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A THEORETICAL REVIEW OF QUANTUM DOT TECHNOLOGY IN GREENCOMPUTER

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Abstract

The LED Screen display manufacturing sector has advanced significantlyin the recent years. The capacity to create flexible, translucent, and ultra- thin screens using organic light emitting diodes is one of the most significant advancements(QLED).Researchers in this discipline are always striving to bet- ter the situation. Quantum dot(QD)technology has been demonstrated to be useful in this method.In this paper, we theoretically analysis all the possible sce-narios that the results of current studies on quantum dot based light emitting diodes(QDLEDs) and how this nanoparticle might increases QDLED perfor- mance. The presence of quantum dots in QDLEDs can result in a significant increases in efficiency and lifespan due to the usage of a colloidal nanocrystal- based active layer. This whitepaper aims to establish the foundation for a through understanding of the science behind the quantum dot(QD) technology and it's popular and promising application in quantum dot displays.

Keywords— Quantum Dots, Nanotechnology, QLED TV, Photo-luminescemce,Optical Microscopy, Cancer Treatment, Enviroment-friendly materials, En- hancement layer, Color filters,

1 Introduction

Quantum dots are nanoscale semiconductor particles with unique optical and electri-cal capabilities due to their small size. Quantum dot crystals, emit light of specific frequencies when exposed to light, and their physics is dictated by quantum mechan-ics. Quantum dots can be accurately controlled in size, energy levels, and emission colour, making them suitable in a range of applications such as bioimaging, QLED displays, and solar cells. This makes nanotechnology scalable and beneficial for dis- play applications.

How the Quantum Dots works? When the energy is applied to the atom, electrons are energized and move up to a higher level, and when the electron returnto its previous stable state, the additional energy is emitted as the Light energy of a particular frequency[Fig1]. Quantum Dots works in the same way but the quantumdot crystal acts as one very large atom. The energy source used to excite the quantum dot is mainly Ultraviolet and the frequency emitted during the excitation phase is mainly depends upon the size of the quantum dot.

Figure 1: how do the quantum dots works

1.1 What makes quantum dots so unique?

In regular semiconductors like silicon, the bands are formed by the merger of adja-cent energy of a very large number of the the atoms and molecules. However, asthe particle size reaches the nano- scales and the quantity of atoms and molecules decreases substantially, the number of overlapping energy levels decreases, causingthe width of the band to increases. As Quantum Dots are so tiny, they have a higher energy gap between the valence and conduction bands, compared to the Silicon based Semiconductor [Fig 2].In QDs, the electron and hole energies depend on the compo- sition of the QD and of the barrier material and on the QD shape and size, similar to what happens in QWs.Being zero dimensional, quantum dots have a sharper densityof states than higher-dimensional structures. Their small size also means that elec-trons do not have to travel as far as with larger particles, thus electronic devices can operate faster. Examples of applications taking advantage of these unique electronic properties This should make clear why it is interesting to study them!

Figure 2: what so special about Quantum Dot Displays

2 Types of Quantum Dot Displays:

2.1 Photo-emissive

Photo-emissive quantum dot particles are used in a Quantum Dot layer which uses the blue light from a backlight to emit pure basic colors which improve display bright- ness and color gamut by reducing light losses and colors cross talks in RGB LCD color filters replacing traditional colored photoresists in RGB LCD color filters. This technology is used in LED Backlit Led's.As Shown in [Fig.3]

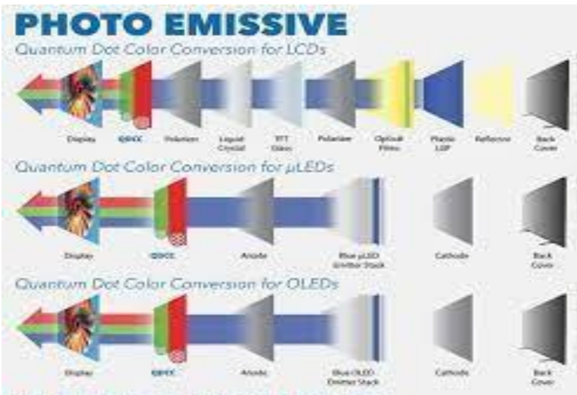

Figure 3: Photo-emissive Quantum Dot Structure

2.2 Electro-emissive

Electro-emissive quantum dot displays are an experimental type of display basedon quantum-dot light-emitting diodes. These displays are similar to AMOLED and Micro Led's displays.As Shown in [Fig.4]

