

ELECTROLUMINESCENCE FROM COPPER DOPED CdTe NANOCOMPOSITES

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Abstract: *Structural and electro-optical studies on self assembled films composed of copper doped CdTe quantum dots prepared through a simple chemical route has been reported. It is demonstrated by XRD, EDAX, and HRTEM measurements that CdTe:Cu quantum dots can successfully be incorporated into homogeneous thin film. The surface roughness is observed by SEM micrographs. Cubic structure CdTe:Cu quantum dots having size less than 15nm are obtained. The absorption spectra and electroluminescence of the films doped with different concentration of Copper are measured. Blue shifted sharp absorption edge is observed at 426 nm and the band gap energies increased by 1.23 eV. It is shown that the electroluminescence (EL) spectra of CdTe:Cu are identical to Fluorescence spectra (FL). Smooth and sharp emission peaks are observed at 605-614 nm for different doping concentration of Copper. Enhanced luminescent emission peak attributed due to the incorporation of copper in CdTe nanocomposite. These nanocomposites are amenable to being printed into nano light emitting devices.*

keywords: *Chemical route, Copper doped, Electroluminescence, nano-LEDs.*

I. INTRODUCTION

Electroluminescence of transition metal doped nano composites or quantum dots (QDs) is an ongoing interest due to their wide spread acceptance in solid state nano light emitting devices (nano-LEDs) (1-3). Low dimensional structures, i.e., quantum dots reveals significant enhancement in density of states, so increasing the probability of light emission (4). The inherent advantage in doped QDs as nano-LEDs is low cost in manufacturing. Peoples are working with II-VI group semiconductor nanocomposites (1-7) because of their wide applicability and the fundamental importance of exhibiting quantum size effects (3). Nanocomposites such as CdSe, CdTe, CdS ZnS and ZnSe have been studied extensively (8-10), and QDs with a CdSe core and a ZnS shell are currently commercially available. Though many methods have been developed to synthesize II-VI nanocrystals, most of the techniques are expensive (11). Synthesis of highly monodisperse quantum dots over a range of chemical composition is still a challenge in material science. Hence, there is an ever-growing need to develop cheap and nontoxic synthesis procedures. However, the long term stability, colour tunability and quantum efficiencies of nano-LEDs are a challenging work and still have to be improved. This study concerns the preparation of Copper doped Cadmium telluride (CdTe) quantum dots through

chemical route, where we have adopted a completely new approach (12). Synthesis by chemical route has many advantages over other methods. Two main advantages are chemical stability and slow agglomeration rate, which make the study more authentic and reliable (13). XRD, EDAX, HRTEM and SEM micrograph are used to investigate the structural properties of the prepared CdTe:Cu QDs. UV-Vis absorption spectroscopy and FL spectroscopy have been used to observe the optical behavior. Electroluminescence studied has reveals sharp intense luminescence peak. This indicates that CdTe:Cu QDs can be used as nano light emitting devices.

II. EXPERIMENTAL

A chemical route has been adopted to prepare CdTe QDs. 1.25 gm of tellurium powder is mixed with 50 ml of liquid paraffin in a beaker by continuous stirring using magnetic stirrer at 200 OC for nearly 2 hours until a dark gray colour appears (tellurium precursor). Then, 2 gm of cadmium oxide, 10 ml of oleic acid and 40 ml of liquid paraffin are mixed in another beaker by continuous stirring by magnetic stirrer at 150 OC for nearly 1 hour until it turns light brown colour (cadmium precursor). Finally, 5 ml of cadmium precursor is quickly added to the tellurium precursor and the content is stirred continuously using magnetic stirrer for nearly 45 min at 200 OC. Again Copper Chloride is poured with the solution and stirred for another 6 h. Next, the sample is kept at room temperature for 10 hours and methanol is added to precipitate CdTe QDs. Finally, the sample is washed with ethanol at 40 OC for characterization. The purpose of washing with ethanol is the removal of other by-products. The prepared samples are characterized by using UV-visible absorption spectrophotometer (using Perkin Elmer Lambda-25) and absorption spectra are recorded. X-ray diffraction (XRD) measurement is performed with a Bruker X-ray diffractometer (Cu KR radiation, $\lambda = 1.5406 \text{ \AA}$). High Resolution Transmission Electron Microscope (HRTEM) observations are performed by using a Jeol JEM-2100 transmission electron microscope, operating at 200 kV accelerating voltage, with an interpretable resolution limit of 0.16 nm. For TEM experiments of CdTe samples, a small drop has been dropped onto a carbon coated copper grid, allowing the alcohol to evaporate. High resolution TEM image and selected area electron diffraction (SAED) patterns are obtained in order to evaluate the particle shape, structure and diameter distribution. The surface morphology has been examined using scanning electron microscopy (JSM 6390LV). Fluorescence (FL) and Electroluminescence (EL)

