The Study of the Second Harmonic Generation of the Hybrid CdS nanobelts

Nada Abdul Hadi Kareem
University of Al-Qadisiya/College of Education/Physics Department
nadahadi2012@gmail.com

Submission date:- 6/11/2018 Acceptance date:- 11/12/2018 Publication date:- 22/1/2019

Keyword: Second Harmonic Generation, Laser, Nanobelts, CdS

Abstract:

In this work, first we studied the second-harmonic generation, preparation of high-quality CdS including CdS (cadmium powder, powder, 99.995% basis for trace minerals) on the silicon substrate in nanobelts (CdS) manufactured by Chemical Evaporation Deposition (CVD), (XRD), TEM, scanning electron microscopy (SEM), nonlinear optical properties using optical microscopy, microscopic optical measurements, and second- harmonic generation measurements using Ti: Sappire laser femto second (800 nm). The results showed that the prepared CdS nanobelts, had a blue emission and the wavelength is 400 nm, which is due to deep emissions resulting from imperfections or impurities.

1.Introduction.

The study of the second harmonic generation (SHG) is a nonlinear optical process in which two-wavelength photons interact to form one photon at half wavelength and with a double frequency of 2ω. Figure 1 (a) shows the SHG mechanism in semiconductor nanotubes, so semi-conductor nanowires are visually moving at the basic frequency ω. They produce the frequency at exactly 2ω, and (b) the SHG energy graph shows. The solid line in the figure represents the atomic floor state, and the thin lines represent hypothetical levels.[1]

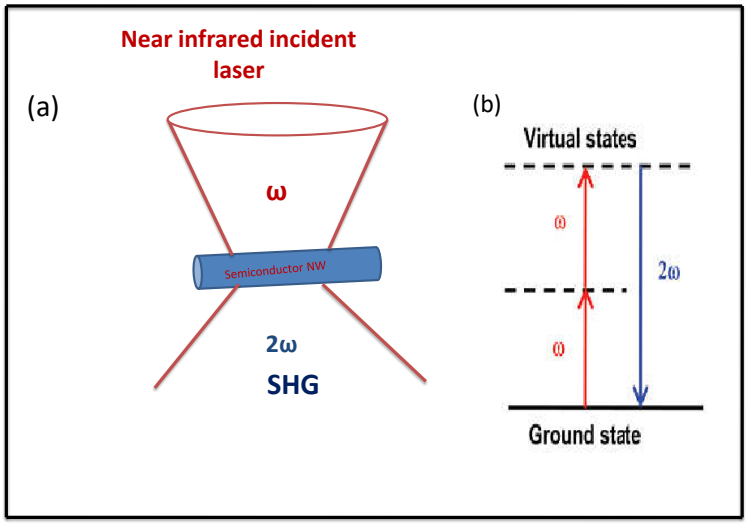


Figure 1) (a) Diagram of the SHG mechanism in semiconductor nanowire.
(b) Energy-level diagram showing the second- harmonic generation[1].

According to the equation (1) if we consider monochromatic beam of E_0 amplitude and angular frequency ω, expressed as:

$$E = E_0 \sin(\omega t) \quad (1)$$

When this electric field (E) occurs on a nonlinear material, the resulting electrolysis is P :

$$P=\varepsilon_0 \chi^{(1)}E_0\sin(\omega t) + \varepsilon_0\chi^{(2)}:E_0^2\sin^2(\omega t) + \varepsilon_0\chi^{(3)}:E_0^3\sin^3(\omega t) +\ldots \quad (2)$$

using the basic trigonometry can find the polarization from this equation:

$$P =\varepsilon_0 \chi^{(1)}E_0 \sin 2(\omega t) +\frac{1}{2} \varepsilon_0 \chi^{(2)}:E_0^2(1-\cos 2\omega t) +\frac{1}{4} \varepsilon_0\chi^{(3)}:E_0^3 (3\sin \omega t-\sin \omega t) +.. \quad (3)$$