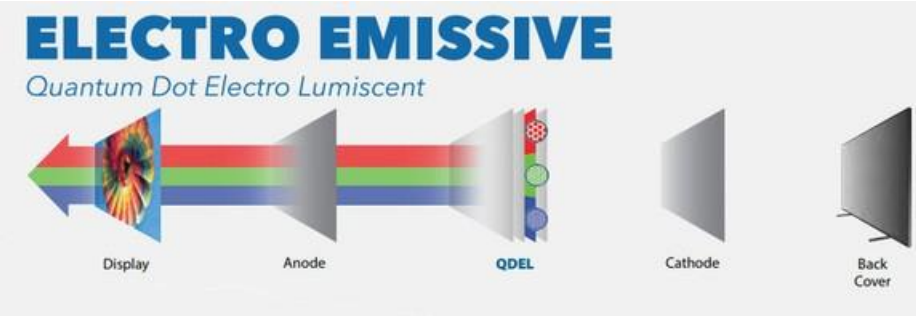

Figure 4: Electro-emissive Quantum Dot Structure

Quantum Dot Size and Color: Quantum dots have properties intermediate between silicon semiconductors and discrete atoms or molecules. Their optoelectronic properties change as a function of both size and shape. Larger QDs of 5– 6 nm diameter emit longer wavelengths, with colors such as orange or red.[Fig 5]

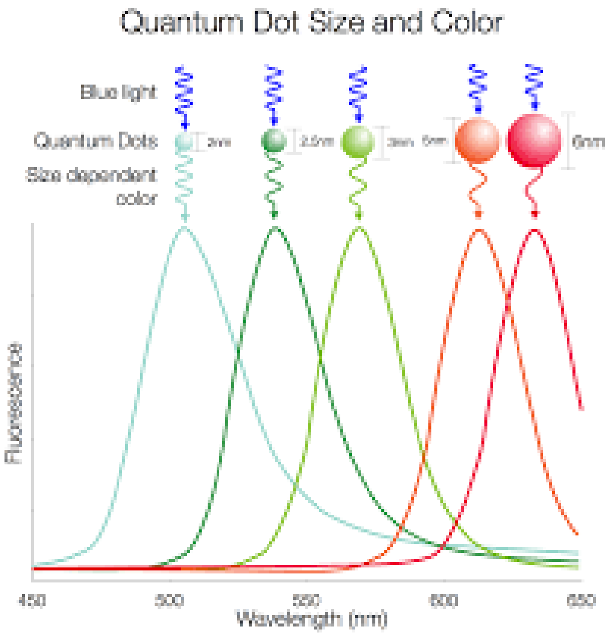

Figure 5: Dependencies of wavelength in respective of Quantum Dot Size

3 Quantum Dot Materials

Quantum dots can be made from a range of materials, currently the most commonlyused materials include zinc sulphide, lead sulphide, cadmium selenide and indium phosphide they are potentially harmful to the environment due to the toxic Cd2+ theyrelease as nanoparticles degrade. After extensive research, Samsung has developed a unique technology to create indium-based (In) Quantum dots that match or exceed the performance of those based on cadmium. Samsung is currently a leading producer of cadmium-free quantum dot monitors[Fig.6]

