19.7.2 Applications of Quantum Dots

Semiconductor quantum dots (CQ) can be tuned and adjusted for many applications, including optics, medicine, and quantum computation. Quantum dots are used in biolabelling, in anticounterfeiting applications to create special inks, in dyes and paints, in light displays, and in chemical sensing.

(a) Life science

Innumerable applications of quantum dots are found in life science. Cadmium telluride (CdTe) and CdSe nanocrystals are of great industrial interest for developing photoluminescence-based biomedical labelling reagents. Noncadmium quantum dots can be used for in vivo imaging (Fig. 19.36). Quantum dots preferentially stain the vascular and lymphatic system, tumours, etc. in large multicellular animals such as mice. Western blotting, cell staining, flow cytometry, and cellular uptake are other examples of quantum dot applications. Figure 19.36 shows an application of noncadmium quantum dots for life science: in vivo imaging with preferential staining in specific parts.

FIGURE 19.36 *Quantum dots application in in vivo imaging.*

(b) Display

The applications of quantum dots are both in organic and inorganic light emitter devices such as electroluminescence (EL) devices.

The quantum dot material is dispersed within or between phosphor layers and emits a specific colour of light. Quantum dots can be applied over large areas using liquid phase deposition techniques such as roll-to-roll printing and spin coating. The emission of colours of nanophosphors based on quantum dots, which can be tuned by changing the size of the quantum dot. Also, quantum dots are utilized to enhance light-emitting diodes and can emit almost any colour. Figure 19.37 shows an application of quantum dots for a colour display device.

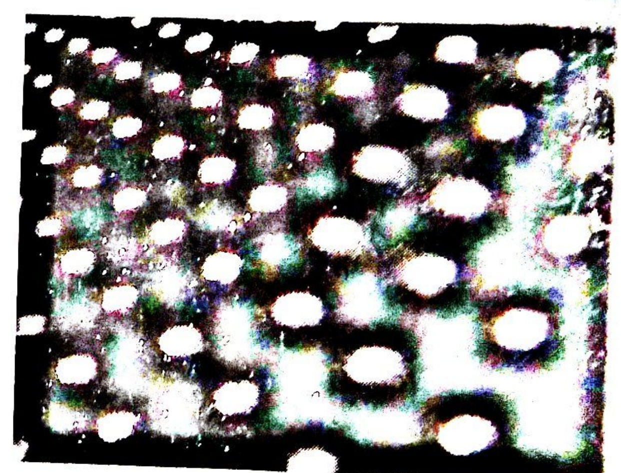

FIGURE 19.37 *Quantum dots application in display device.*

(c) Photovoltaic devices

The properties of quantum dots can be tuned to desired sizes and band gaps. Interestingly, it is possible to get multiple energy band gaps for quantum dots containing different size materials. Different layers of different band gaps can then be used to reduce loss of incident light. Multiple band gaps can absorb photons from several different wavelengths according to their band gap energies. This allows increased photon-to-electron conversion efficiency in photovoltaic devices. Also, quantum dots are cost-effective and can be incorporated into semiconductor polymers or inks and deposited onto low-cost substrate by roll-to-roll printing techniques.

(d) Photonics and telecommunications

The properties of quantum dots provide an opportunity to exploit and develop optical switches, modulators, and other nonlinear optic devices. The reason for this behaviour is that quantum confinement enhances nonlinear absorption and nonlinear refractive index.

The optical switches and logic gates that work faster than 15 terabits per second can be achieved when quantum dots are being used.

The quantum dot laser device is another potential application. The tunable band gap of quantum dots makes the laser wavelength changeable. Also, lasers with quantum dots have potential for very low-threshold current density, which is the current required to stimulate the laser or create output power from the device. The most studied material for the quantum dot laser are InGaAs/AlGaAs, GaAs/InAs. For laser application, single- or multiquantum dot layers are used. Figure 19.38 shows the structure of a quantum dot laser with multiple active layers.

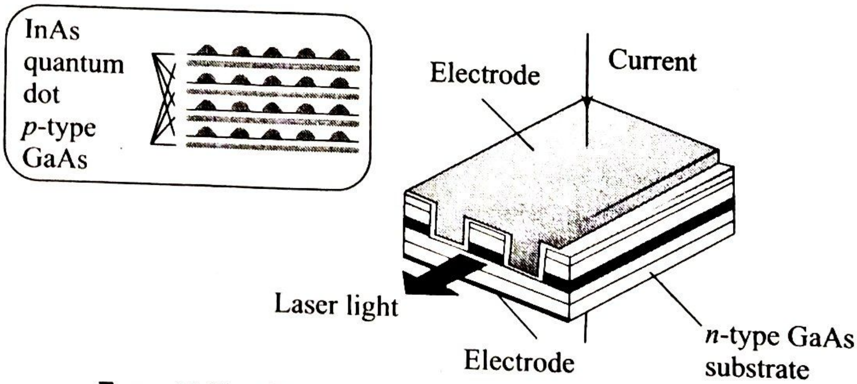

Figure 19.38 *Structure of a typical quantum dot laser.*

(e) Security inks

For security and anticounterfeiting applications, inks and paints incorporated with quantum dots can be applied to many types of surfaces, including papers, plastics and metals. The wide range of colour combinations of multiple quantum dots and other pigment creates a unique visible image that identifies any subject or document when exposed to UV light (Fig. 19.39).

Adjusting the quantum dots can produce info-ink that consists of CdSe quantum dots, toluene and polystyrene.

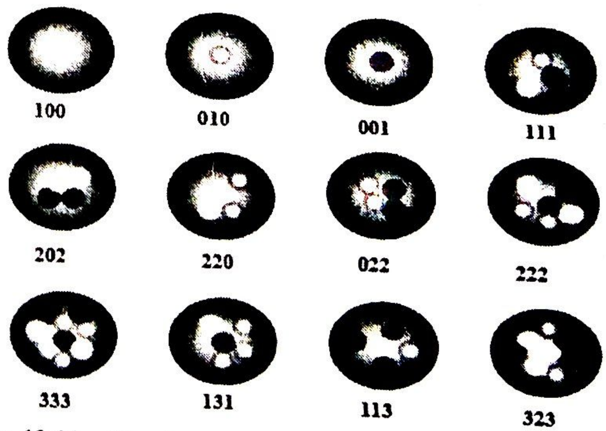

Figure 19.39 *Illustrates schematically the samples of info-inks consisting of three different quantum dots with different emission wavelengths.*