Features of nano system:

Nanotechnology (sometimes shortened to "**nanotech**") is the study of manipulating matter on an atomic and molecular scale. Generally, nanotechnology deals with developing materials, devices, or other structures possessing at least one dimension sized from 1 to 100 nanometres. Quantum mechanical effects are important at this quantum-realm scale.

Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale to direct control of matter on the atomic scale. Nanotechnology entails the application of fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, microfabrication, etc.

There is much debate on the future implications of nanotechnology. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicine, electronics, biomaterials and energy production. On the other hand, nanotechnology raises many of the same issues as any new technology, including concerns about the toxicity and environmental impact of nanomaterials, and their potential effects on global economics, as well as speculation about various doomsday scenarios. These concerns have led to a debate among advocacy groups and governments on whether special regulation of nanotechnology is warranted.

Although nanotechnology is a relatively recent development in scientific research, the development of its central concepts happened over a longer period of time.

The emergence of nanotechnology in the 1980s was caused by the convergence of experimental advances such as the invention of the scanning tunneling microscope in 1981 and the discovery of fullerenes in 1985

Around the same time, K. Eric Drexler developed and popularized the concept of nanotechnology and founded the field of molecular nanotechnology.

In 1979, Drexler encountered Richard Feynman's 1959 talk "There's Plenty of Room at the Bottom". The term "nanotechnology", originally coined by Norio Taniguchi in 1974, was unknowingly appropriated by Drexler in his 1986 book *Engines of Creation: The Coming Era of Nanotechnology*, which proposed the idea of a nanoscale "assembler" which would be able to build a copy of itself and of other items of arbitrary complexity. He also first published the term "grey goo" to describe what might happen if a hypothetical self-replicating molecular nanotechnology went out of control. Drexler's vision of nanotechnology is often called "Molecular Nanotechnology" (MNT) or "molecular manufacturing," and Drexler at one point proposed the term "zettatech" which never became popular.

Fundamental concepts

Nanotechnology is the engineering of functional systems at the molecular scale. This covers both current work and concepts that are more advanced. In its original sense, nanotechnology refers to the projected ability to construct items from the bottom up, using techniques and tools being developed today to make complete, high performance products.

One nanometer (nm) is one billionth, or 10^{-9}, of a meter. By comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 0.12–0.15 nm, and a DNA double-helix has a diameter around 2 nm. On the other hand, the smallest cellular life-forms, the bacteria of the genus Mycoplasma, are around 200 nm in length. By convention, nanotechnology is taken as the scale range 1 to 100 nm .

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Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macroscale, enabling unique applications. For instance, opaque substances become transparent (copper); stable materials turn combustible (aluminum); insoluble materials become soluble (gold). A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscales. Much of the fascination with nanotechnology stems from these quantum and surface phenomena that matter exhibits at the nanoscale.

Applications

The National Science Foundation (a major distributor for nanotechnology research in the United States) funded researcher David Berube to study the field of nanotechnology. His findings are published in the monograph Nano-Hype: The Truth Behind the Nanotechnology Buzz. This study concludes that much of what is sold as “nanotechnology” is in fact a recasting of straightforward materials science, which is leading to a “nanotech industry built solely on selling nanotubes, nanowires, and the like” which will “end up with a few suppliers selling low margin products in huge volumes." Further applications which require actual manipulation or arrangement of nanoscale components await further research. Though technologies branded with the term 'nano' are sometimes little related to and fall far short of the most ambitious and transformative technological goals of the sort in molecular manufacturing proposals, the term still connotes such ideas. According to Berube, there may be a danger that a "nano bubble" will form, or is forming already, from the use of the term by scientists and entrepreneurs to garner funding, regardless of interest in the transformative possibilities of more ambitious and far-sighted work.[

Implications

The Center for Responsible Nanotechnology warns of the broad societal implications of untraceable weapons of mass destruction, networked cameras for use by the government, and weapons developments fast enough to destabilize arms races.

Another area of concern is the effect that industrial-scale manufacturing and use of nanomaterials would have on human health and the environment, as suggested by nanotoxicology research. For these reasons, groups such as the Center for Responsible Nanotechnology advocate that nanotechnology be regulated by governments. Others counter that overregulation would stifle scientific research and the development of beneficial innovations.

Some nanoparticle products may have unintended consequences. Researchers have discovered that bacteriostatic silver nanoparticles used in socks to reduce foot odor are being released in the wash. These particles are then flushed into the waste water stream and may destroy bacteria which are critical components of natural ecosystems, farms, and waste treatment processes.

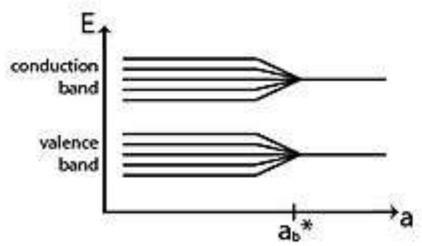
2nd topic

A **quantum dot** is a portion of matter (e.g., semiconductor) whose excitons are confined in all three spatial dimensions. Consequently, such materials have electronic properties intermediate between those of bulk semiconductors and those of discrete molecules.[1][2][3] They were discovered at the beginning of the 1980s by Alexei Ekimov[4] in a glass matrix and by Louis E. Brus in colloidal solutions. The term "quantum dot" was coined by Mark Reed.[5]

Researchers have studied quantum dots in transistors, solar cells, LEDs, and diode lasers. They have also investigated quantum dots as agents for medical imaging and hope to use them as qubits in quantum computing.