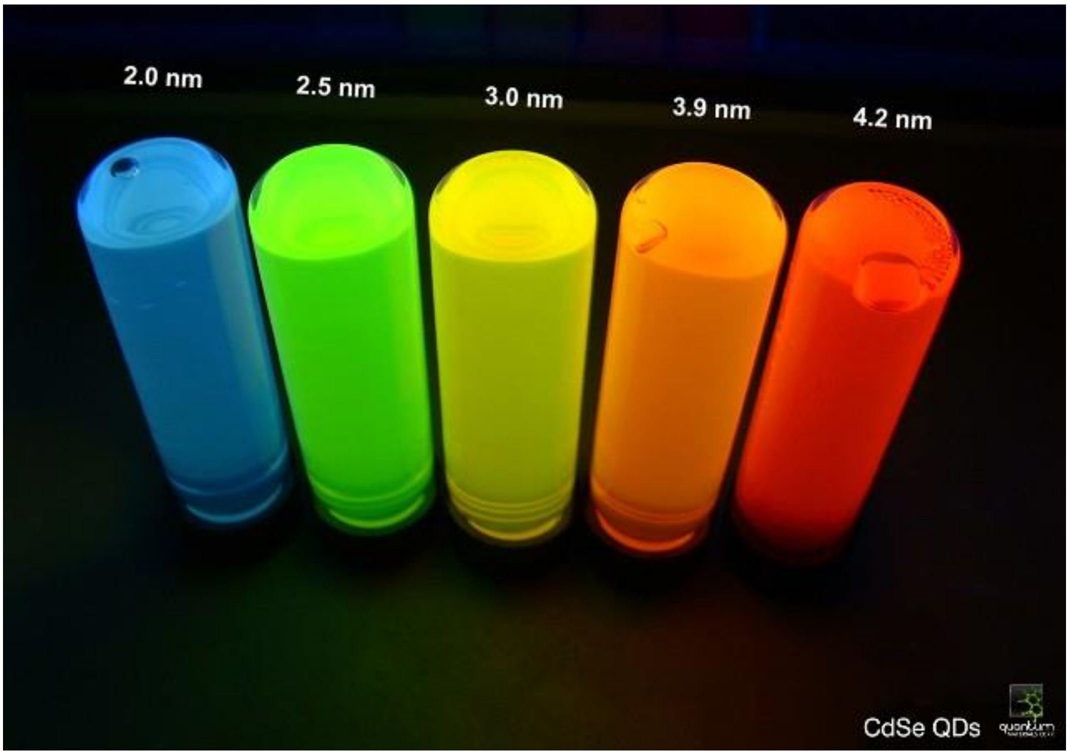

Figure 6: Quantum Dot Materials

4 How can we use Quantum Dots for Display Tech-nology

4.1 Quantum Dot Enhancement Layer

The use of a quantum dot enhancement film (QDEF) layer to increase LED backlight- ing in LCD TVs is a common practical use. QDs transform light from a blue LED backlight to relatively pure red and green, resulting in less blue-green crosstalk and light absorption in the color filters following the LCD panel. As a result, the useable light throughput is increased, and the color gamut is improved. There are millions of tiny Quantum Dot Phosphors on each sheet of QDEF[Fig.7]. By generating a high-quality tri-color white light from a conventional blue LED light source, QDEF allowsLED-backlit LCDs to be brighter and more vivid. Larger than a water molecule, butsmaller than a virus, these tiny phosphors convert blue light from a standard GalliumNitride (GaN) LED into different wavelengths based upon their size. Larger dots emit longer wavelengths (red), while smaller dots emit shorter wavelengths (green).

