© Applied Science Innovations Pvt. Ltd., India Carbon – Sci. Tech. 5/1 (2013) 211- 217

Carbon – Science and Technology

ISSN 0974 – 0546

http://www.applied-science-innovations.com

ARTICLE (Advanced *Non-Carbon* Materials) *Received: 01/07/2013, Accepted: 29/07/2013*

Nanocrystalline CdTe thin films by electrochemical synthesis

Ramesh S. Kapadnis [A, B], **Sanjay B. Bansode** [A], **Sampat S. Kale** [C, *], **Habib M. Pathan** [A, *]

(A) Advanced Physics Laboratory, Department of Physics, University of Pune, 411007, India.
(B) Material Science Laboratory, M. V. P. Samaj's, K.T.H. M. College, Nashik, 422002, India
(C) M. V. P. Samaj's, Arts, Science and Commerce College, Dindori 422209, Nashik, India

Cadmium telluride thin films were deposited onto different substrates as copper, Fluorine-doped tin oxide (FTO), Indium tin oxide (ITO), Aluminum and zinc at room temperature via electrochemical route. The morphology of the film shows the nanostructures on the deposited surface of the films and their growth in vertical direction. Different nanostructures developed on different substrates. The X-ray diffraction study reveals that the deposited films are nanocrystalline in nature. UV-Visible absorption spectrum shows the wide range of absorption in the visible region. Energy-dispersive spectroscopy confirms the formation of cadmium telluride.

Keywords : Cadmium telluride, Scanning electron microscopy, electrochemical synthesis.

Introduction : Inorganic materials synthesis is vast developing field, not only due to new materials are constantly synthesized but because tuning of the reaction schemes enables the creation of nanocrystals with a precise control of their size [1], shape [2], composition and crystal structures [3]. In semiconductors, shape is an important parameter because it affects strongly the strongly the electronic spectrum of charge carriers as well as optical properties of nanocrystals. Nanoparticle based thin films have great potential for next generation of semiconductor devices including solar cells and transistors. The high surface to volume of ratio of nanoparticles in thin film form can be trap electrons and ultimately and it forms a limit device performance [4]. In semiconductor materials, shape is very important parameter since it resulted strongly on the electronic charge carriers and also optical properties of nanomaterials.

The recent interest in utilizing semiconductor nanocrystals for harvesting light energy has drawn great attention towards metal chalcogenide-based systems of CdTe, CdS [5, 6, 7]. Cadmium telluride (CdTe) is a semiconductor that has been widely used for variety of applications. The direct band gap 1.5 eV at room temperature and high optical absorption coefficient [8] in the visible spectrum makes CdTe an ideal material for photovoltaics. The growth of high quality CdTe is important material because of their applications in solar energy, X-ray detection, gamma ray detection [9] and infrared detectors [8]. CdTe usually crystallizes with the cubic zinc blend structure and it can considerably to be stable only in a 1:1 CdTe ratio [10]. In addition, innovative research involving nanoscale CdTe materials including zero and one dimensional growth has been investigated over last few years for several attractive features, high chemical robustness are most important for large area production of CdTe solar modules at industrial scale. Several techniques have been developed by variety of techniques such as electrochemical synthesis, close space sublimation, vapour transport deposition, electron beam evaporation, metal organic chemical vapour deposition, sputtering etc. Among all these techniques electrochemical synthesis is an attractive method which has successfully been employed for the preparation of elemental, binary, intermetallic and ternary compounds. It is an isothermal process mainly controlled by electrical parameters which are easily adjusted to controlled thin film thickness, morphology and composition [9]. Electrochemical synthesis is preferable, as it is relatively simple, scalable and can produce a shell of reasonable density and uniformity. Most of electrolytes currently used in electrodeposition of CdTe are either acidic solutions (pH 1 - 3) or basic solutions (pH 10) containing ammonia [8, 11, 12].

Electrochemical method is depicted as a novel and powerful route for synthesis of nano-crystalline / crystalline thin films deposited on to different conducting substrates as copper, FTO, ITO, Zinc and Al. Electrochemical route is not only the lower deposition temperature but also the small grain size of the deposit obtained which required for high-density magneto-optic recording media. It prevents the inhalation of toxic gases produced at high temperature during processing. So, the electrochemical route is not only interesting as a field of study of chemical reactions but also as an environmental friendly process [13]. It is an isothermal process, mainly adjusted to control film thickness, morphology, composition [9].

