ISSN: 0067-2904
GIF: 0.851

Growth and Characterization of CdTe Nanorods Flower-like shape

Fatima A. Hassan[1]*, Asama N. Naje[1], Rawa K. Ibrahim[2]
[1]Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq
[2]Ministry of Science and Technology, Iraq

Abstract

CdTe nanorods were prepared by using aqueous chemical synthesis. The influences of reaction time (1-3 hours) on the optical and structural properties were studied. The UV-visible absorption spectrum reflects a wide absorption range in the visible spectrum. The energy gap calculations show decrease in the energy gap with increasing reaction time. The SEM images show that the CdTe appears as flower of nanorods-like.

Keywords: CdTe nanorods, absorption spectrum, SEM

تنمية و تشخيص القضبان النانومترية للكادميوم تيلوريد بشكل زهرة

فاطمة عامر حسن[1]*، اسامة ناطق ناجي[1]، روى خليل أبراهيم[2]
[1]قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق
[2]وزارة العلوم والتكنولوجيا، بغداد، العراق

الخلاصة

تم تحضير قضبان الكادميوم تيلوريد النانومترية باستخدام التقنية الكيميائية المائية. تمت دراسة تأثير زمن التفاعل (1-3 ساعات) على الخصائص البصرية و التركيبية. طيف الامتصاص الفوق بنفسجي-المرئي عكس امتصاص واسع ضمن مدى الطيف المرئي. حسابات فجوة الطاقة اظهرت نقصان في فجوة الطاقة بزيادة زمن التفاعل. صور المجهر الألكتروني الماسح اظهرت ان شكل الكادميوم تيلوريد هو زهرة من القضبان النانومترية.

الكلمات المفتاحية: قضبان الكادميوم تيلوريد النانومترية، طيف الأمتصاص، المجهر الألكتروني الماسح.

Introduction

Cadmium-chalcogenide Nano-materials of varied shape (rods, wires, discs, etc.) over the last twenty years prepared with varied range of size and compositions specially colloidal CdTe because of the efficiency of its synthesis, the high quality of the resulting sample, and the fact that the optical gap lies in the visible range which makes it promising material in opto-electronic devices [1,2]. Nanostructures such as nanorods and nanowires are reported to have better materials properties in comparison to classical semiconductor nanoparticles network charge can be transferred through the optimal arrangement of nanorods or nanowires without losses, because of recombination at the nanoparticle boundaries in contrast to bulk semiconductor. Further, the energy band gaps of nanostructured materials are sensitive to their size of nanoparticles [1]. A lot of interest was focused on the synthesis of CdTe nanoparticles with a suitable method in an aqueous system due to the usage of simple precursors, and simple experimental arrangements [3]. Moreover, aqueous synthesis is more reproducible, cheaper, less toxic, and the as-prepared Nanocrystals (NCs) are more water-soluble and bio-compatible [4]. Several improvements of the conventional aqueous synthetic method for thiol-capped CdTe nanoparticles have been reported recently by different groups, including the hydrothermal synthesis [5], microwave irradiation [6], or solvothermal decomposition [1]. However,

---

*Email:Fatima.amer.h@gmail.com

in most of aqueous synthesis, Te powder [2,7-9] or TeO_2 [4], Na_2Te[10], Al_2Te_3 lumps [11] is often used as tellurium sources, which needs a pretreatment to synthesize the instable tellurium precursor (NaHTe or H_2Te) and the process of preparing nano -CdTe requires nitrogen or argon as the protective gas at the initial stage.

In this work, synthesize Cysteine-CdTe nanorods by wet chemical aqueous route in air conditions, using Te powder as Te source and $NaBH_4$ as reductant. The influence of reaction time on CdTe nanorods has been investigated. The crystal structure and shape of CdTe nanorods were characterized by XRD and SEM.