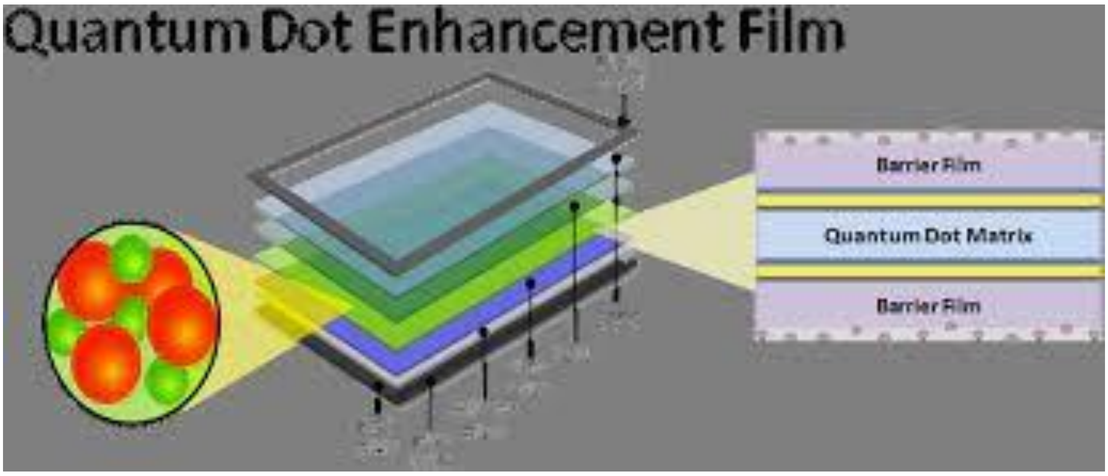

Figure 7: Quantum Dot Enhancement Layer

4.2 Quantum Dot color filters

Ordinary colour filters in screens are made to let some wavelengths of light through while blocking others. These colour filters can have poor colour rendering due to colour leakage into other channels, which is one of the reasons quantum dots arebeing investigated as colour filters.
Quantum dots in red and green could be utilised to replace the coloured materialscurrently employed in display colour filters. To pattern and harden the photopolymer, the present colour filters are made by patterning photoresists, and each colour must be deposited and patterned over a wide region separately.. Only the red and green QD layers would be present in a QD colour filter, and the blue sub-pixel would be vacant, allowing the blue LED backlight to pass through. Rather of blocking light,the colour filter now converts it!
Samsung Display has announced a 10.8 billion dollar investment in research and development, with the goal of converting all of their 8G panel facilities to QD-OLED production between 2019 and 2025.

Benefits

Compared to traditional color filters in displays, those that use quantum dots have a range of benefits. Quantum dot color filters improve the color gamut ofa display, which results in a brighter output.

The use of quantum dots also helps to reduce the size of the display, resultingin thinning displays, which are highly demanded.

Quantum dots also provide a wider viewing angle on displays, as they emit inall directions and are placed closer to the front of the display.

Further from LED source and after the liquid crystal and polarizers means it’sa less harsh environment for the QDs to withstand.

4.3 Self-emissive quantum dot diodes

The QLED display is a self-emissive display in which light is generated by individualsubpixels that may be controlled individually. Each subpixel in an LED display is made up of liquid crystal and a color filter, resulting in lower power efficiency and reduced functionality. The basic design of a QD-LED is similar to that of an OLED.