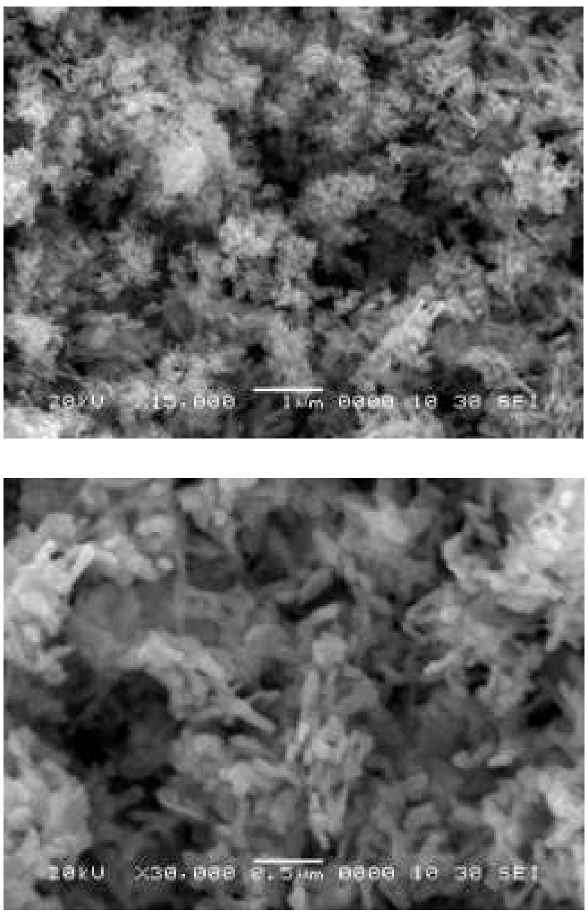
The microstructure of CdTe films depends on the crystallinity of the substrate, temperature and rate of deposition. In general the grain size increased with increasing substrate temperature and increasing film thickness [14]. The interesting future of electrochemical deposition could be employed as one of the step in preparation of semiconductors, oxides, ceramics, conducting polymers and superconductors. It is a unique process occurring on the working electrodes, where either oxidation or reduction takes place without any chemical reagent being required for the reaction and there is no by-product.

Experimental : In this report, the deposition of CdTe thin films onto different conducting substrates from electrochemical route is described. The different processing parameters such as deposition potential, deposition period, bath temperature and pH of solution can optimized and reported good quality CdTe thin films on conducting bases. CdTe thin films were electrodeposited at room temperature from the solutions of 0.1M of cadmium sulphate and sodium telluride complexed with tartaric acid. The solution was prepared in freshly prepared doubly distilled water. The synthesis of crystalline thin films deposited on to different conducting substrates as copper, FTO, ITO, Al and Zn. The substrates were polished with smooth (zero grade) polish paper and cleaned by ultrasonic cleaner with chromic acid and lebolene solution. A simple two electrode method used for the deposition of films on different substrates, the substrates as cathode with respect to the graphite electrode as a cathode. Further the films characterized by scanning electron microscopy (SEM) techniques (JOEL-JSM 6360-A) at different magnifications for observing the surface morphology, X-ray diffraction (XRD) (Rigaku D/max-2400 with Cu-Kα = 0.154 nm) patterns were recorded with monochromatized CuKα radiation at the scattering rate of 0.03 per second, ranging from 20^0 to 80^0 (2 theta) for structural elucidation, micro structural information of the films was obtained using optical microscopy (UV-VIS-NIS spectrophotometer Hitachi 330, Japan).

Results and Discussion : SEM is a convenient, versatile and promising technique which provides information regarding the growth mechanism, shape of grain structure on the film and to determine grain size of the particles.