The second harmonic term of the polarization is therefore:

$$P^2= \frac{1}{2} \varepsilon_0 \chi^{(2)}:E_0^2(1-\cos 2 \omega t) \quad (4)$$

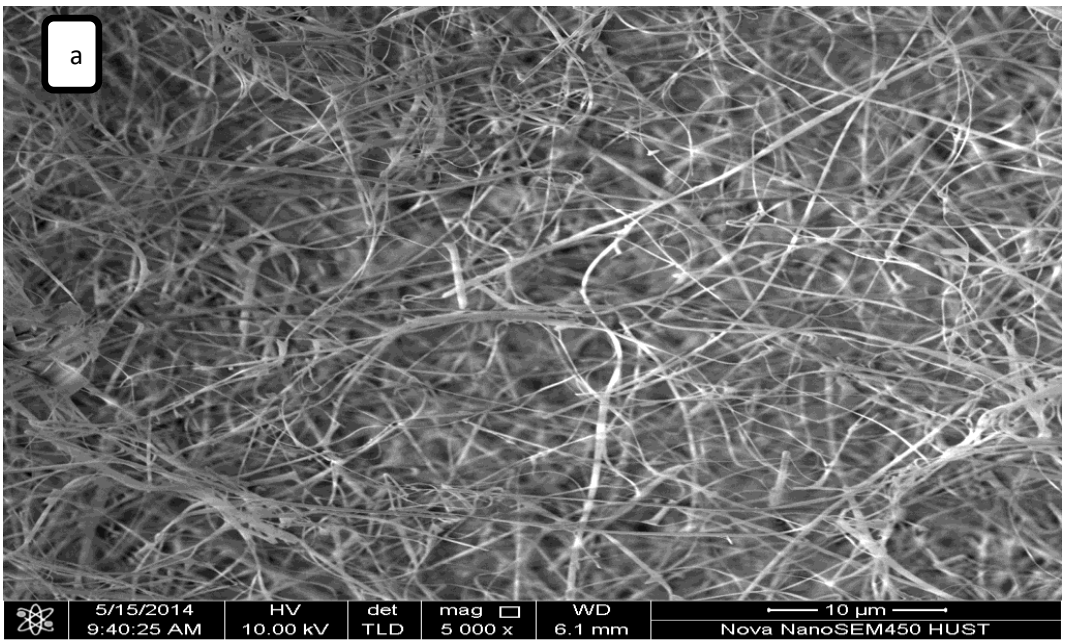
Equation (4) shows two important points in the second harmonic term. The first term indicates that polarization of the second order consists of a component at zero frequency, known as optical correction [1]. This term does not generate electromagnetic radiation. The second term corresponds to the changes in the electric polarization at double the base frequency, generating light that radiates at frequency. This process is known as the second harmonic generation, or SHG [2]. The effect of second harmonic generation refers to directly stimulate the optical frequency multiplier a non- linear optical effect. In 1961, the Fraken team used laser pulse Ruby laser (wavelength of 694.3nm) focused on the quartz wafer, successfully observed 347.2nm UV wavelength second harmonic generation. Compared the two- photon or multiphoton absorption induced by UV radiation, SHG is a more convenient and effective method, microscopic imaging of in [3, 4] nonlinear optical frequency converters and all-optical signal processing and so there is a good prospect. In the present semiconductor - materials such as CdS ZnO , GaN, GaAs, ZnS and ZnTe SHG in reports, strong optical nonlinear effects in the field of physical mechanisms are as follows: (1) electronic effects. Strong light field in the media, will bring about changes in the electronic distribution of atoms or molecules in the medium, thus causes the refractive index change. Electronic effect the response times for the $10^{-14} \sim 10^{-15}$ s. (2) the reorientation and redistribution. In bright light under the field, containing anisotropic molecular medium, HF Kerr effect refractive index change is mainly caused by reasons. Molecular reorientation response time is about $10^{-11} \sim 10^{-12}$ s. (3) the electrostrictive effect. When strong light field, electro magnetostrictive effect will bring about changes in the density of the medium, thus causes the refractive index changes, the response time is about $10^{-8}\sim 10^{-9}$ s. (4) Media absorbs laser energy through a non-radiative transition into thermal energy, lead medium temperature, density changing, causing the refractive index changes. The thermal response time of