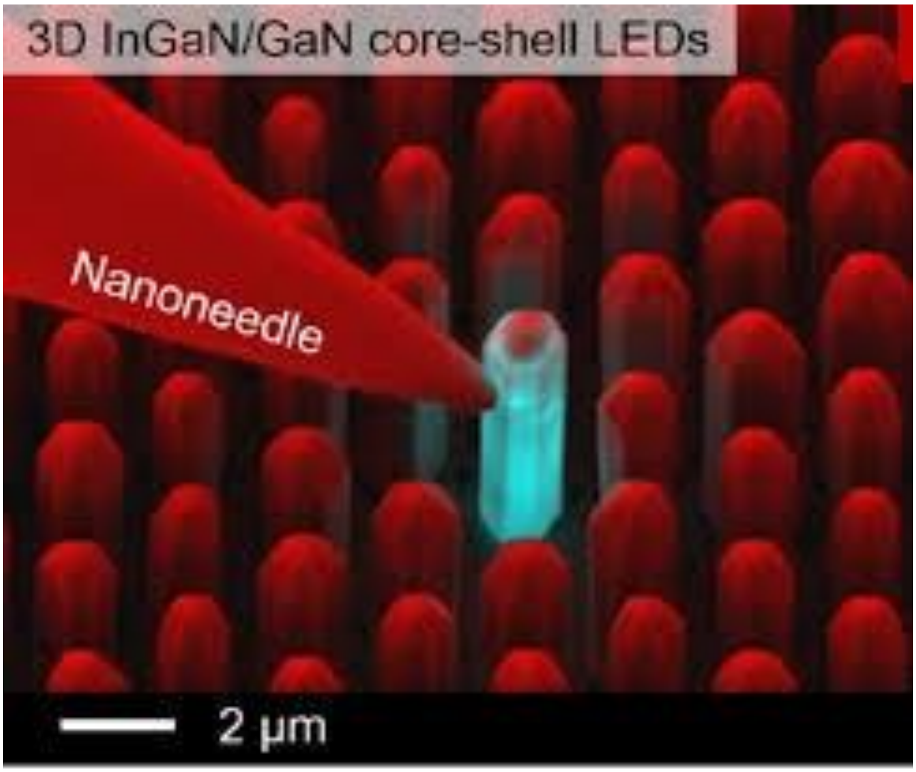

Figure 8: Self-emissive quantum dot diodes

5 Manufacturing and Development Process:

5.1 Phase separation

Phase separation is a well-known process for creating large-area (cm2), ordered mono- layers of colloidal nanocrystal quantum dots. The QD thin films are spun-cast froma combined solution of aromatic organic materials and aliphatic-capped QDs in a single process. During solvent drying, the two distinct materials phases separate, generating the required QD monolayer on top of the organic semiconductor interface. Previous research has demonstrated the robustness and flexibility of this phase sepa-ration method, as well as the precision and repeatability with which the properties ofthe resultant films can be regulated. The resulting thin film structure can be affectedby parameters such as solution concentration, solvent ratio, QD size distribution, andQD aspect ratio. Controlling these variables enables for the production of QD-LEDs with great colour saturation and efficiency. The resulting thin film structure can be affected by parameters such as solution concentration, solvent ratio, QD size distri- bution, and QD aspect ratio. Controlling these variables enables for the production of QD-LEDs with great colour saturation and efficiency. This approach, however,is not suitable for all research and device applications. We must co-deposit an or- ganic thin film with the QD monolayer to achieve phase separation, which is not always ideal. The resulting thin film structure can be affected by parameters suchas solution concentration, solvent ratio,

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QD size distribution, and QD aspect ratio. Controlling these variables enables the production of QD-LEDs with great color satu-ration and efficiency. The resulting thin film structure can be affected by parameterssuch as solution concentration, solvent ratio, QD size distribution, and QD aspect ratio. Controlling these variables enables the production of QD-LEDs with great color saturation and efficiency. Finally, while this method successfully assembles QDmonolayers across entire surfaces, it does not allow us to construct the red, green, and blue QD monolayers near together, which is obviously desirable if we want to make a full colour QD-LED display.

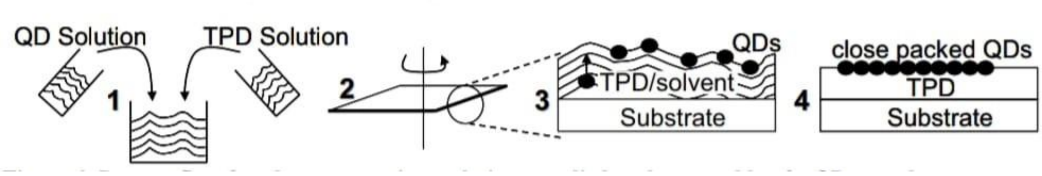

Figure 9: Phase Separation Method applying at the top of Quantum Dot Monolayer

5.2 Contact Printing

All devices are made on glass substrates that go through a routine cleaning process that includes rinsing in Decon, deionized water, drying in an oven, and ultimately plasma cleaning. Thermal evaporation is used to evaporate the electrode and tiny molecular organic CTLs on precleaned glass substrates under a high vacuum, with the vacuum being broken once for QD deposition. To define the anode and cathode,as well as build four devices on each substrate, a shadow mask is used. In a vacuum,all of the organic layers are thermally formed at a rate that is measured in real- timeby a quartz oscillator. Anode and hole transport layers (HTLs) have been evaporatedon the precleaned glass substrate before QDs deposition .10] As a result, the researchwill aid in the development of efficient QD-LED displays with a high aperture ratio, a wide colour spectrum, and consistent colour. Anode and hole transport layers (HTLs)have been evaporated on the precleaned glass substrate before QDs deposition .10] As a result, the research will aid in the development of efficient QD-LED displays with a high aperture ratio, a wide colour spectrum, and consistent colour.