spectra of the samples are recorded (Perkin Elmer LS-45 luminescent spectrometer) to investigate luminescence properties. Optical measurements are carried out at room temperature under ambient condition.

III. RESULTS AND DISCUSSION

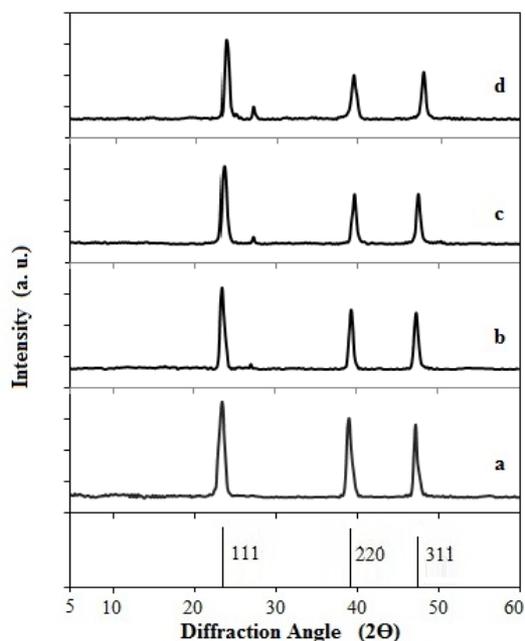


Fig. 1 X-ray diffraction (XRD) patterns of CdTe:Cu samples with different doping concentration. Sample 'a' is undoped CdTe samples, and 'b', 'c' & 'd' are doped samples with 1%, 2% and 3% doping concentration of copper respectively.

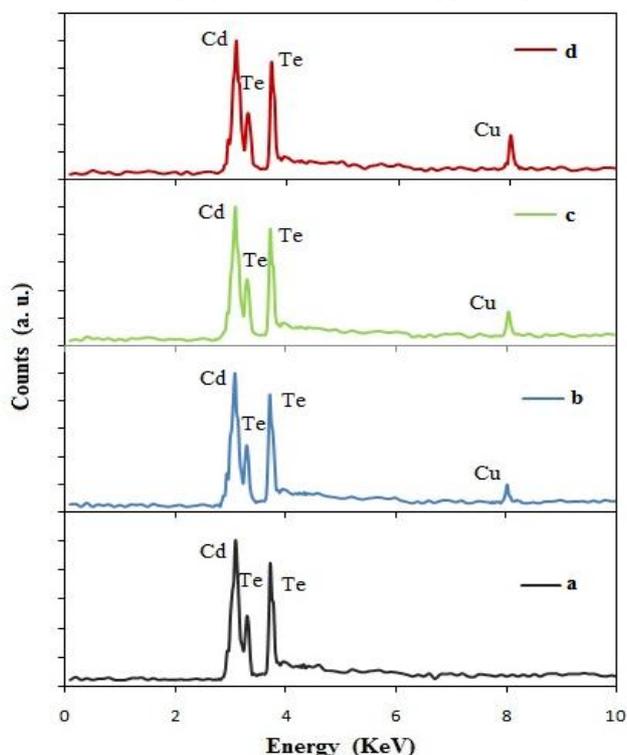


Fig. 2 EDAX patterns of and CdTe:Cu samples.

The structure and phase of nanocrystals are in general determined by X-ray diffraction and TEM studies. X-ray diffraction (XRD) spectra of undoped CdTe and copper doped CdTe samples (a, b, c and d with doping concentration 0%, 1%, 2% and 3% respectively) are shown in Fig. 1. By comparison with the data from JCPDS, the diffraction peaks observed at 23.3°, 39.1°, and 47.3° respectively for all doped and undoped samples can be indexed as (111), (220) and (311) planes and it can be ascribed the cubic cadmium telluride crystal. A low intense peak observed at 27.18° for the Cu doped CdTe samples which is differ from the undoped sample. EDAX analysis (Fig. 2) of the samples reveals the presence of copper in CdTe nanocomposite. The average crystallite size is estimated from the full width at half maximum (FWHM) of the diffraction peaks using the well known Debye-Scherrer formula (3). The average diameter estimates for the CdTe nanocrystals is about 6.8nm (12) and for doped samples b, c and d, it's 7.3nm, 7.5nm and 7.9 nm respectively. Here, sizes of doped samples are very close to undoped CdTe nanocomposites.