Figure (1) shows the SEM images of as-deposited cadmium telluride nanocrystalline structures on conducting substrate as copper at different magnifications. In Figure 1 (a), it shows the nanocrstalline dense structure on entire surface of the film. The direction of growth of nanorods in a vertical direction and the length of nanorods is 5 to 7 μm and their average diameter as 45 to 50 nm. At large magnifications (Figure 1b), the nanorods clearly identified and understand their growth arrays in a vertical direction on entire surface of film.

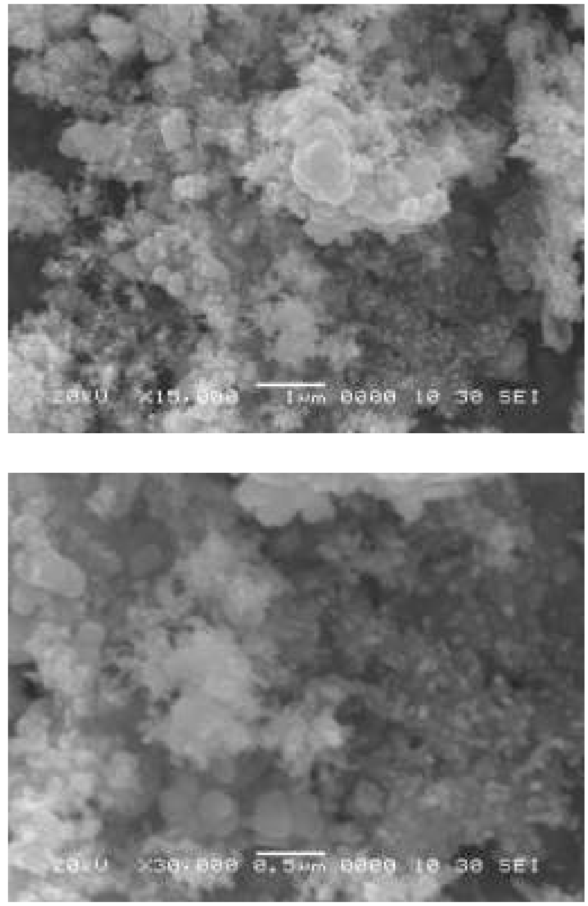
In Figure (2), shows the SEM of as-deposited CdTe nanocrystalline structures on conducting substrate as FTO at different magnifications. In figure 2 (a), shows the nanocrstalline structure of the films and it appears as a bush like structure which flourished in every direction on the entire surface of the film. At some places the overgrowth of Cd and Te material. The direction of growth of nanocables in a vertical and horizontal direction and the average length of nanocables is 1 to 2 μm. By the clear observation of SEM, a shadow region appears at the corners of the film but there were growth of nanocrystals and further would develop as a nanocables and their average diameter as 10 – 20 nm.



(a)

(b)

Figure (1) : SEM structures of CdTe thin film deposited on conducting surface (copper) via electrochemical synthesis by simple two electrode method at pH 2.8 for 10min (a) at low magnification X15000 (b) at higher magnification X30000.

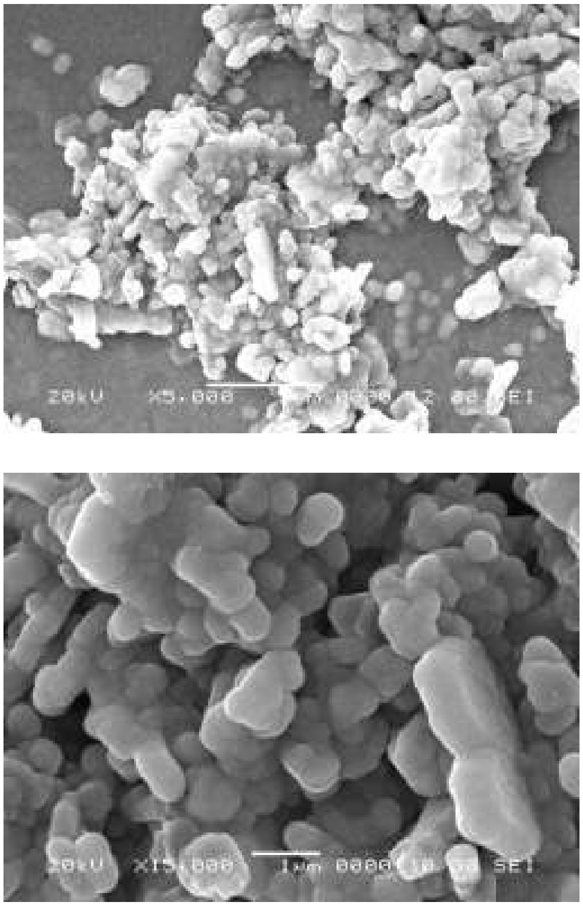


(a)