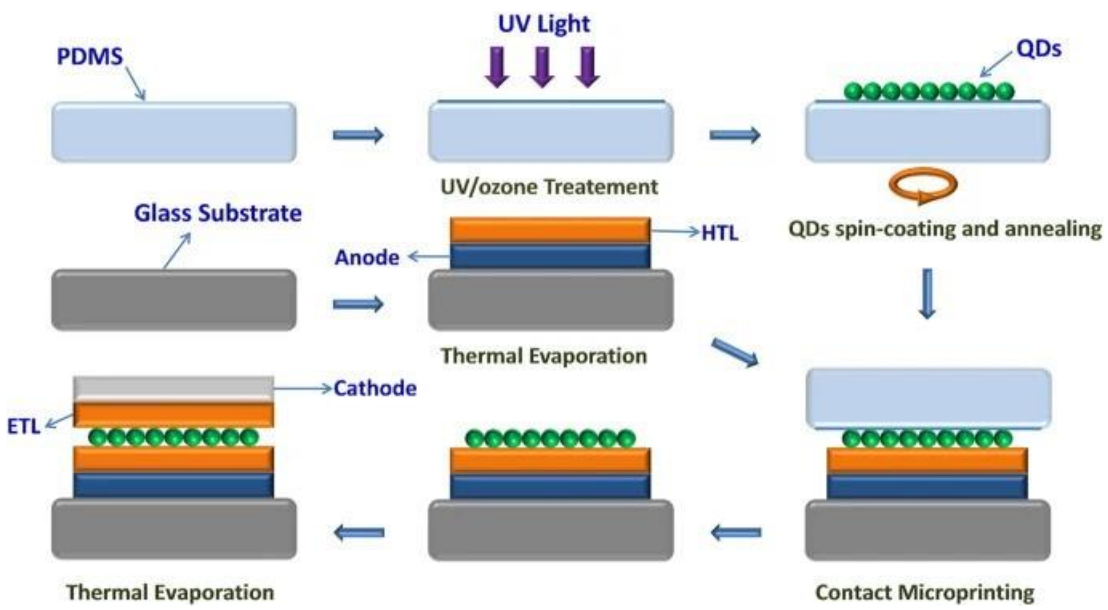

Figure 10: Contact Printing

5.3 Chemical Vapour Deposition

Colloidal synthesis to chemical vapour deposition (CVD)is the cheapest and simplest method same as benchtop colloidal synthesis.On a substrate material, electrochemical methods and CVD can be employed to build ordered arrays of quantum dots. Sim- ilar to tabletop colloidal synthesis, colloidal synthesis to chemical vapour deposition (CVD) is the cheapest and easiest approach. On a substrate material, electrochem- ical methods and CVD can be employed to build ordered arrays of quantum dots. Chemical vapor deposition (CVD) was used for the first time to create fluorescent carbon quantum dots (C-CQDs) with graphitic structure. The C-CQDs synthesized using this method have a superb crystalline graphitic character, with an average di- ameter of 3.5 nm and a high concentration of hydrophobic CH3 terminal groups. Chemical vapor deposition (CVD) was used for the first time to create fluorescent carbon quantum dots (C- CQDs) with graphitic structure. The C-CQDs synthesized using this method have a superb crystalline graphitic character, with an average di- ameter of 3.5 nm and a high concentration of hydrophobic CH3 terminal groups. C-CQDs have an optical band gap of 3.16 eV, and low-lying HOMO/LUMOenergy levels have been detected for these C-CQDs using cyclic voltammetry. The electron transporting layer (ETL) of polymer solar cells was made and evaluated utilizing solution-processed C-CQDs. The C-CQDs-based devices appear to have equivalent or slightly improved device performance to the LiF-based devices, according to the results. These C-CQDs-based devices had lower series resistance (RS), implying a superior interfacial interaction between the Al electrode and polymer with this ETL. More crucially, better thermal stability for CQD-based devices was confirmed, whichwas attributed to CCQDs' lower diffusion potential in a solid film. electrode and polymer with this ETL. More crucially, better thermal stability for CQD-based de- vices was confirmed, which was attributed to CCQDs' lower diffusion potential in a solid film. The current study found that CVD-synthesised C-CQDs can be used as a solution-processed ETL in organic solar cells, resulting in improved device stability.

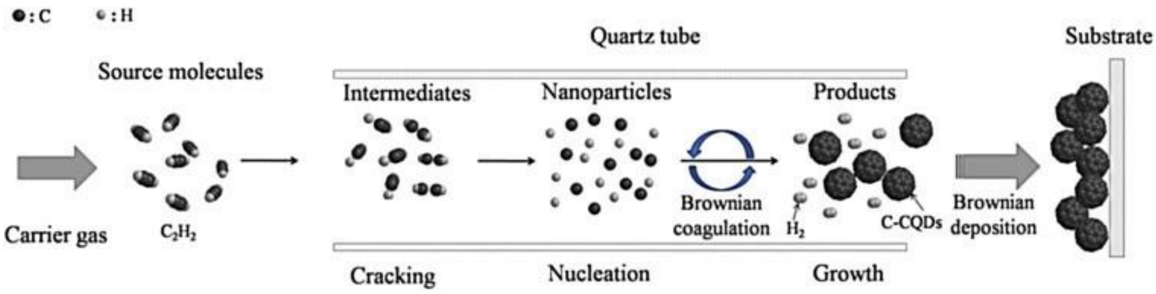

Figure 11: Chemical Vapour Deposition

6 Performance and Challenges

6.1 QD charging and QD luminescence quenching in thinfilm

When a DC current travels through a QD film, QD charging can occur. It gets more difficult to pass current through the device and maintain QD electroluminescence asthe QDs become more charged (EL). Because the time scales connected with QD charging span from minutes to days, it's difficult to get consistent illumination from a QD film that's been subjected to a lot of QD charging.