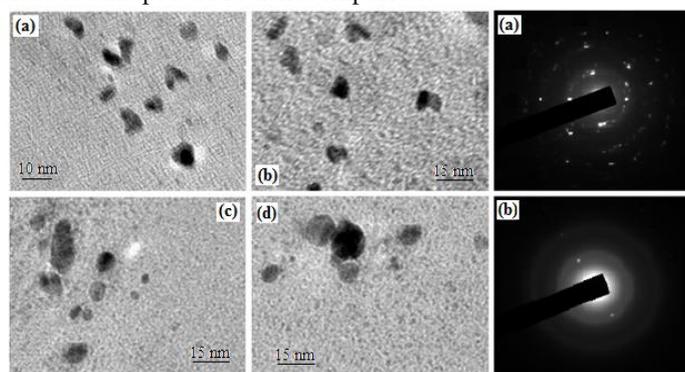


Fig. 3 High-resolution (HR) TEM images, SAED patterns of CdTe:Cu QDs.

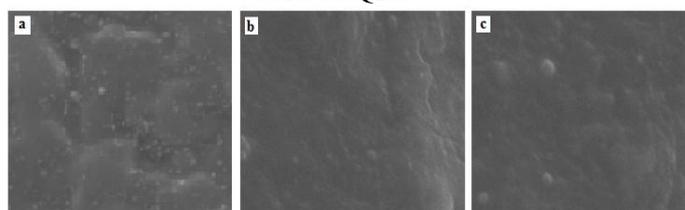


Fig. 4 SEM images of undoped and doped CdTe and QDs.

The Morphology of the CdTe:Cu QDs are observed by TEM and SEM as shown in fig. 3 and fig. 4. It is evident from the TEM (HR) micrographs that the average size of particles as directly measured from the ruler of the image is 3-14 nm. The selected area electron diffraction (SAED) patterns (Fig. 3a, b) show the good diffraction rings which indicates the lattice planes <111>, <220> and <311>. The intensity of the diffraction rings for sample A and C indicates that the particles c crystallized with good crystalline nature. The high resolution TEM micrograph shown in Fig. 3(a), clearly endorses the formation of well-separated and crystalline nanoparticles of CdTe:Cu. The SEM images indicates rough surfaces of CdTe:Cu QDs.

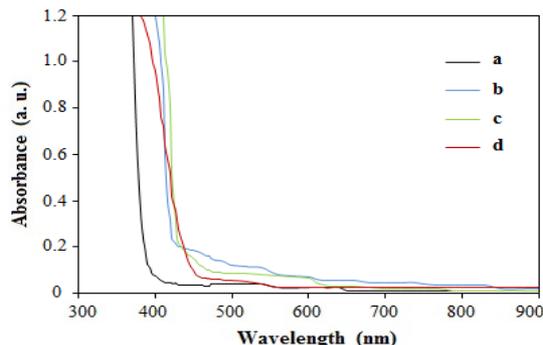


Fig. 5 Optical absorption spectra of CdTe:Cu QDs.

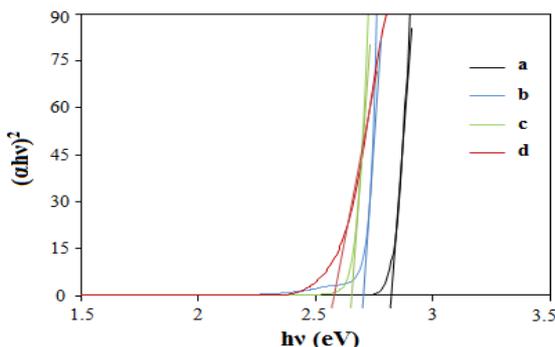


Fig. 6 Band gap energy spectra of CdTe:Cu QDs.