Experimental Work

Hydrous $CdCl_2.H_2O$ (molecular weight-201.32gm/mole), Tellurium powder (molecular weight-127.6gm/mole) and $NaBH_4$ (molecular weight-37.83 gm/mole) have been taken to prepare different samples. L-Cysteine ($C_3H_7NO_2S$) has been used as a capping agent. Sodium borohydride has been taken to initiate the reaction at 60°C. In order to prepare different samples, the amounts of L-cysteine, $CdCl_2$, Te and $NaBH_4$ were taken in the ratios of 4:2:1:2.The reaction of Te powder with $NaBH_4$ and 3ml of distilled water was used as tellurium ions source in a dark violet solution of NaHTe. The precursor $CdCl_2.H_2O$ was dissolved in 25ml of water, followed by adjusting the pH to the appropriate value (10.6) by drop wise addition of 1M solution of NaOH, and an appropriate amount of the stabilizer (L-cysteine) was added under stirring. The solution is placed in a three-necked flask fitted with a septum and valves and is aerated by Argon gas bubbling for 30 min at 60°C, the NaHTe solution added to the $CdCl_2.H_2O$ solution. CdTe precursors are formed at this stage, which is accompanied by a change of the solution color to orange. The stirring was continued for 3 hours at 40-30°C; the reactions are as follows [9]:

$$\mathbf{2Te+4NaBH_4+7H_2O \longrightarrow 2NaHTe+Na_2B_4O_7+14H_2 \uparrow}$$

$$\mathbf{Cd^{2-}(C_3H_7NO_2S) +Te^{2+} \longrightarrow CdTe/Cd\,(C_3H_7NO_2S)}$$

The samples were taken at different time intervals (1h, 2h and 3h). The XRD spectra was carried out by using a XRD-6000 Labx, supplied by SHIMADZU, X-ray source is Cu Kα X-ray diffract-meter with radiation (λ=1.5406 Å). Scanning Electron Microscope studies were used to determine the nanoparticles distribution, nanoparticles size and show the structure and shape of nanocrystals using VEGA3 TESCAN, mode SE from TESCAN ORSAY HOLDING, a.s, Czech Republic. The UV-visible absorption spectrum of the prepared CdTe, measured using Shimadzu UV-1800 spectrophotometer and photoluminescence spectrum of CdTe nanorods solution is plotted using SL 174 SPECTROFLUOROMETER. The energy gap of the prepared nanoparticles obtained from the relation $(\alpha h\upsilon)^2$= C $(h\upsilon-\Delta E_g)$, where C is constant [2].

Results and discussion

The CdTe nanoparticles crystallization has been studied at different reaction time periods (1, 2 and 3 hours) using XRD spectra where the samples dried on quartz substrates. The position of all the diffraction peaks matches well those of the bulk CdTe peaks in the PCPDFWIN data (CAS No.1306-25-8), that appears to be hexagonal phase and polycrystalline structure as shown in Figure-1. These peaks are comparatively wider than that of the bulk materials due to finite crystalline size [4] as in the reports [6-8] that prepared with different methods. It seems from Figure-1, that the peaks get narrower when the crystal size up to microstructure at sample 3. Also, there is a new peak present at sample 2 (*hkl*=101) not found in sample 1 but sample 3 show new crystallizations in all peaks. The average grain size of crystallites calculated according to the Scherer's formula [12]:

$$\tau = \frac{k\lambda}{\beta \cos\theta} \quad \mathbf{(1)}$$

Where k is the shape factor, the shape factor has typical value 0.9, λ is the X-ray wavelength, β is the line broadening at half the maximum intensity (FWHM) in radians, and θ is the Bragg angle; τ is the mean size of the ordered (crystalline) domains, which may be smaller or equal to the grain size. Average sizes of crystallite (grain) calculated from Debye Scherer equation, are (7.194, 14.0605, 32.4216 nm), respectively for CdTe nanoparticles.

