Fabrication of QD Structures Showing Diode Characteristics for Electroluminescence (EL) and Other Applications

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1 ABSTRACT

Pseudomorophic ZnCdSe-based cladded quantum dots were grown with an improved methodology using a process of photo-assisted metal organic chemical vapor deposition enhanced with microwave plasma (PMP-MOCVD). The nucleation of dots depends on temperature, plasma power, molar ratio and partial pressure of alkyl precursors. Emitting wavelength depends on corresponding core size and composition of the quantum dots. Increasing the incorporation of Zn in ZnCdSe, using photo assisted growth, results in the formation of pseudomorphic cladding which provides a nearly defect-free lattice at the core-cladding interface. The cladding and the core dimension of the quantum dot were estimated using photoluminescence (PL) and x-ray diffraction data and with the help of Scherrer's formula and Brus's equation. Unlike our previous studies, heating of the region in and outside of the microwave cavity (to 370 ˚C) results in the deposition of quantum dots free of undesirable metallic and non-stochiometric dots.

Keywords: Cladded quantum dot, PMP-MOCVD, Scherrer's formula, Brus equation, ZnCdSe.

2 INTRODUCTION

In recent years, the development of flat-panel displays have progressed rapidly for computers, car-navigation systems, home televisions and many others as an alternative to cathode ray tube (CRT) displays. The CRT has a disadvantage of being bulky and heavy hence hindering them in the use of mobile applications. Liquid-crystal (LC) panels came into play and have been used as an alternative to the CRT. However, LC is non-emissive and has many inferior properties that CRTs do not. Therefore the other option is to use quantum dots (QD) for the fact that they are of great interest due to their unique superior optical and electronic properties and in addition they will eliminate the problems of LC's and CRT's. The core-shell ZnCdSe quantum dots, used in this device, show 20 times or more of enhanced luminescence quantum yield as those of uncladded ZnCdSe quantum dots [1].

3 EXPERIMENT

3.1 Growth

The most exciting feature of this device is that it is all solid state. The structure is simple, it has a substrate of indium tin oxide (ITO) coated glass substrate which was cleaned using warm trichloroethylene, acetone, and methanol and left in boiling propanol before it was loaded inside the PMP-MOCVD reactor. The substrate was heated in the reactor along with the purging of the carrier gas. The heating of the substrate is to remove any excess water and chemicals left on the surface from cleaning procedure. In addition to this, the heating helps in the nucleation of ZnCdSe dots. With the plasma turned on, the deposition was seen nucleating on the surface of the substrate. The UV lamp assisted in the incorporation of Zn thus forming the core/shell of $Zn_xCd_{1-x}Se/Zn_yCd_{1-y}Se$ ($x<y$) with different composition of ZnCdSe in the core and shell of the quantum dot [2, 3]. Top contact and bottom contact of aluminum metal were put on the sample after the QD growth using a thermal

evaporator. At the top contacts, the dot sizes of the aluminum were 10 mils.

3.2 Characterization

There were different methods used to characterize the cladded quantum dots which were grown on the substrate. One of the most applied methods used frequently is the X-ray diffraction (XRD) which is used more often with photoluminescence (PL) spectroscopy. In this case, a special technique of a wide-angle X-ray diffraction (WAXRD) was used. Figure 1 shows the X-ray diffraction plot of grown dots on ITO/ glass substrate. The primary use of this technique is to estimate the effective composition of the film and determine the average particle size using Scherrer's formula. Scherrer's formula will give you an estimate of the whole dimension of the quantum dot including the core and shell.

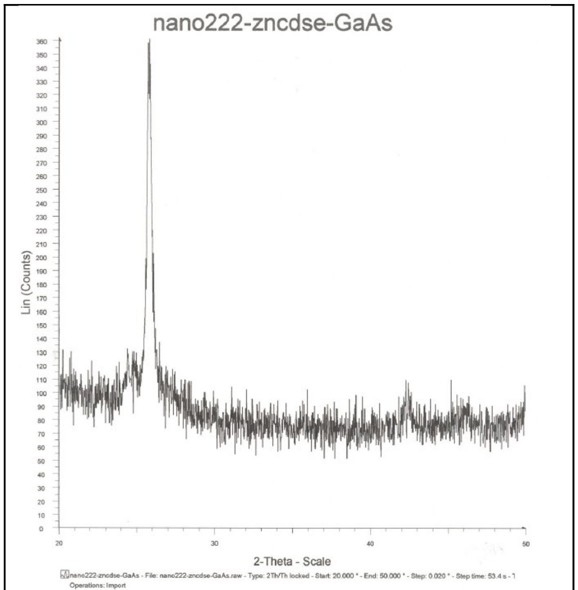

Figure1. X-Ray Diffraction plot of grown dots on ITO/glass substrate

On the other hand, the photoluminescence spectroscopy technique used can give much more than just the band gap of the quantum dot. It can also give the size of the core from the help of Brus's equation. Figure 2 shows the two peaks of wavelengths of two different sizes of quantum dot. With these two analyses from the XRD and PL, we can find the dimensions of the core and the cladding of $Zn_xCd_{1-x}Se/Zn_yCd_{1-y}Se$.