Fig. 5 compares the optical absorption spectra of CdTe QDs with CdTe:Cu QDs using different doping concentration. The absorption spectra have been observed at room temperature. Blue shifted absorption edges are observed for all the three samples compared to bulk counterpart, which may be caused due to the quantum confinement (14). The absorption edges are appeared at 397 nm, 426 nm, 434nm and 453 nm for the samples a, b, c and d respectively. The sharp absorption peaks reveals that the size of the CdTe:Cu QDs could be close to monodisperse (15). Energy band gap of the particles have been determined from the fig. 5 using the Tauqe model (16). A graph has been plotted $(\alpha hv)^2$ vs hv , where α is the absorption coefficient, and hv is the energy in eV. For the samples a, b, c and d, the band gaps energies are attained 2.82 eV, 2.65 eV, 2.62eV and 2.52 eV respectively (12); where the band gap energy for bulk ZnTe is 1.44 eV. The band gap decreases gradually with the increase of doping concentration of copper. From the band gap information, the sizes of the CdTe:Cu QDs are calculated using the effective mass approximation (EMA) method (17). The values of the particle sizes are calculated to be 6.6 nm, 7 nm, 7.1 nm and 7.4 nm for a, b, c and d respectively.

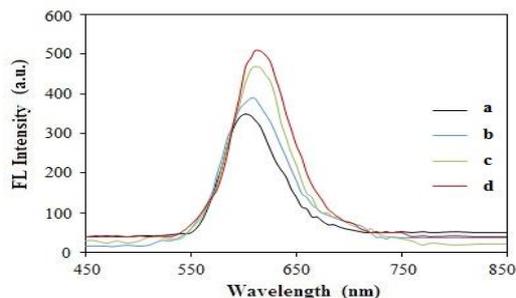


Fig. 7 Fluorescence spectra of the CdTe:Cu QDs.

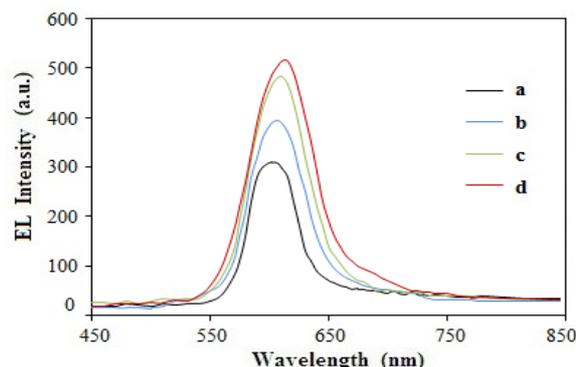


Fig. 8 Electroluminescence spectra of the CdTe:Cu QDs.

Fig. 7 displays fluorescence spectra recorded at room temperature for all the prepared samples. It has been observed that for an excitation wavelength at 350 nm, a luminescent peak appears at 602 nm, 607 nm and at 611 nm and 614 nm for samples a, b, c and d respectively (12). Electroluminescence spectra (Fig. 8) of the samples follow the FL spectra in the same wave length range. The luminescence peaks are attributed the intermediate surface states of the QDs (18). Peak intensity gradually increase with the increase of doping concentration of Copper and becomes tend to saturate at higher concentration. The increased luminescence intensity of CdTe:Cu is probably due to involvement of Cu^{2+} ions in all doped samples (19). Additionally, the emission peak is slightly shifted to the higher wavelength side with the increase of doping concentration and the peak width become wide, which may be due to the increase in the size of the CdTe:Cu QDs (20). But the EL peaks are narrow and sharper than FL peaks. Consequently, CdTe:Cu QDs are applicable for producing light emitting devices (LEDs) in green region.

IV. CONCLUSIONS

In this effort, we have synthesized CdTe quantum dots doped with copper of sizes <15 nm by a simple chemical route. The XRD patterns exhibited the cubic structure for all the samples and no other crystalline phase is detected. Due to the quantum confinement effect, the absorption edges of all samples are blue shifted and consequently the band gap of the nanoparticles is 1.08 eV higher compared with bulk materials. The luminescence peak is observed within 602–614 nm. The luminescence peak can be attributed to intermediate surface states in CdTe:Cu QDs. The emission peak is slightly shifted to longer wavelength for higher doping concentration. The present advancement of CdTe:Cu QDs open up the possibility of developing nano LEDs.

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