(b)

Figure (2): SEM structures of CdTe thin film as-deposited on conducting surface (FTO) via electrochemical synthesis by Simple two electrode method at pH 2.8 for 10 min (a) at low magnification X15000 (b) higher magnification X30000.

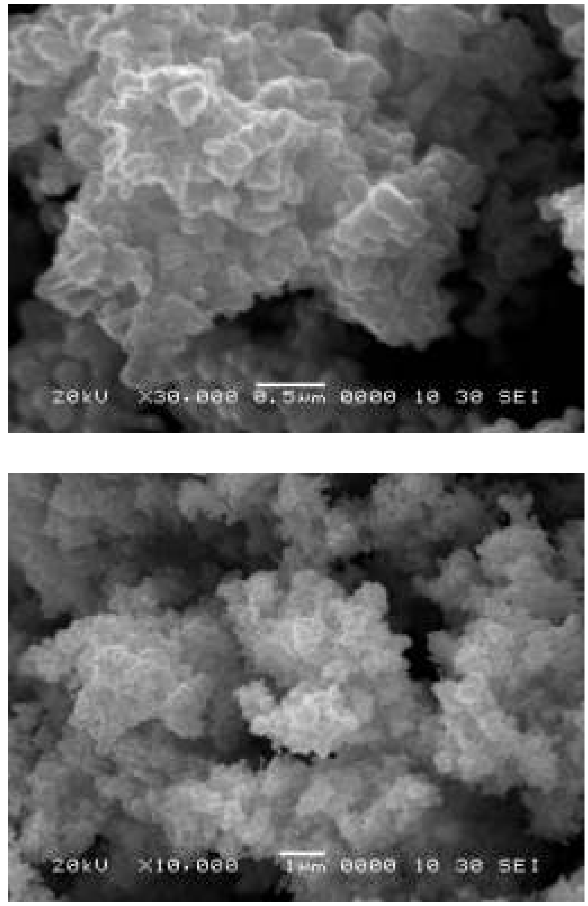
Figure (3), shows the SEM structure of as-deposited CdTe nanocrystals on ITO. The nanocrystalline structure develops on the films as spherical granules were found on surface. The compact grains with each other and they overlap one another. Some of the granules were just appears on the films of same features. The grains were form a dense structure on the film which shows the growth in all direction.



(a)

(b)

Figure (3) : SEM structures of CdTe thin film as-deposited on conducting surface (ITO) via electrochemical synthesis by simple two electrode method at pH 2.8 for 10 min (a) at low magnification X5000 (b) higher magnification X15000.



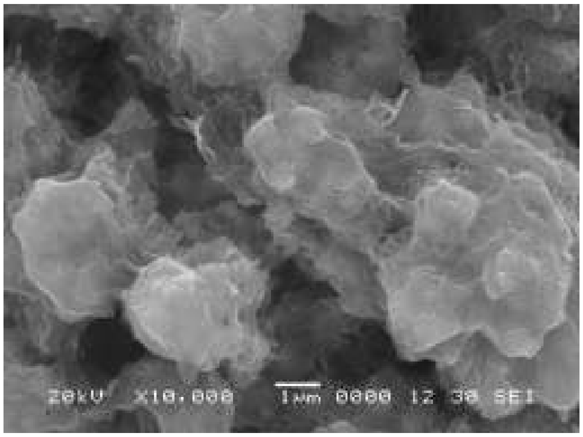
(a)

(b)

