very specific gaussian distributions. This can result in a display that more accurately renders the colors that the human eye can perceive. Quantum dots also require very little power since they are not color filtered. Additionally, since the discovery of "white-light emitting" QD, general solid-state lighting applications appear closer than ever.[34] A color liquid crystal display

(LCD), for example, is usually powered by a single fluorescent lamp (or occasionally, conventional white LEDs) that is color filtered to produce red, green, and blue pixels. Displays that intrinsically produce monochromatic light can be more efficient, since more of the light produced reaches the eye.

Immunoassay

An immunoassay readout method based on fluorescent imaging analysis with laser confocal scanning is described. The ZnS-coated CdSe quantum dots (ZnS/CdSe QDs) were linked to a detection antibody. Immunoassay was carried out on a glass chip using a sandwich assay approach, where antibody covalently bound to a glass chip was allowed to capture antigen specially. Afterwards, the detection antibody labeled with QD was allowed to bind selectively to the captured antigen. The fluorescent signals of the sandwich conjugate were detected by a laser confocal scanner. A diode laser was used to excite efficiently the fluorescent signals while bovine serum albumin was used to eliminate nonspecific binding sites. The specificity of the QDs-labeled immunoglobulin G (IgG) was tested by an experiment using goat IgG and human IgG samples. The result was consistent with the binding specificity in a sandwich-type assay.[35]

Biosensor and biolabels

A number of analytical tools have been developed with application of this smart and potential technology. These tools are employed for determination of various pathological proteins and physiological-biochemical indicator associated with disease or disrupted metabolic conditions of body.[36]

Detection of viral infections

Quantum dots are multi-colored, microscopic fluorescent beads, which bind to molecular structures that are unique to the virus' coat and the cells that it infects.The Vanderbilt researchers report that not only can a quantum dot system detect the presence of particles of the respiratory syncytial virus (RSV) in a matter of hours, rather than the two to five days required by current tests, but it is also more sensitive, allowing it to detect the virus earlier in the course of an infection.[37]

FRET-Fluorescence Resonance Energy

Transfer Fluorescence Resonance Energy Transfer (FRET) is a powerful technique to measure the co-localization of events such as protein interactions. The technique involves the nonradiative transfer of energy from the donor (which absorbs excitation light) to an acceptor (which emits light at a different wavelength) over an extremely short distance (typically less than 10-20nm).

The maximum energy transfer between donor-acceptor pairs occurs when the overlap between the donor emission spectrum with the absorption of the acceptor is greatest. However, noise will be introduced if either the

emission spectrum of the donor crosses over into the emission band of the acceptor or if the absorption band of the acceptor crosses over into the excitation source waveband. Quantum dots are far superior to organic dyes when used as a FRET donor. Quantum dots can be pumped at a wavelength far from where they emit and the emission spectrum is narrow and tunable allowing for maximal energy transfer to a given organic acceptor while mitigating the sources of noise.[38]

Quantum Dot Products:

EviDots® Core & core-shell quantum dots EviDots are available as core quantum dots in their fundamental state, or enhanced with our proprietary coating technologies as core-shell semiconductor nanocrystal quantum dots. EviDots are available in wavelengths ranging from 490nm - 2100nm.

EviComposites™ Quantum dot composites. EviComposites use the properties of Evident's proprietary EviDot quantum dots as well as common insulating polymer matrix materials.

EviTags™ Water soluble quantum dots. EviTags are conjugation-ready with a bio-active surface. Carboxyl or amine functionalized dots are available in wavelengths ranging from 490nm - 680nm.

EviFluors® Water soluble quantum dots conjugated to antibodies and proteins. EviFluors are ready-to-use high quality, activated quantum dots coupled to secondary antibodies and proteins. Goat anti-Mouse, Goat anti-Rabbit, Goat anti-Rat, Streptavidin, and Biotin conjugated quantum dots are available in wavelengths ranging from 520nm - 680nm.

CONCLUSION

Quantum dots have been received as new technology with novel characteristics that could greatly developed biological imaging and detection. It can help to improve different field of biomedical sciences such as:

- Design and produce of nanoparticles and nano-device with multiple functions.
- Use of QD complex for analyzing of biomarkers and detection of disease.
- Design and make of biocompatible and biodegradable nanoparticles to solve the problem like non-specific organ uptake and RES scavenging.
- Deliver of nanoparticles for of imaging and therapeutic aim into solid tumors beyond the vascular endothelium.

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