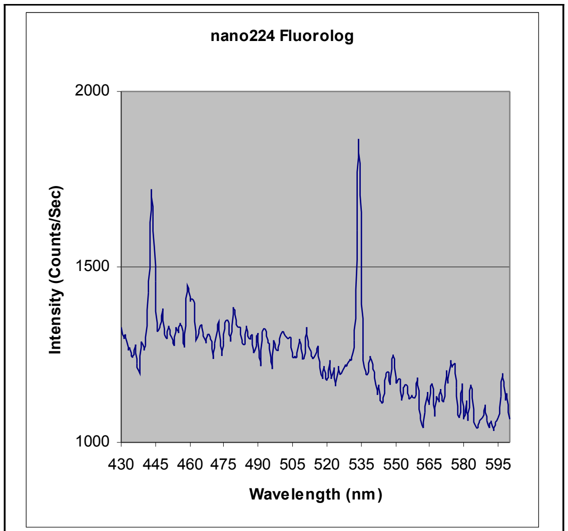

Figure 2. Fluorescence intensity spectra of two different sizes QDs.

In addition to these analyses, high resolution transmission electron microscope (HRTEM) was used to determine the uniformity and the size of the QDs. Figure 3 shows the dots grown on a 400 mesh copper TEM grid. The dots seen by HRTEM seem to be comparable to dots prepared by other methods [3, 4].

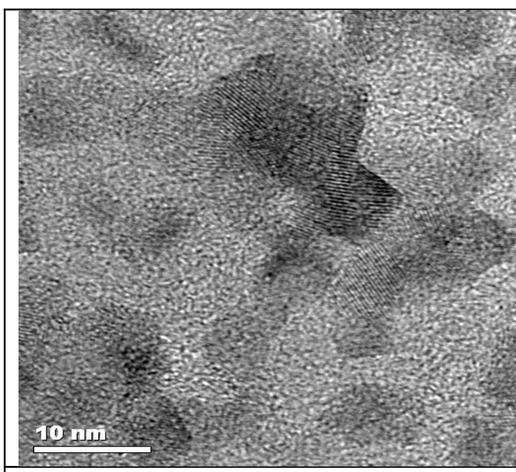

Figure 3. Transmission electron micrograph of ZnCdSe dots on TEM grid

4 DISCUSSION AND RESULTS

The testing was done by applying positive voltage on the ITO contact. Figure 4 shows the current-voltage characteristic of fabricated ZnCdSe QD diodes grown on ITO coated glass substrate.

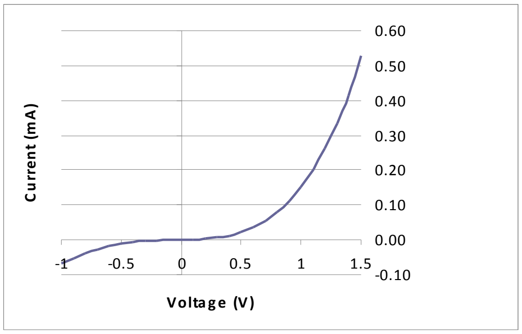

Figure 4. Current-Voltage characteristic of a ZnCdSe diode

We have also simulated the optical gain of these cladded quantum dots including the effect of strain in the cladding for different composition of cladding layer. Simulation is based on excitonic model reported by Jain and Huang [5] with some modification.

5 CONCLUSION

We have presented growth and characterization of ZnCdSe quantum dots using PMP-MOCVD vapor phase nucleation methodology. The color of emitted light depends on the size of the dots. Smaller dots emit blue or ultraviolet and larger dots emit red light. This means when the larger cladded ZnCdSe shrinks in size the light becomes shorter in wavelength (see Table I). The fabricated diodes exhibit good reverse characteristics. The forward characteristics do not show higher built-in voltage as we expected. Mesa etching (using reactive ion etching via methane/hydrogen chemistry) followed by wet etching will be used to eliminate interface states. This will remove the pathway to non-radiative transitions, and we anticipate observing larger built-in voltage. This in turn will result in improved minority carrier injection and photon emission.

Table I. Emitted Peaks Observed in PL Spectra

Dot diameter	Emission wavelength (nm)	Peak Height Arb. Units (Counts/Sec)
D1	443	1715
D2	534	1865

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