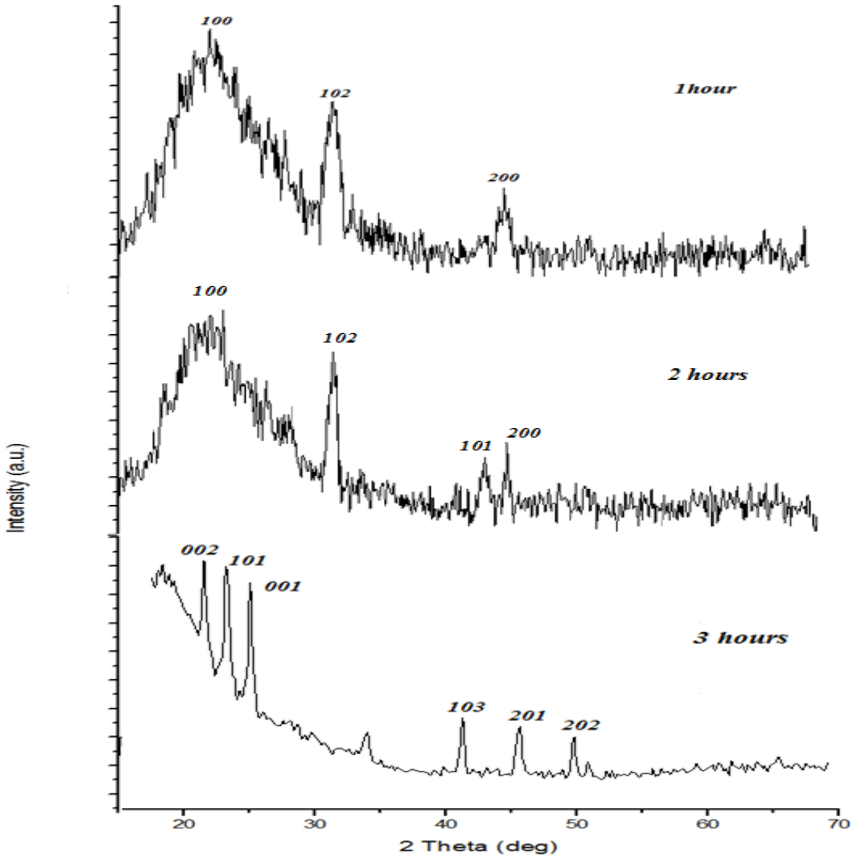
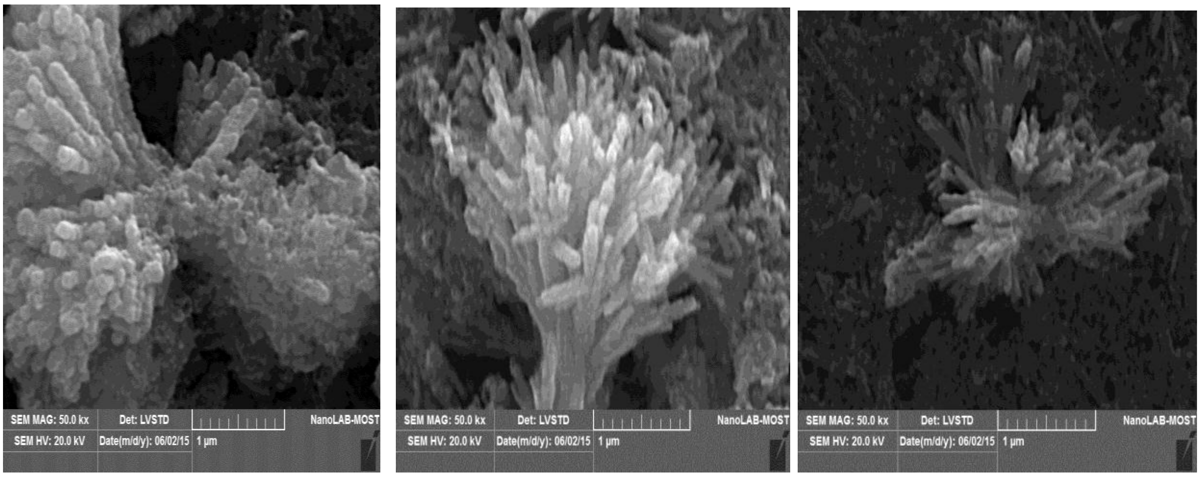


Figure 1-The X-ray diffraction pattern of CdTe nanoparticles.

Figure-2 shows a high magnification SEM image of the deposited CdTe samples on a glass substrate by drop casting method. These images show that the CdTe nanoparticles were flower of rods-like structures. The unequal film thickness due to deposition technique cause agglomerated particles and each nanorod seems to be stacked to other nanorods to form the flower like shape. There was an increase in particles size with increasing reaction time as shown in Table-1, the average dimensions (length and width) of CdTe nanorods evaluated from the SEM images using drawing scale, and the sample (3hour) had the largest average of nanorod width approaches the micrometer, while the average length of all nanorods were in microns.



(a) 1 hour (b) 2 hours (c) 3 hours

Figure 2-SEM pictures of CdTe nanoparticles synthesized by aqueous chemical way for 3 hours of reaction time.