6.2 Photoluminescence Quantum Yields

Photoluminescence quantum yields of 95 percent are common for QDs suspended in solution; however, when the QDs are deposited in a densely packed thin film, the lu- minescence efficiency drops by an order of magnitude (to 5 or 10 percent). The degree of QD luminescence quenching observed in close-packed QD structures is reduced by embedding QDs in an insulating polymer matrix, although dc electrical conductivitythrough these QD-polymer composites is hampered by the low conductance of the wide bandgap polymers.

6.3 Maintaining efficiency

For high-performance QD-LEDs, efficient electron and hole injection, charge carrier balance arriving to the QD active layer, and minimising of the electric field across the QDs are all critical design criteria. These design parameters, on the other hand, arevery device specific and difficult to meet in the same device for several colour emitters with varying chemistries and sizes.

6.4 Toxic Materials

The problem is that cadmium is poisonous. It was agreed by the EU to prohibit it beginning in October of last year. However, a fresh consultation is underway, with anew extension largely likely. On the lighting front, the creators claim, and rightly so,that there is currently no feasible alternative. In the near or even medium-term, this argument will most likely prevail. However, it is not a long-term solution, implyingthat non-cadmium alternatives with sufficient stability will be necessary, indicating a critical potential for innovation and development.

7 Applications

7.1 Quantum dot light-emitting diodes for phototherapy

Phototherapy with quantum dots LEDs (QDLEDs). A medical dressing with an oc- clusive and translucent covering is one example. Within the occlusive layer, quantumdot light-emitting diode chips are designed to provide light of a certain wavelength foruse in phototherapy. A medical dressing comprising an occlusive layer and a translu-cent layer in which quantum dot material is inserted or impregnated within one or both layers is another embodiment. Phototherapy, often known as heliotherapy, is the treatment of medical conditions with the light. Phototherapy has been used to treata variety of ailments since then, including skin problems, circadian rhythm disorders,and seasonal affective disorders, neonatal jaundice, and tumors. Phototherapy for skin disorders such as psoriasis, eczema, dermatitis, and acne vulgaris is mostly de- pendent on UV radiation, but red to infrared (IR) light can be utilized to enhance wound healing. Within the occlusive layer, quantum dot light-emitting diode chips are designed to provide light of a certain wavelength for use in phototherapy.

7.2 Near- field scanning optical microscopy (NSOM)

Excitation and imaging of near-field fluorescence using a quantum dot (QD) light- emitting diode (QDLED) integrated at the tip of a scanning probe. In a near-field scanning optical microscopy configuration, the tip-embedded QDLED is used to di- rectly excite a secondary colloidal QD sample. Electrically pumped QDs offer multi- color, self-illuminating probes without the use of traditional optics. The ultra-thin (10–15 nm) light source can be precisely controlled thanks to monolayer QDs stampedat the very tip of a micromachined silicon probe. The sensitivity of fluorescence in- tensity to the distance between the QDLED and the QD sample was evaluated down to the 50 nm order, indicating spatially resolved imaging.

7.3 Incandescent bulbs

“QD-LEDs can potentially provide many advantages over standard lighting technolo-gies, such as incandescent bulbs, especially in the areas of efficiency, operating lifetime and the color quality of the emitted light,” said Victor Klimov of Los Alamos. Incan- descent bulbs, known for converting only 10 percent of electrical energy into light and losing 90 percent of it to heat, are rapidly being replaced worldwide by less wasteful fluorescent light sources. However, the most efficient approach to lighting is direct conversion of electricity into light using electroluminescent devices such as LEDs.