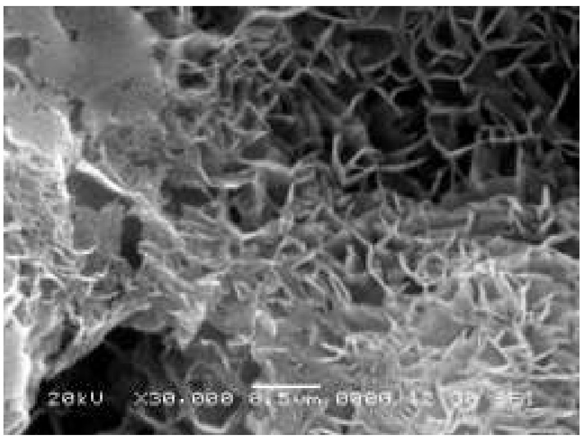
Figure (4) : SEM structures of CdTe thin film as-deposited on conducting surface (Al) via electrochemical synthesis by simple two electrode method at pH 2.8 for 10 min (a) at low magnification X10000 (b) higher magnification X30000.

The SEM microstructure of CdTe on Al as-deposited by two electrode method by electrochemical synthesis method is as shown in Figure (4). It shows the cauliflower like structure which grows of on entire surface. Small granules compact with each other with small spherical structures. Each granular structure was closely grown on the surface of film with approximately same grain size. There were no major differences in the morphology of each grain.

In Figure (5), nanocrystalline structure of CdTe form on the zinc substrates. In Figure (5b), at the higher magnification, the hexagonal shape structure formed on film surface. It looks like as nanofibers but these are the walls of hexagonal structure and having approximately same grain size can be seen.



(a)



(b)

Figure (5) : SEM structure of CdTe thin film as-deposited on conducting surface (Zn) via electrochemical synthesis by simple two electrode method at pH 2.8 for 10 min (a) at low magnification X10000 (b) higher magnification X30000.

Figure (6) represents the structural analysis of as-deposited CdTe films on the FTO substrate of nanocrystalline by XRD with Cu-Kα (λ=0.15406 nm). The peaks appearing at 2θ angles (34.12), (63.7) and (67.2) and their planes (020), (012) and (200) respectively of the FCC structure and the deposited film were good agreement with JCPDS file No.41-0941 of CdTe. The comparison of XRD features of experimental 2θ values and standard 2θ values and good agreement between them, However a small deflection in standard 2θ values and experimental 2θ values.

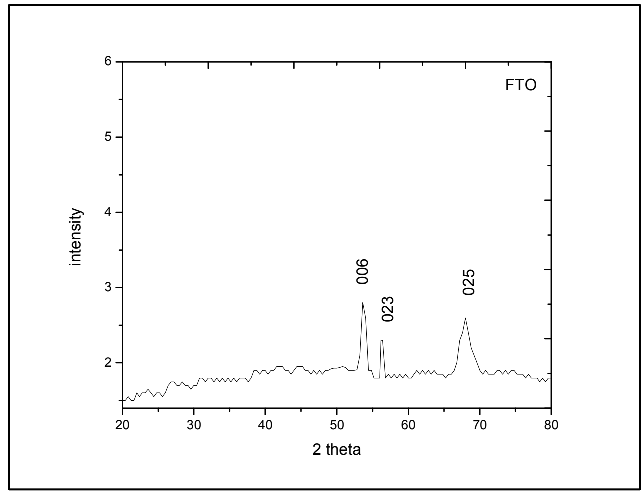


Figure (6) : XRD pattern of CdTe on FTO by electrochemical synthesis for 10 min compare with standard JCPDS data card No. 80-0090.

In Figure (7), it is the elemental composition of CdTe deposited on Cu substrate by electrochemical route. It shows the composition of Cd:Te in the ratio of 49:51 by the voltage 20 KV in counting cycle rate of 11264 cps and energy range of 0 – 20 KeV.

