**The QUANTUM DOTS**

The optoelectronic properties of the fine particles are sensitive to particle size, crystal habit and to their composition.

The quantum size effect is one of the properties that are enhanced by the nanoparticles, in fact, when the size of a particle becomes smaller than the effective Bohr radius, approximately 10 nm, the electrons are confined and their bands become discrete, as happens in a single atom. The quantum dots are considered artificial atoms, as the possibility of changing the energy states of the electrons by changing an applied voltage led to the idea of being able to change the nature of matter. In other words, since it is possible to change the energy band of the materials by changing their size it is possible to obtain entirely new applications (see an image of a quantum dot in Fig. 1).

Among the materials that exhibit these characteristics there are the semiconductor particles of the COE type where E = S, Se, Te. At the beginning of the 90s Murray and others prepare CdSe particles of between 1 and 11 nm for pyrolysis and measured the absorption spectra of these particles as a function of size. The result was to observe a continuous change of the spectra to vary the same size (see Fig. 2). This effect can be observed only with very uniform nanoparticles having a standard deviation less than 5% in the particle size distribution. The result is an outstanding control of the length of the light radiated from these particles in the visible range (see fig. 3).

These particles are normally coated on the surface with a surfactant to prevent their aggregation or covered with a shell from another semiconductor (ZnS, ZnSe, CdS, etc.). The shell of the material may change the optical characteristics of the material, while changing the surface active agent can change the hydrophobicity, the pH etc. (See fig. 4). Thanks to their fluorescence these particles can be used in biomedicine on the basis of their functionalization that allows their bond with the cells to detect. For the high exposed surface per unit of weight, their optical characteristics may be influenced by the environment in which they are placed, so they can be used as sensors

One of the most interesting applications, under development, is the use of these compounds as optical memories. In fact, if a thin film of a suspension of these particles, subjected to an irradiation, increases its fluorescence and is stored in a dark environment, to a subsequent irradiation it manifests the same intensity of fluorescence. Specifically, core-shell nanoparticles of CdSe in ZnS size of 4 nm have been used to coat a glass slide using the spin-coating technique. Initially an area of 60 $um_2$ It was irradiated with light having an intensity of 0.6 nW. The fluorescence was observed uniformly. Then, there has been an excitation light on a surface of 7.4 $uM_{2(}$ write operation). After this observation has returned to observe the total area under an intensity of light of

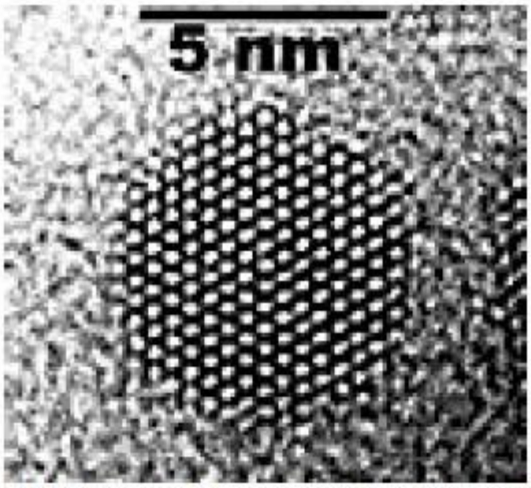
0.6 nW and was observed on the area where previously there had been an increase in the intensity of the light beam the same high fluorescence (reading operation) (see fig. 5). The observation of this phenomenon shows the possibility of using quantum dots for optical memories.

The preparation of the nanoparticles of CdS, CdSe and CdTe can be obtained, as shown by Murrey, by pyrolysis, in the absence of oxygen, of organometallic reagents. E 'can control the final size by varying the growth temperature. In particular, the author quoted used dimethyl cadmium, which cadmium source,

and bis (trimethylsilyl) sulfide, bis (trimethylsilyl) selenide and trioctylphosphine telluride in tri-n-octylphosphine oxide solvents (TOPO). A mixed solution of the compounds of Cd and the other element are sent in an oven at 300 ° C where there is the solvent.

A second method for the production of such nanoparticles is based on the method of microemulsions water-in-oil (see "Nanoparticles for Biomedical").