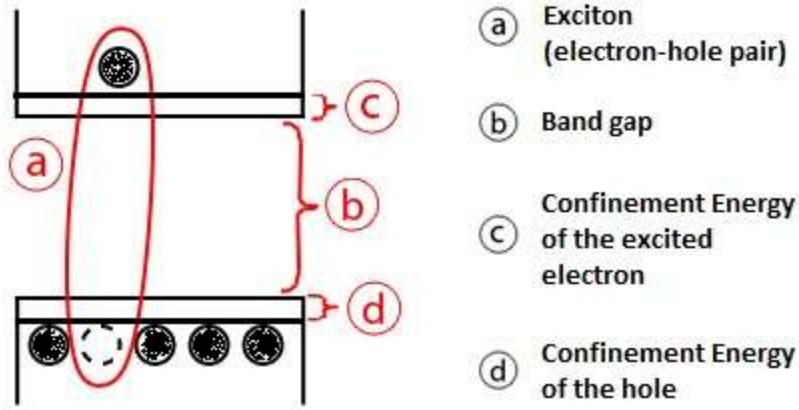
Stated simply, quantum dots are semiconductors whose electronic characteristics are closely related to the size and shape of the individual crystal. Generally, the smaller the size of the crystal, the larger the band gap, the greater the difference in energy between the highest valence band and the lowest conduction band becomes, therefore more energy is needed to excite the dot, and concurrently, more energy is released when the crystal returns to its resting state. For example, in fluorescent dye applications, this equates to higher frequencies of light emitted after excitation of the dot as the crystal size grows smaller, resulting in a color shift from red to blue in the light emitted. In addition to such tuning, a main advantage with quantum dots is that, because of the high level of control possible over the size of the crystals produced, it is possible to have very precise control over the conductive properties of the material.[6] Quantum dots of different sizes can be assembled into a gradient multi-layer nanofilm.

In a semiconductor crystal lattice, the electrons are squeezed together, since no two nearby electrons can share exactly the same energy level according to Pauli exclusion principle, leading to quantum confinement. The energy level can then be modeled using particle in a box, which leads to the conclusion that the energy levels of the quantum dot is dependent on its size. When the size of the quantum dot is smaller than the critical characteristic length called the Exciton Bohr radius, the electrons crowding lead to the splitting of the original energy levels into smaller ones with smaller gaps between each successive level. The Exciton Bohr radius is larger than the Bohr radius due to the effect of dielectric screening and the influence of periodic lattice structure of the crystal. The quantum dots that have radii larger than the Exciton Bohr radius are said to be in the 'weak confinement regime' and the ones that have radii smaller than the Exciton Bohr radius are said to be in the 'strong confinement regime'. Thus, if the size of the quantum dot is small enough that the quantum confinement effects dominate(typically less than 10 nm), the electronic and optical properties change, and the fluorescent wavelength is determined by the size.



Splitting of energy levels for small quantum dots due to the quantum confinement effect. The horizontal axis is the radius, or the size, of the quantum dots and a_b* is the Exciton Bohr radius.

The fluorescence of the quantum dots is a result of exciting the valence electron with a certain energy(or wavelength) and the emission of lower energy in the form of photons as the excited electron return to the ground state combining with the hole. The energy of the emitted photon is determined by the size of the quantum dot due to quantum confinement effects. In a simplified model of the excitation, the energy of the emitted photon can be seen as a sum of the band gap energy between occupied level and unoccupied energy level, the confinement energies of the hole and the excited electron, and the bound energy of the exciton(the electron-hole pair):



Band gap energy

The band gap can become smaller in the strong confinement regime where the size of the quantum dot is smaller than the Exciton Bohr radius (a_b* in the figure) as the energy levels split up.

$$a_b^* = \varepsilon_r \left(\frac{m}{\mu}\right) a_b$$

where a_b is the Bohr radius=0.053 nm, m is the mass, μ is the reduced mass, and ε_r is the size-dependent dielectric constant

This results in the increase in the total emission energy(the sum of the energy levels in the smaller band gaps in the strong confinement regime is larger than the energy levels in the band gaps of the original levels in the weak confinement regime) and the emission at various wavelengths; which is precisely what happens in the sun, where the quantum confinement effects are completely dominant and the energy levels split up to the degree that the energy spectrum is almost continuous, thus emitting white light.

Exciton Bohr radius, the Coulomb interaction must be modified to fit the situation.