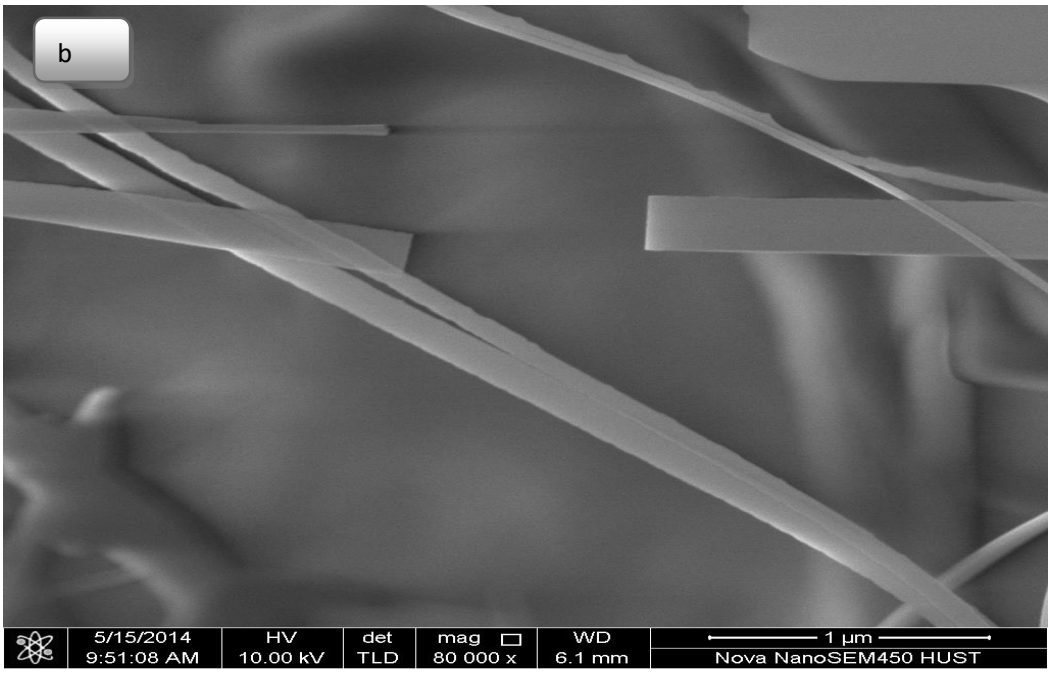
approximately is 1 ~10^{-8} s. In general, different nonlinear media, as well as different kinds of laser pulse width, the main mechanism is effects of different, and can sometimes be several mechanisms of interaction, which required under specific conditions for analysis [5].