Figure 6 shows international companies engaged in the production and use of quantum dots.




*TEM image if a quantum dot. It is seen the distribution of atoms. Copyright Quantum Dot Corporation, Hayward, CA, USA.*

**Figure 1**

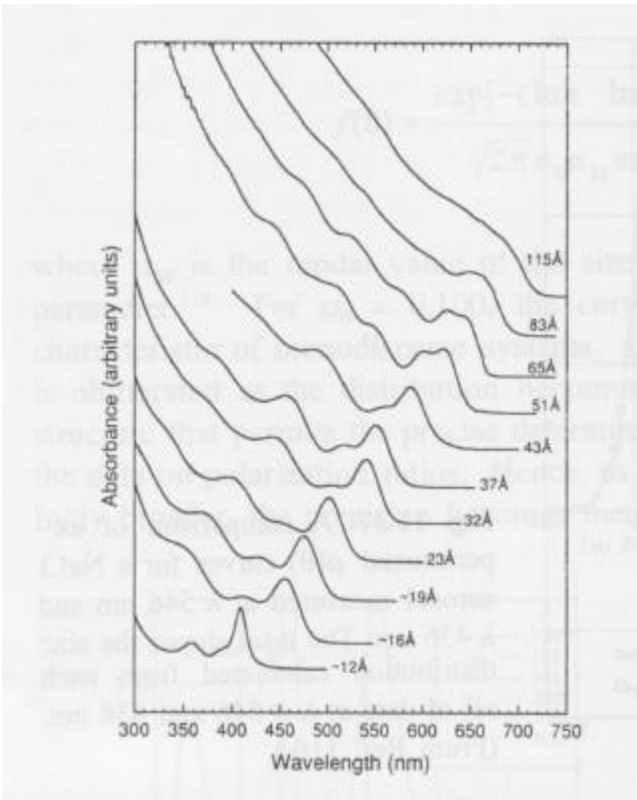



**Figure 2** Absorption spectra of CdSe nanoparticles with different sizes

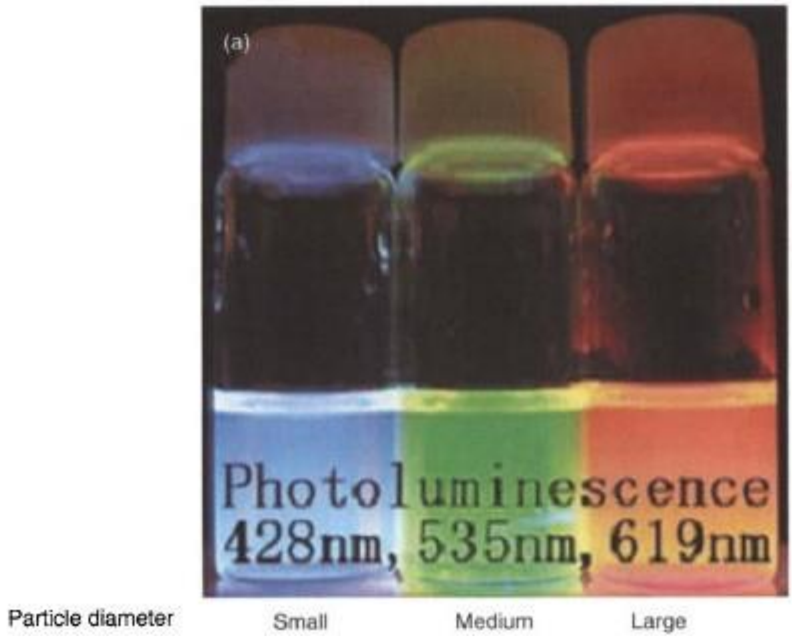



**Figure 3** Fluorescence of CdSe nanoparticles as a function of size

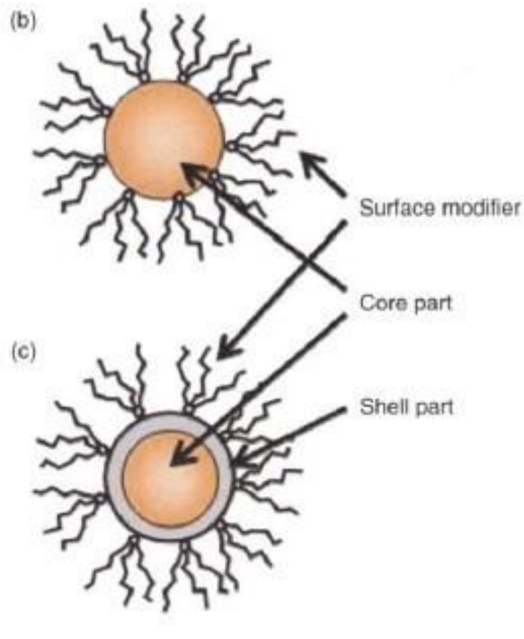



**Figure 4** Nanoparticles of CdSe with external disagglomerante agent (b) and with a shell and disagglomerante agent (c)

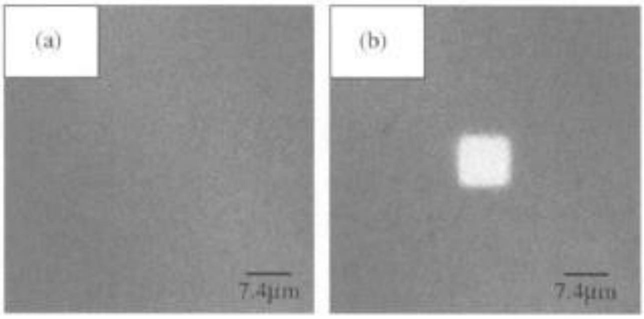



**Figure 5:** image of fluorescence) before the "writing"; b) after writing

## Companies Working with Quantum Dots

| ***Company*** | ***Activity*** |
|---|---|
| ASM INTERNATIONAL | Researching a process for the production of silicon quantum dots on aluminum oxide. |
| BIOCRYSTAL | Produce a labeling technique for living tissues using quantum dots. |
| BIODOT CORP. | Have commercialized a technology using quantum-dot microbeads for tagging biological molecules. |
| EVIDENT TECHNOLOGIES | Produce a DNA probe, consisting of quantum dots attached to DNA. |
| FUJITSU | Doing research into quantum dots (growth, study, and applications). |
| HEWLETT-PACKARD CO. | The molecular electronics program of the Quantum Science Research Group has three components: defect-tolerant architectures, nanostructure fabrication (quantum dots and nanowires), and molecular switches. |
| HYNIX SEMICONDUCTOR INC. | Have patented a method for the production of semiconductor quantum dot memories. |