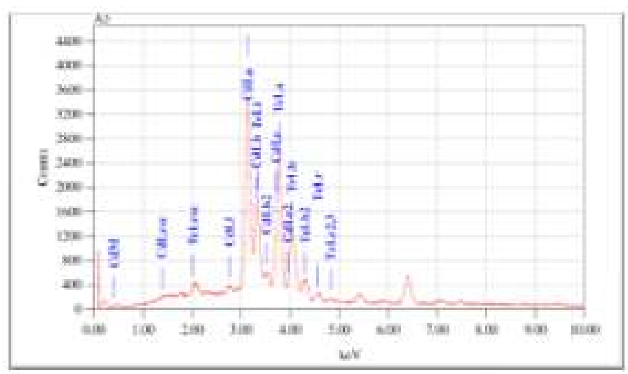


Figure (7): EDS of CdTe thin film on Copper by electrochemical synthesis

The atomic percentage of Cd and Te were shown in EDS as Cd = 48.93% while Te = 51.07% which is exactly equal composition of materials Cd and Te deposited on copper substrate.

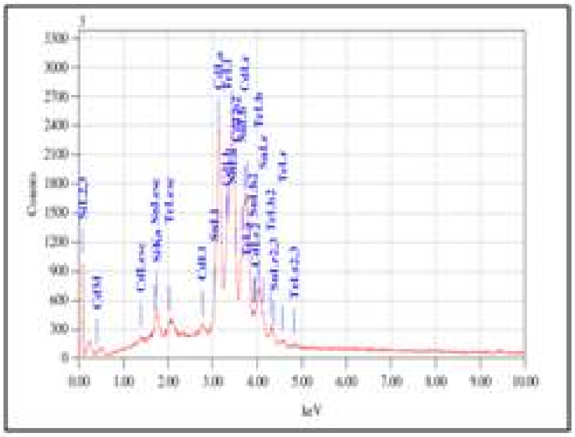


Figure (8) : EDS of CdTe thin film on FTO by electrochemical synthesis. The atomic % of Cd and Tee were shown in EDS as Cd = 33.93 % while Te = 25.23 % which deposited on copper substrate

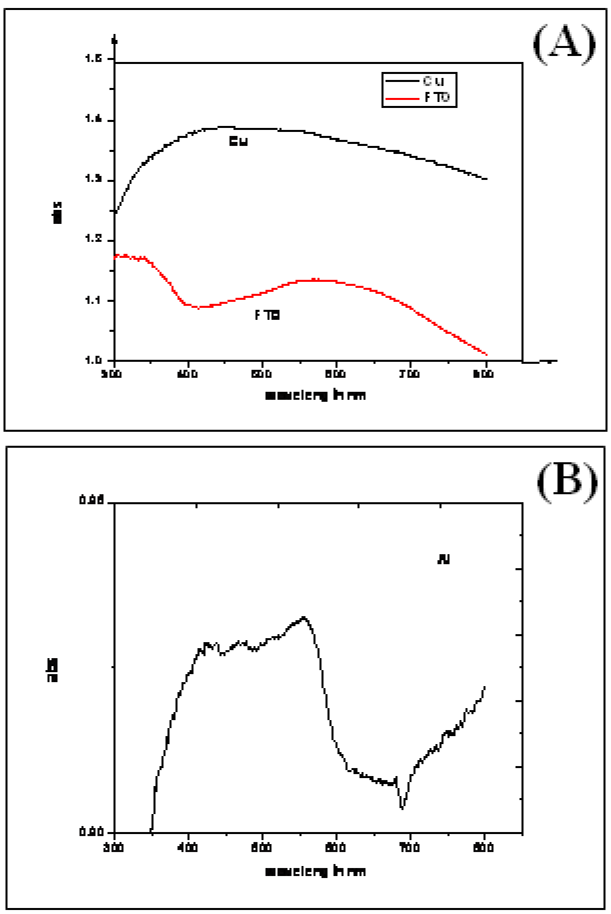


Figure (9) : Optical absorption of CdTe films on conducting substrates as (a) Cu, FTO and (b) Al

In Figure (8) shows the composition of Cd:Te in the ratio of 49:51 by the voltage 20 KV in counting cycle rate of 10535 cps and energy range of 0 – 20 KeV. Optical studies have been performed for CdTe thin for Cu, FTO and Al samples in the range of 200 - 800 nm wavelength range. The optical absorption of CdTe material deposited on Cu, FTO and Al with using the reference by transmitting mode. CdTe layer serves as the active layer for solar cells. This layer absorbs the photons, which means that absorption coefficient of the material is important. CdTe deposited on Cu substrate at room temperature and the nature absorbance spectra shows due to the presence of textured surface **[15]**. CdTe deposited on Al substrate shows the abrupt edge which holds absorption coefficient. During the deposition, approximately same parameter used till different nature of graphs shown it is due the substrate on which the CdTe deposited.