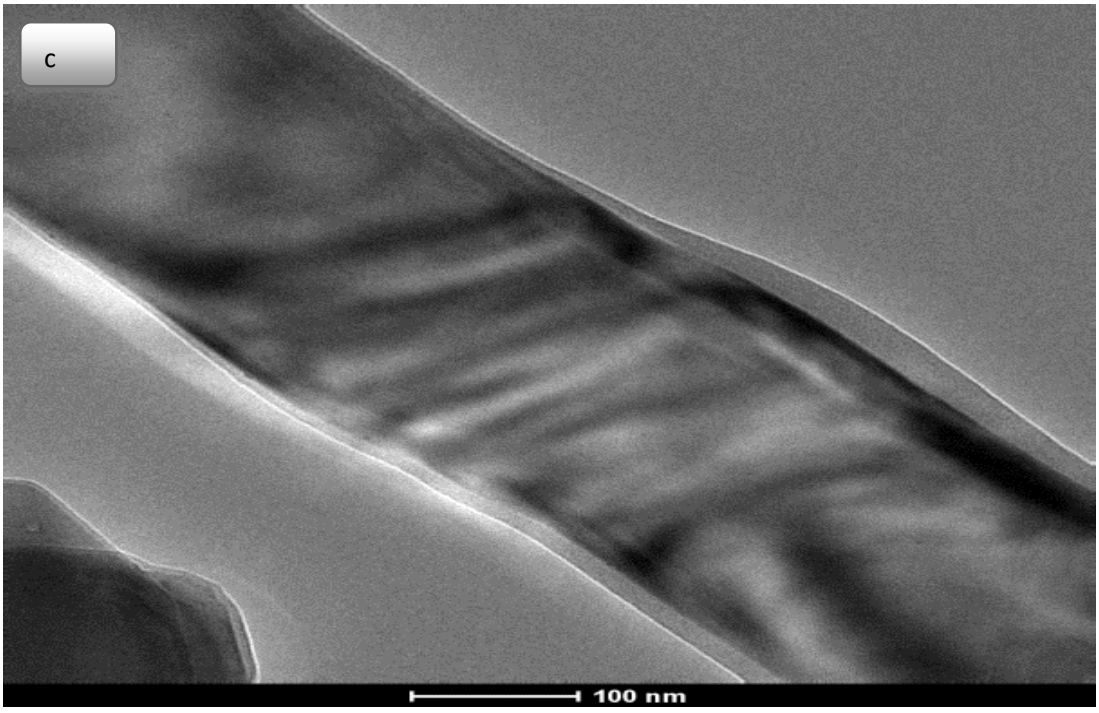
Semiconductor materials have been extensively studied due to their potential applications in optical optical stimulation, optical and optical fields [5-7]. Cadmium CdS is an II-VI composite semiconductor with a large-scale direct gap (eg = 3.6 ~ 3.8 eV) [8]. Furthermore, the CdS has a high refractive index [9]. Several techniques including sputtering [10], molecular beam epitaxial [11], Pulsed laser deposition [12], chemical path deposition (CPD), successive ionic layer uptake and interaction [14], pyrolysis spray [15] and chemical vapor deposition (CVD) [16,17]. The nonlinear optical properties of semiconductor nanoparticles attracted their attention due to the potential optical microscope [18] and visual communication [19]. The second harmonic generation (SHG) is a nonlinear optical process that directly multiplies the falling light frequency. Provides a convenient and efficient way to obtain ultraviolet radiation using an infrared-close laser, which shows great promise for applications such as microscopic / probe transducers [20], nonlinear converters [21, 22], and full light signal processor [23] . In particular, SHG in nanobelts shows special advantages for homogeneous nanometer sources and integrated optical circuits, which have been widely studied in ZnO [25], GaN [26], and nanboirs [20,27]. In this paper, first, we reported on the preparation and characterization of CdS nanobelts, and the effect of Au stimuli was discussed on the obtained forms of CdS nanobelts obtained, second, the study of SHG measurements.

2- Experimental Details:

CdS was manufactured by chemical vapor deposition (CVD) using a simple conventional tube furnace with a 50 mm quartz tube at 1050 ° C, a high purity powder (Alfa Aesar, purity 99.99%) was used as precursors and placed in a quartz boat placed in the middle Oven tube. A thin layer of silica coated with steel coils in the downstream direction of the source material was placed as sediment substrates. After the closure of the tube, a nuclear gas escaped from pure nitrogen at a flow rate of 50 cubic meters (sccm). The source is heated to 1050 ° C at 30 ° C / min and remains at this temperature for one hour. After cooling the tube oven to room temperature, a thin layer of silica coated with silicon coils was placed below the source material, as deposit substrates. After the tube was closed, the carrier gas of pure argon was escorted at a flow rate of 50 cubic meters. Finally, the yellow products were deposited on the Si substrate.




