Quantum Dots and their Applications in Life Sciences

Introduction

Edison made a giant leap when he lit up the wire filament in that first incandescent light bulb. He was the hero of his days, but he was working in dark ages when compared to nano technology of these days. World has just become brighter with the invention of quantum dots[1]. Quantum dots are nano technology crystals that emit light. The wavelength with which they emit light depends on the size of the crystals. Quantum dots are made of various materials, such as lead sulfide, cadmium silinate etc[1]. Quantum dots are important because of their power to emit a particular wavelength and color depending on their composition and size. The main aim of this work is to find application of the quantum dots work to detect biological entities such as unicell organism (bacterial, micro organisms), single cell genes[2]. In this paper we are going to see some Biological, Life Science application of quantum dots.

How are quantum dots made?

First we discuss how Quantum dots are made. This Method of producing Quantum dots is to confine the electrons using electrodes. We start off with a layered structure which contains a quantum well and deposit narrow metal strips on the structure so as to define a square area [2]. If we make all of the metals strips negatively charged then the electrons in the quantum well beneath the surface will be repelled [2]. However, since they are confined to a thin layer which is parallel to the surface, the only direction they can move is side ways. As a result, the electrons are concentrated only into a tiny cluster directly underneath the central square defined by the electrodes [2]. If we make this area small enough we can have a quantum dot. The interesting thing about this method is that we can control the number of dots by varying the voltage on the electrode [2]. Whereas the shape of the quantum dots depends on the external electrodes and the barriers around the quantum well, which constrain the electron.

Application of the Quantum dots:

Let me first discuss how the quantum dots could be used in micro electronics. Suppose we produce an array of quantum dots using a grid of electrodes which divides the surface into squares about a tenth of a micron across [3]. A quick calculation shows that we could place ten billion of these on an area of one square centimeter [3]. If each one serves as a resonant tunneling transistor, performing the function of several conventional transistors, such a structure should have a capacity far in excess of the most powerful present-day supercomputer, and all this on a single chip [3].
Quantum dots have applications in the biological world as fluorescent tags.
Quantum dots are nanometer-scale Nano crystals composed of a few hundred to a few thousand semiconductors atoms out of bio-inert materials – meaning they are non intrusive and nontoxic to the body.

Additionally, unlike fluorescent dyes (which tend to decompose and lose their ability to fluoresce), quantum dots maintain their integrity with standing more cycles of excitation and light emission before they start to fade. Changing their size or composition allows us to cater their optical properties- which means they are fluoresce in a multitude of color [4].

Interestingly enough, quantum dots can even be tuned to fluoresce in different colors with the same wavelength of light i.e. we can choose quantum dots size where the frequency of light required to make one group of dots fluoresce is an even multiple of the frequency required to make another group of dots fluoresce [4]; both dots then fluoresces with the same wavelength of light. This allows multiple tags to be tracked while using a single light source.

Quantum dots are insoluble in water soluble. This is the main reason they are restricted in biological uses. To overcome this problem the quantum dots are coated with polymer layer [5]. This enables quantum dot to mix with water

Quantum dots are also used to detection the behavior of the cells which cause breast cancer a burning problem in the present day world. Using this technology scientist are planning to find the properties of the cancer cells so that they can make a nano drug that can cure the infected part of the cell [5].

Another application of quantum dots is in deoxyribonucleic acid (DNA). DNA is the nucleic acid carrying the genetic blueprint of all forms of cellular life [1]. The double helix structure of DNA is shown in figure. We can map our DNA using Quantum dots. DNA can be attached to gold or silver nanodots (14nm wide) that are suspended in a liquid [1]. Each gold particle has the same base pair- but when a linker (such as Anthrax DNA) is introduced, the gold particles form larger clusters, which change their optical properties as shown in Figure 4.

Here particle size indicates the wave length of the light, hence color. Imagine with out the linker, the liquid looks purple; with the linker however looks red- providing a quick macroscopic analysis. Because of this color change, these are
called colorimetric sensors [3].

The type of DNA damage is not repaired by a single protein. “In these types of processes there are likely multiple proteins that come into play. So, one of the current challenges is observing this complex process happening in a live cell in real time. This can be done using quantum dots technique [3].

**Application of Quantum dots flour dyes**

These are used in
- Oligonucleotides can be successfully couples to molecular beacons which can serve as basis for DNA, RNA assay [3]
- Flowcytometry application as recorders by emitting multiple laser sources of conventional flow cytometers so that we can reduce cost of cytometer system [3].
- High throughput screening assay (due to the ability to conjugate to small molecules) [3].
- Quantum dot flour dyes have 15 -20nm fluorescence lifetime which will enable them to study the signal noise ratio effectively [4].

Quantum dots can also be used in the study of antibiotic release into the cell

![Quantum dots in antibiotic applications](image)

Figure 5. Quantum dots in antibiotic applications

Figure 5 shows two different wave length of quantum dots (red and green) that are attached to the antibiotic which are used to cure the effected cells.

Quantum dots can also be used in live and fixed fluorescence cell labeling such as cellular tracking, stem cell differentiation tracking, genetic instability monitoring, molecular location tracking. Figure 6 below shows us the tracking of cells in mice which is presently carried out by Evidenttech

![Near Infrared EviTag Control](image)

Figure 6. mice cell detection using quantum dots

**Conclusion**

The whole concentration of this paper was to provide application of quantum dots in life sciences and biotechnology. Quantum dots application in study of breast cancer cells, antibiotic drugs is still at research level. Research is to be carried out in the areas like DNA moments, labeling of proteins, tagging of nucleic acid and so on. It if definite that using quantum dots many of the dark spots of life science can be studied.

**For More information on related products, please visit [www.aladdin-e.com](http://www.aladdin-e.com)**

**References**

3. available online http://www.nserc.ca/news/features/quantum_e.htm