Detection of UV Rays Using CdTe Quantum Dots

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ABSTRACT

Development of simple UV detection system using CdTe quantum dots (QDs) as primary detector with scintillating property on exposure to UV rays is reported. CdTe, CdTe/ZnS and CdTe/CdS QDs were synthesized in aqueous phase using mercaptosuccinic acid (MSA) as a capping agent and studied for its properties like crystallite size, band gap energy, fluorescence emission intensity and uniformity in size distribution. The prepared QDs were exposed to different radiations such as infrared (IR), ultraviolet (UV) and X-rays. The fluorescent emission was recorded by an optoelectronic circuit in terms of electrical signal. The result of this study shows that CdTe/ZnS QDs is better suited for the detection and measurement of UV rays. Hence these QDs could be used as a sensing element while fabricating nanosensor for UV detection.

Keywords: *IR, MSA, Phototransistor, Quantum Dot, Radiation, Ultraviolet, X-Rays*

1. INTRODUCTION

Quantum dots (QDs) are generally semiconductor nanocrystal that are bright and photo stable flurophores. They have a broad excitation spectrum and a narrow Gaussian emission spectrum at wavelengths controllable by size of the material. The most fundamental characteristics shared by every quantum dots is that they possess quantum confined electrons in all three dimensions, and thus making it behave like an artificial atom (Tellez, 2010). The phenomenon of 3-dimensional quantum confinement leads to large dependence of band gap energy on the size of the quantum dot. This allows by changing the size and shape of the molecule, the electronic and optical properties of quantum dots to be highly tunable (Smith & Nie, 2000). Modifying the surface of the QDs by using surface ligands is another way to control the band gap energy. Surface ligands which

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are similar to dopants in semiconductors that modify the band gap energy by giving additional electrons or holes to the nanoparticles. Shell of ligands allows the quantum dots to be suspended in a variety of organic solvents and water, permitting diverse applications.

The absorption and emission spectral range of QDs due to external applied energy are the result of the band gap energy. The allowed energy transitions include excitations from the ground state (valance band) to a excited state (conduction band); any additional energy from the absorbed photon goes to higher vibrational and rotational energy sub-levels in the excited state as shown in Figure 1. However, fluorescence emission can only occur from the lowest sub-level of the excited state. This means an electron has gone to relax, through vibrational losses to the crystal lattice, before it can fluorescence. The energy difference from the absorbed photon to emitted photon caused by relaxation is called the Stokes shift and it can be seen in Figure 1. The necessity for an electron to relax and fluorescence from the lowest vibrational energy level is what makes the fluorescence spectrum narrower (Kang, 2011) than the absorption spectrum.

Radioactivity is a natural and spontaneous process by which the unstable atoms of an element emit or radiate excess energy in the form of particles or waves. These emissions are collectively called ionizing radiations, which posses high energy that when they interact with materials, can remove electrons from the atoms. Though ionizing radiation is hazardous (Knoll & Glenn, 2010) it plays an important role in society. While X-rays and gamma rays are commonly referred to as ionizing radiations, high energy UV radiations have enough energy to cause ionization of an atom. UV radiations have both positive and negative effects on human system. While short exposures to UV radiations are beneficial as they generate Vitamin D longer exposures or high intensity exposures can be detrimental causing skin problems and sometimes skin cancer also. Man made sources of UV radiation include welding arcs and tanning beds. Since, these radiations cannot be seen or felt, sensitive instruments are necessary to indicate its presence and its detection becomes very important in terms of human safety.

Inspired by new high energy physics experiments, the first radiation detector in positron emission tomography (PET), computer tomography (CT), and gamma cameras were built of scintillators combined with vacuum phototubes and later on, the scintillators/photomultiplier

Figure 1. Optical properties of quantum dots