b
5/15/2014
9:51:08 AM
HV
10.00 kV
det
TLD
mag
80 000 x
WD
6.1 mm
1 µm
Nova NanoSEM450 HUST


c
100 nm

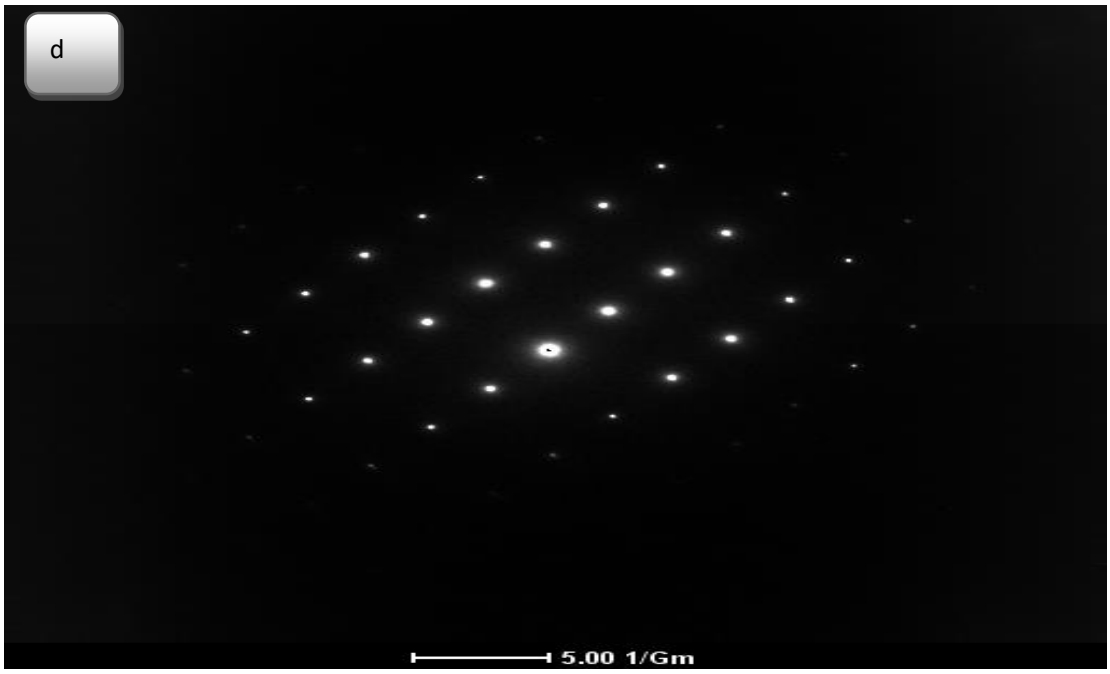
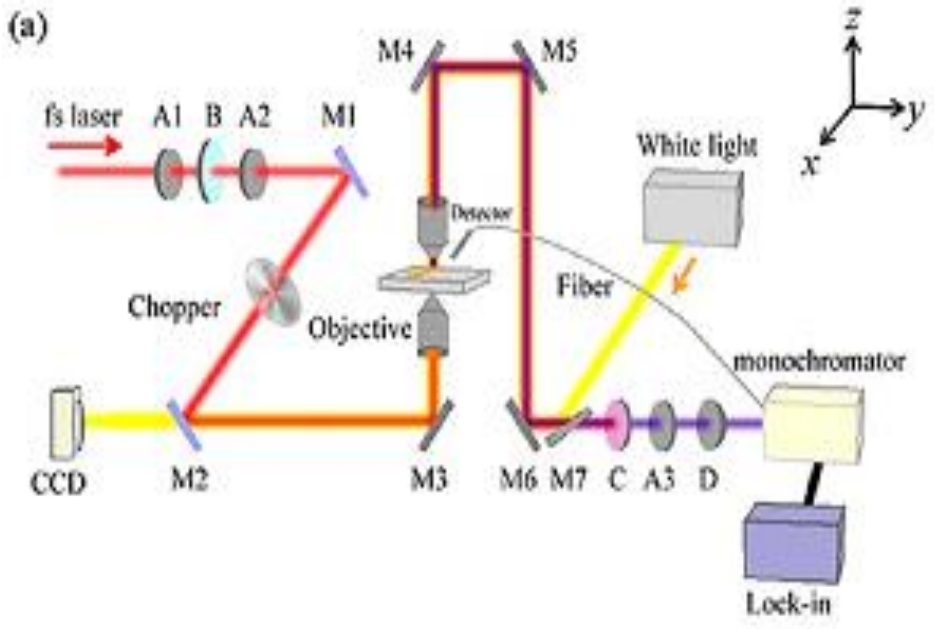