Table 1-The Average Dimensions of CdTe Nanorods from SEM images

Reaction time period at 40°C	**Average Length of nanorods (µm)**	**Average Width of nanorods (nm)**
1 hour	1.7087	80.6
2 hours	1.695	93.7
3 hours	0.9454	103.8

Figure-3 shows the absorption spectrum of CdTe nanoparticles in suspend, it reflects wide absorption range in the visible spectrum unlike the bulk material which have step absorption edges at 840 nm [4,13] and the absorption for CdTe nanoparticles increases monotonically with decreasing wavelength towards the UV. Also, the absorption peaks for CdTe are shifted toward the longer wavelength (red shift) with increasing time as well as increasing size of nanoparticles as a consequence of the quantum confinement like in reports [3,5,13] that synthesized CdTe nanoparticles with different ways.

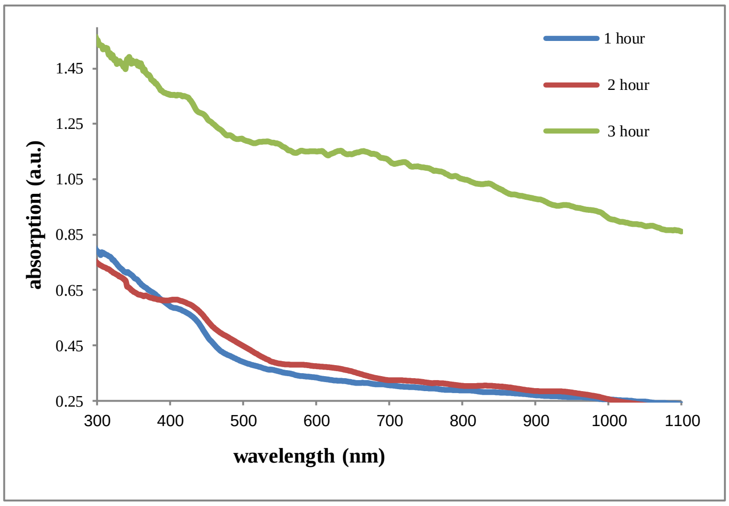


Figure 3-Optical absorption spectrum of CdTe nanoparticles

The energy gap for each reaction time for the prepared nanoparticles determined as shown in Figure-4.

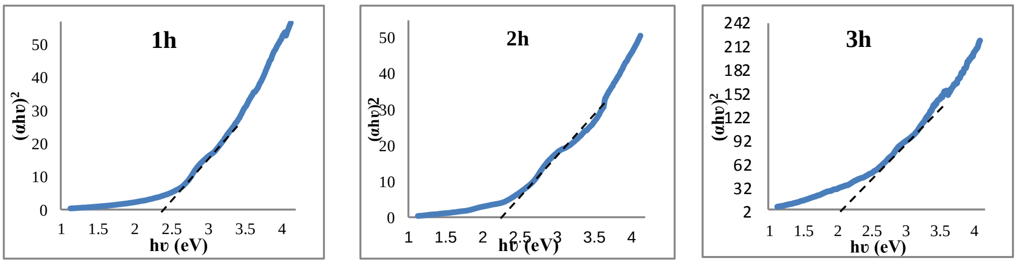
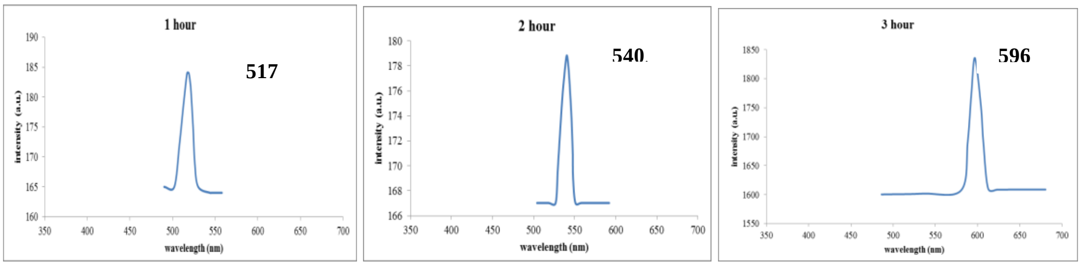


Figure 4-Plot of $(\alpha h\upsilon)^2$ verses Energy (hυ) to determine energy band gap for each reaction time period

It is shown that the energy gap decreases with time increasing, its values are approximately (2.4, 2.3, 2.1 eV) respectively which prove that the particle size increases with time.The photoluminescence emission spectra of CdTe nanoparticles at 300 nm excitation are shown in Figure-5.



a) 1 hour b) 2 hour c) 3 hour

Figure 5-Photoluminescence emission spectra of CdTe nanoparticles

Photoluminescence (PL) studies provide information of different energy state available between valence and conduction bands responsible for irradiative recombination. The spectrum displays luminescence peak at (517, 540, and 596 nm) for reaction times (1h, 2h, and 3h) respectively also take place a red shift indicating the growth of the nanoparticles. Theses peaks due to the intrinsic band to band transition which corresponds to the energy gap of the nanoparticles and it is originated from the recombination of the free exciton [4,11]. The values of energy gap estimated from luminescence peaks are (2.398, 2.296, 2.08 eV) which is matches with the energy gap values estimated from absorption spectrum.