Figure 12: Incandescent Bulb

7.4 Medical Applications and Cancer Treatments

Quantum dots can be encapsulated in a shell that is tailored to resemble the body's biological sensors. These receptors can be linked to certain diseases, infections, or other objects. The quantum dots will then seek out the sickness in large numbers and attach themselves to it. The location of the problem is then made obvious dueto the fluorescent nature of quantum dots. The number of receptors required on the dot's surface is modest in comparison to the dot's surface area. This frees up a lot of space on the dot to put other items. This might include a variety of medications for treating sickness that the quantum dot has been programmed to detect.

Quantum dots can be tweaked in this way to seek out cancer cells and administer chemotherapy medications directly to them. This prevents cancer medicines from damaging healthy cells, resulting in the dreadful side effects that come with them.

Other Applications Nanophotonics, optical micro/nanoelectromechanical sys- tems (MEMS/NEMS), and biological sensing and imaging all benefit from quantum-dot-based light-emitting diodes (LEDs) manufactured on silicon. Microcontact print-ing allows for precise control of the nanoparticle thickness and area during deposition. Near-field microscopy beyond the diffraction limit, MEMS-based medical endoscopes for sub-cellular imaging, and small light-on-chip biosensors and biochips are just a few of the unique optoelectronic applications for QD-LED.

8 Future of Quantum Dot Technology

Quantum dots are a promising nanomaterial in a variety of developing applications due to their unique performance features and tunability. Quantum dots (QDs) are a type of semiconducting nanoparticle that combines optical and electrical capabilitiesin a unique way. In existing applications, QDs, for example, offer many of the same advantages as organic dyes, but they are more durable in terms of light-conversion capabilities and can tolerate strong chemical solvents, greater temperatures, and cor-rosion, while also offering a wider light-absorption band. Because of its capacity to emit exceptionally clean colours for long periods of time, QDs have been widely usedto improve the display qualities of high-end televisions. Micro and small LEDs, sen- sors, illumination, solar windows, anti-counterfeiting, and biosciences are all emerging market categories. Quantum dot vendors, display makers, and OEMs are all examined in the Global Market for Quantum Dots. By 2030, the global market for quantum dots (QD)-based goods is expected to be worth more than 35 billion US dollars. The optoelectronics market, specifically High Definition TVs-QLED-TVs, accounts for the great majority of this statistic.

With a rapidly rising market for QD monitors, TV displays continue to dominate the end user segment for QD-based devices. Large QD-TVs are also becoming more affordable. However, the use of QDs extends far beyond consumer electronics, with applications ranging from solar power to agriculture to water purification. Quantum dots are best recognised for their ability to provide vibrant colours to electronic displays, but their chemistry and tunability make them ripe for use in a variety ofother applications. According to Allied Market Research, the market for quantum dots is expected to increase by over 30 percent by 2025. Quantum dots are still being investigated by companies and researchers. These particles are being studied for their possible applications of quantum computing, biosensors, transistors, diode lasers, and battery technologies.

Figure 13: Future Of Quantum Dot Technology

9 Conclusion

In this whitepaper, we discussed the fundamental functional concepts of nanocrystal technology and its use in displays. QD-LED-based display technology is regarded asthe optimum alternative for future generation displays due to their exciting potential benefits in terms of performance, power consumption, contrast ratio, longevity, and response time. The synthesis of QD/organic bilayers using phase separation duringspin-casting is a reliable and versatile method. It has already been demonstrated to be a valuable technology for the production of new optoelectronic device archi- tectures, allowing high-efficiency QD-LEDs to be made. This approach allows the development and investigation of large-scale hcp crystal (super-lattice) domains of only two dimensions, which may be manufactured in seconds, in addition to single monolayers of QDs on top of organic semiconductor contacts. These domains have a controlled size scale, with a demonstrated maximum grain size of less than a square micrometer. The maximum grain size that can be created has very definitely not been attained. The ability to create macroscale devices from nanoscale materials requiresthe easy assembly of large-area arrays of tiny active elements. Furthermore, col- loidal QD-LEDs are employed as colour down-converters for LEDs to achieve efficient lighting and high-quality displays. There are still numerous obstacles to overcome.Components, materials, processes, products, and costs are all improving all of the time. The expansion of QD display technology is underway. In the near future, a breakthrough in the field of QDs-based LEDs for application in display technologiesis expected. To overcome the issues of QD implementation and structural changes, science is still progressing.

10 Acknowledgments

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