Figure 2 (a) Low zoom image of SEM, (b) High SEM image magnification, (C) Low-zoom image of TEM, (D) is the corresponding SAED pattern of CdS nanobelts.

The Second harmonic-generation measurements were recorded at room temperature, using a long Ti / Sapphire laser with a wavelength of 800 nm with the duration of the pulse –fs (femto-second), as the source of the excitation light.



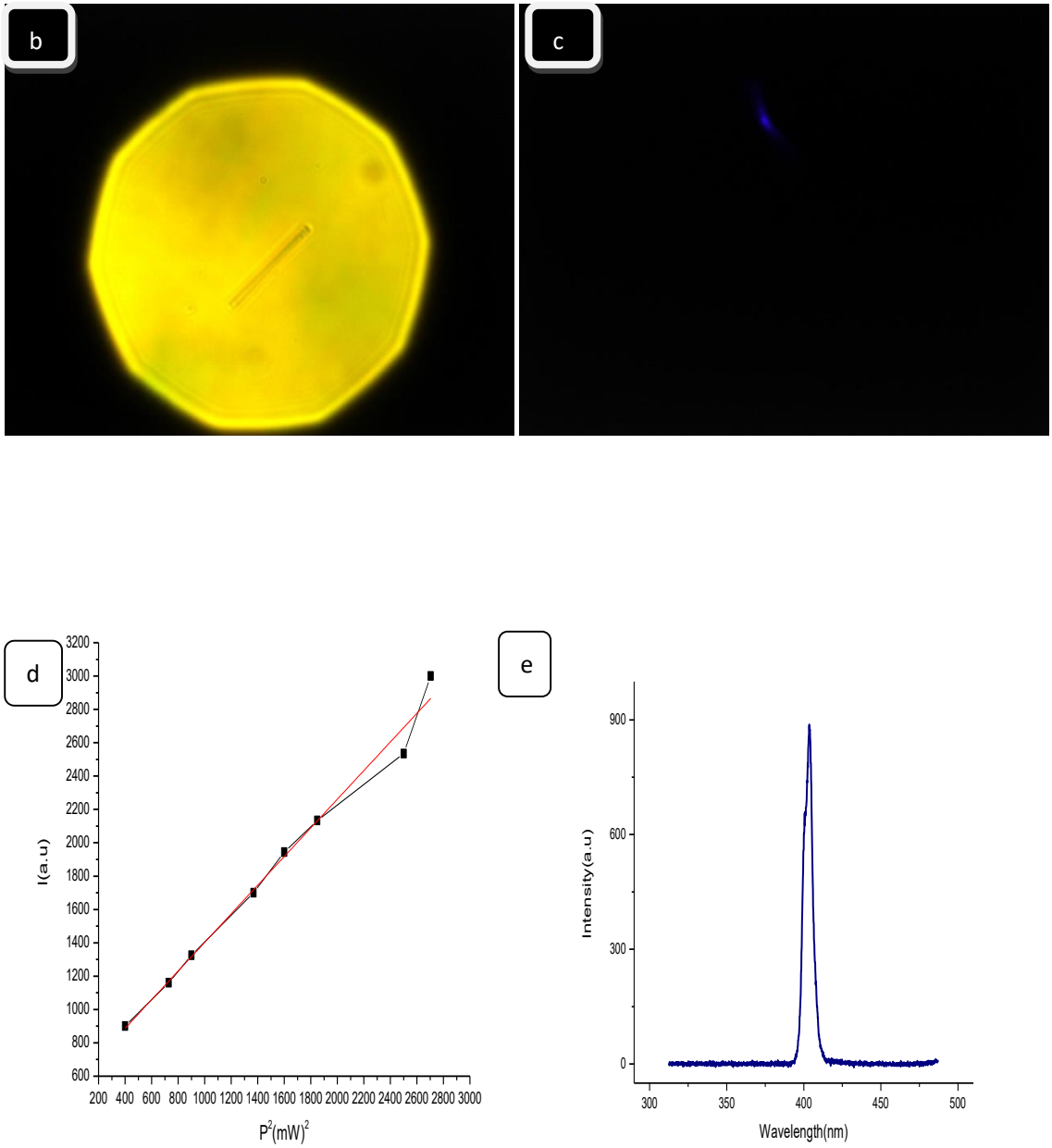


Figure **3** (a) shows the experimental setup schemes of the SHG optical measurement, (b) illustrates the bright – field image of the CdS nanobelt, (c) illustrates the dark–Field image of resulted SHG, (d) shows the spectral emission of the SHG using a pumping power of 20 mW (~31.8k W/ cm^2), (e) Shows the relation between power density of doubled frequency Ti:Sappire irradiation and square value of power.

3. Results and Discussion:

In general, the crystalline structures of CdS are in two forms, namely a cube (mixed cadmium) and wurtzite phases. The CdS cube is fixed at room temperature, while the hexagonal CdS is configured as the temperature is higher than 1020 °C [28]. General formulations of products manufactured using SEM, which were shown in Figure 2, were examined. Figure 2 (a) is a low magnification SEM image of CdS nanobelts, one can find large amounts of belt-like structures covered on the Si substrate. Figure 2 (b) shows a high magnifying SEM image for CdS nanobelts. This figure shows that the product consists of nanobelts with a diameter of Ca.45 nm (from SEM and TEM measurements) and a length of up to 4μm.