Conclusions

CdTe Nanorods Flower-like shape were prepared by aqueous chemical synthesis using L-cysteine as a stabilizer. The magnification SEM images of the CdTe samples shows flower of rods-like structures with an average diameter (width) of (80.6, 93.7, 103.8 nm) increasing with increasing reaction time. The absorption spectrum of CdTe nanoparticles in suspend shows a wide absorption range in the visible spectrum that make it very useful as a photo-detector for future work. Both absorption and PL spectra had "quantum size effect". The exatonic peak position in absorption and PL shifted toward longer wavelengths indicates growth of CdTe nanoparticles during the reaction.

References

1. Tiwari, A.K., Verma,V.K. , Jain, T.A. and Bajpai, P.K. **2013**.Conclusive growth of CdTe nanorods by solvothermal decomposition using single source precursors. *Soft Nanoscience Letters*,3,pp: 52-57.
2. Saha,S. and Bera,S.R. **2013**.Growth and characterization of CdTe nanostructures grown by chemical reduction route. *International Journal of Metallurgical & Materials*, 3(1), pp: 37-40.
3. Ananthakumar, S. Ramkumar,J. and Babu,S.M. **2014**.Facile synthesis and transformation of Te nanorods to CdTe nanoparticles. *Materials Science in Semiconductor Processing*, 27, pp: 12-18.
4. Wang,X.N. Wang,J. Zhou,M.J. Wang,H. Xiao,X.D. and Li,Q. **2010**.CdTe nanorods formation via nanoparticle self-assembly by thermal chemistry method. *Journal of Crystal Growth*, 312, pp: 2310-2314.
5. Jain, K. Srivastava,V. and Chouksey,A. **2009**.Synthesis and optical properties of CdTe nanocrystals with improved optical properties. *Indian Journal of Engineering & Materials Sciences*, 16, pp: 188-192.
6. He,Y., Lu, H., Sai,L., Lai,W., Fan, Q., Wang, L. and Huang,W. **2006**.Synthesis of CdTe nanocrystals through program process of microwave irradiation. *J. Phys. Chem. B*, 110(27), pp: 13352-13356.
7. Rogach, A.L. **2000**.Nanocrystalline CdTe and CdTe(S) particles: wet chemical preparation, size-dependent optical properties and perspectives of optoelectronic applications. *Materials Science and Engineering*, B69 (70), pp: 435-440.
8. Silva,F.O., Carvalho,M.S., Mendonca,R., Macedo,W.A., Balzuweit,K., Reiss,P. and Schiavon, M.A. **2012**. Effect of surface ligands on the optical properties of aqueous soluble CdTe quantum dots. *Nanoscale Research Letters*, 7, p: 536.
9. Shan,Y. Xiao,Z. Chuan,Y. Li,H. Yuan,M. **2014**.One –pot aqueous synthesis of cysteine-capped CdTe/CdS core-shell nanowires. *Journal of Nanoparticle Research*, 16(2420), pp: 1-11.
10. Li,Y., Jing,L., Qiao,R. and Gao,M. **2011**.Aqueous synthesis of CdTe nanocrystals: progresses and perspectives. *Chem. Commun.*, 47, pp: 9293-9311.
11. Abd El-sadek, M.S. and Babu, S.M. **2010**. Growth and optical characterization of colloidal CdTe nanoparticles capped by a bifunctional molecule. *Physica B*, 405, pp: 3279-3283.
12. Shaaban, E.R., Yahia, I. S., Afify, N., Salem, G.F. and Dobowolski,W. **2014**. Structural and optical dispersion parameters of nano-CdTe thin film/flexible substrate. *Materials Science in Semiconductor Processing*, 19, pp: 107-113.
13. Ruth, A.A. and Young, J.A. **2006**. Generation of CdSe and CdTe nanoparticles by laser ablation in liquids. *Colloids and Surfaces A: Physichem. Eng. Aspects*, 279, pp:121-127.