Conclusions : Electrochemical synthesis of CdTe thin films on deposited on various conducting substrates such as Cu, FTO, Zn and Al. SEM micrographs shows different structural nanocrystalline nature of deposited films. SEM of CdTe shows different structures due to different deposition substrates were used because all the parameters were same for deposition with same deposition time. X-ray diffraction study revealed that, CdTe films are crystalline surface with FCC structures. The UV-VIS absorption spectrum shows that it having a wide range of absorption in the visible region. EDS shows the elemental composition of CdTe on the substrates which is approximately equal percentage.

References :

[1] C. B. Murray, D. J. Norris, M. G. Bawendi, "Synthesis and characterization of nearly monodisperse CdE (E=S, Se, Te) semiconductor nanocrystallites", J. Am. Chem. Soc. **115** (1993) 8706-8715.

[2] L. Manna, D. J. Milliron, A. Meisel, E. C. Scher, A. P. Alivisators," Controlled growth of tetrapod-branched inorganic nanocrystals", Nature Mater. **2** (2003) 382-385.

[3] S. Ithurria, M. D. Tessier, B. Mahler, R.P.S.M. Lobo, B. Dubertret, Al. L. Efros, “Colloidal nanoplatelets with two – dimensional electronic structure”, Nature Mater. **10** (2011) 936- 941.

[4] A. Bezryadina, C. France, R. Graham, L, Yang, S. A. Carter, G. B. Alers, “Mid-gap trap states in CdTe nanoparticles solar cells”, Appl. Phys. Lett. **100** (2012) 0135081-84.

[5] P.V. Kamat, “QD solar cells, semiconductors nanocrystals as a light harvesters”, J. Phys. Chem. 112 (2008) 18737-18753.

[6] J. H. Bang, P. V. Kamat, “QD sensitized solar cells- A tale of two semiconductor nanocrystals CdSe and CdTe”, ACS Nano, **3(6)**, (2009) 1467-1476.

[7] G. Hodes, “Comparison of dye and semiconductor sensitized porous nanocrystalline liquid junction solar cells”, J. Phys. Chem. 112 (2008) 17778-17787.

[8] M. C. Kum, B, Y. Yoo, Y. W. Rheem, K. N. Bozhilov, W. Chen, A. Mulchandani, N. V. Myung, “Synthesis and characterization of cadmium telluride nanowire”, Nanotechnology, 19 (2008) 325711(1-7).

[9] S. J. Lade, M. D. Uplane, C. D. Lokhande, “Electro synthesis of CdTe films from ethylene glycol bath”, Mater. Chem. Phys. **63** (2000) 99-103.

[10] J. D. Beach, B. E. McCandless, “Materials Challenges for CdTe and $CiInSe_2$ photovoltaic’s”, MRS Bulletin **32** (2007) 225-229.

[11] A. W. Zhao, G. W. Meng, L. D. Zang, T. Gao, S. H. Sun, Y. T. Pang, “Electrochemical synthesis of ordered CdTe nanowire arrays”, Appl. Phys. A: Mater. Sci. Process. **76** (2003) 0537-539.

[12] M. B. Dergacheva, V. N. Statsyuk, L. A. Fogel, “Electrodeposition of CdTe from ammonia-chloride buffer electrolytes”, J. Electro Anal. Chem. **579** (2005) 43-49.

[13] S. D. Sartale, C. D. Lokhande, “Electrochemical synthesis of nanocrystalline thin films and their characterization”, *Ceramics International* **28** (2002) 467-77.

[14] T. L. Chu, S. S. Chu, C. Ferekids, C. Q. Wu, J. Britt, C. Wang, “13.4% efficient thin film CdS / CdTe solar cells,” J. Appl. Phys.70(12)(1991) 7608-7612.

[15] J. P. Nair, N. B. Chaure, R. Jaykrishan, R. K. Pandey, J. Phys. Chem. Solids 63(2002) 31.