Figure 2 (c) illustrates a low-TEM image model for the single NBs tones in CdS and the corresponding SAED pattern, explaining that the CDB-style nanobelts have a single crystal structure throughout their length. CdS nanobelt grows a long trend [0001] as shown in Figure 2 (d).

In the SHG experiment, the conventional focal microscope configuration shown in Fig. 3 (a) was used for optical measurements at room temperature. The oscillator Ti / sapphire oscillator (spitfire, spectra-physics, 800 nm, 50 fs, and 800 MHZ) was the source of the pump and the beam was positive at 40 x to at 4μm. The small pump point contributes to a relatively large pumping power density because the laser energy is limited in our experiment, leading to a high SHG signal for the microprocessor. The transmitted signal was collected with the same objective and focused on a monochromatic lens equipped with a Hamamatsh CR131 and an SRS30 amplifier. A 750 nm short-pass filter was placed in front of the monochromor to extract from the laser light pump. The half-wave plate (A2) was combined at 800 nm and the A3 graph to measure the polarization characteristics of the second harmonic generation of the surface (SHG). Figure 3 (b) shows the visual image of the length of the long CdS nanobelts. The high-resolution UV blue signal is emitted to the nanostructural axis at an average pumping power of 4mW (~ 31.8 KW / cm2), as shown in Fig. 2 (c).

The spectra of the remote field appear in Figure 3 (d) at a strong peak at 400 nm, precisely the signal doubling frequency of the laser pump at 800 nm. Figure 3 (e) shows the intensity of the second harmonic construction (SHG) measured as a function of the square of the pumping power source P^2