| MATSUSHITA ELECTRIC INDUSTRIAL | Have developed a method for arranging metallic nanoparticles on a silicon wafer, with applications in production of quantum dots and related devices. |
| MP TECHNOLOGIES LLC | R&D on quantum dot applications with a main focus on optoelectronic devices. |
| NANOSYS INC. | Focused on the development of nanotechnology-enabled systems incorporating zero and one-dimensional nanometer-scale materials such as nanowires, nanotubes and nanodots (quantum dots). |
| NIPPON TELEGRAPH AND TELEPHONE | Their NTT laboratories are working on single electron transistor technology and its applications in circuits. |
| NEC | R&D projects include single electron transistors. |
| QUANTUM DOT CORP. | Develop and commercialize labeling technology using semiconductor quantum dots. |
| QUANTUM LOGIC DEVICES | Develop single electron transistor platforms for applications in electronics as well as a variety of chemical sensing markets. |
| SAMSUNG CORP. | R&D activities include single electron transistors. |
| SI DIAMOND TECHNOLOGY INC. | Have patented a silicon quantum dot that exhibits bright fluorescent radiation in the visible range. |
| SYSTINE INC. | Are conducting research and development on massively parallel fabrication processes for nanometer-sized quantum dot structures on silicon. |
| TOSHIBA | Research includes quantum dots in silicon — they have developed a single photon emitter combining LED and quantum dot technologies. |
| ZIA LASER | Develop and commercialize quantum dot lasers. |

**Figure 6** Companies engaged in the production and applications of quantum dots