Therefore, the sum of these energies can be represented as:

$$E_{\text{confinement}} = \frac{\hbar^2\pi^2}{2a^2}\left(\frac{1}{m_e}+\frac{1}{m_h}\right) = \frac{\hbar^2\pi^2}{2\mu a^2}$$

$$E_{\text{exciton}} = -\frac{1}{\epsilon_r^2}\frac{\mu}{m_e}R_y = -R_y^*$$

$$\begin{aligned} E &= E_{\text{bandgap}} + E_{\text{confinement}} + E_{\text{exciton}} \\ &= E_{\text{bandgap}} + \frac{\hbar^2\pi^2}{2\mu a^2} - R_y^* \end{aligned}$$

where:

- μ is the reduced mass
- a is the radius
- m_e is the free electron mass
- m_h is the hole mass
- ε_r is the size-dependent dielectric constant

Although the above equations were derived using simplifying assumptions, the implications are clear; the energy of the quantum dots are dependent on their size due to the quantum confinement effects, which dominate below the critical size leading to changes in the optical properties. This effect of quantum confinement on the quantum dots have been experimentally verified and is a key feature of many emerging electronic structures.

Production

There are several ways to confine excitons in semiconductors, resulting in different methods to produce quantum dots. In general, quantum wires, wells and dots are grown by advanced epitaxial techniques in nanocrystals produced by chemical methods or by ion implantation, or in nanodevices made by state-of-the-art lithographic techniques.

There are colloidal methods to produce many different semiconductors. Typical dots are made of binary alloys such as cadmium selenide, cadmium sulfide, indium arsenide, and indium phosphide. Dots may also be made from ternary alloys such as cadmium selenide sulfide. These quantum dots can contain as few as 100 to 100,000 atoms within the quantum dot volume, with a diameter of 10 to 50 atoms. This corresponds to about 2 to 10 nanometers, and at 10 nm in diameter, nearly 3 million quantum dots could be lined up end to end and fit within the width of a human thumb.

The quantum dot absorption features correspond to transitions between discrete,three-dimensional particle in a box states of the electron and the hole, both confined to the same nanometer-size box.These discrete transitions are reminiscent of atomic spectra and have resulted in quantum dots also being called *artificial atoms*.

Bulk-manufacture

Conventional, small-scale quantum dot manufacturing relies on a process called “high temperature dual injection” which is impractical for most commercial applications that require large quantities of quantum dots.

Cadmium-free quantum dots

Cadmium-free quantum dots are also called “CFQD”. In many regions of the world there is now a restriction or ban on the use of heavy metals in many household goods which means that most cadmium based quantum dots are unusable for consumer-goods applications.

Applications

Quantum dots are particularly significant for optical applications due to their high extinction co-efficient . In electronic applications they have been proven to operate like a single electron transistor and show the Coulomb blockade effect. Quantum dots have also been suggested as implementations of qubits for quantum information processing.

The ability to tune the size of quantum dots is advantageous for many applications. For instance, larger quantum dots have a greater spectrum-shift towards red compared to smaller dots, and exhibit less pronounced quantum properties. Conversely, the smaller particles allow one to take advantage of more subtle quantum effects.

Computing

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..

Biology

In modern biological analysis, various kinds of organic dyes are used. However, with each passing year, more flexibility is being required of these dyes, and the traditional dyes are often unable to meet the expectations. For single-particle tracking, the irregular blinking of quantum dots is a minor drawback.

The usage of quantum dots for highly sensitive cellular imaging has seen major advances over the past decade. The improved photostability of quantum dots, for example, allows the acquisition of many consecutive focal-plane images that can be reconstructed into a high-resolution three-dimensional image. Semiconductor quantum dots have also been employed for in vitro imaging of pre-labeled cells. The ability to image single-cell migration in real time is expected to be important to several research areas such as embryogenesis, cancer metastasis, stem-cell therapeutics, and lymphocyte immunology.

Photovoltaic 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[33]), 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).

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 show 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.

Photo detector devices

Quantum dot photodetectors (QDPs) can be fabricated either via solution-processing,or from conventional single-crystalline semiconductors. Conventional single-crystalline

QUANTUM SIZE EFFECT:

A number of physical phenomena become pronounced as the size of the system decreases. These include statistical mechanical effects, as well as quantum mechanical effects, for example the “quantum size effect” where the electronic properties of solids are altered with great reductions in particle size. This effect does not come into play by going from macro to micro dimensions.

However, quantum effects become dominant when the nanometer size range is reached, typically at distances of 100 nanometers or less, the so called quantum realm. Additionally, a number of physical (mechanical, electrical, optical, etc.) properties change when compared to macroscopic systems. One example is the increase in surface area to volume ratio altering mechanical, thermal and catalytic properties of materials. Diffusion and reactions at nanoscale, nanostructures materials and nanodevices with fast ion transport are generally referred to nanoionics. *Mechanical* properties of nanosystems are of interest in the nanomechanics research. The catalytic activity of nanomaterials also opens potential risks in their interaction with biomaterials.

Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macroscale, enabling unique applications. For instance, opaque substances become transparent (copper); stable materials turn combustible (aluminum); insoluble materials become soluble (gold). A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscales. Much of the fascination with nanotechnology stems from these quantum and surface phenomena that matter exhibits at the nanoscale.[14]