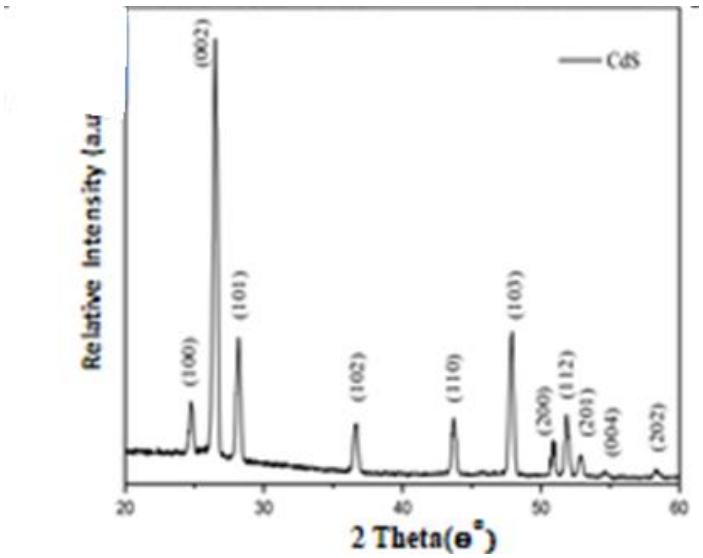


Figure (4) shows XRD pattern.

Figure (4) shows XRD pattern of cultivated products. All diffraction peaks can be indexed as CdS hexagonal structural wurtzite with lattice constant = 3.822 Aº and b = 6.269Aº J CPDS. card: 79-2204 [28]. Indicating that the composite product has a high purity.

4.Conclusions:

The CdS nanobelts have been fabricated by chemical precipitation of vapors (CVD), we can clearly see that the intensity is increasing linearly with P^2-demonstrating the SHG response in our experiment.

Femto second pulsed laser with wavelength near infrared. CdS NBS, generates a second harmonic light generation with increasing intensity as the angle increases between the incident core beam and the nano-axial axis.

CONFLICT OF IN TERESTS

There are no conflicts of interest

References:

[1] X.W, Liu, K. Wang, et. Al, " laterally emitted surface second harmonic generation in a single ZnTe nanowire. *NanoLett*.Vol. 13, pp. 4224-4229, 2013.

[2] M.Y.Lu, Y.A.chung, M.J.chen,Z.L.Wang, and L.J.chen,"Intercrossed sheet.Like.Ga-doped ZnS nanostructures with superstructures with superbphotocatalytic activity and photo response", *The Journal. physical chemistry*, Vol 113,pp.12878-12882,2009

[3] H.Zeng,W.Cai, and P. liuetal., "ZnO-based hollow nanoparticles by selective etching, elimination and reconstruction of metal-Semiconductor interface, improvement of blue emission and photo catalysis," *ACS nano*,Vol.2, no.8,pp 1661-1670,2008.

[4] X.wu, w cai, and F, Qu," Tailoring morphologies and wettability property of ZnO ID nanostructurees" *Acta physicasinica*, Vol. 58, pp.8044-8049,2009.

[5] H.B. Zeng, G.T. Duan, and W.P.Cai, "Blue luminescenence of ZnO nanoparticles process", *Advanced Functional materials*, Vol.20,pp.561-572,2010.

[6] L.J Yu ,F.Y.Qu, and X.Wu, "Facial hydrothermal synthesis of novel ZnOnanocubes" *Journal of Alloys and componds*, Vol.504 ,pp. L1-2011.

[7] J.Wang, Y.Jiao, Y.Liu, and X.Wu, "Gas phse growth of wurtizileZnSnanobelts on a large scale, "*Journal of Nano Materials*, Vol 2013.

[8] K.Ahn, J.H. Jeon, and S.jeanet,al, " chemical bonding states and atomic distribution within ZnO(s,o) Film prepared on CIGS /Mo/ glass substrates by chemical bath deposition," *Current Apllied physics*, Vol. 12, no.6, pp. 1465-1469,2012.

[9] X.C. Jiang ,Y. Xie, and L. Y. Zhu, "simulataneous in situ formation of ZnSnano wires in a liquid crystal template by γ- irradiation, "*chemistry of materials*, Vol.13, PP.1213-1218, 2001.

[10] D.H. Hwang, J.H .Ahn K.N Hui, K,S. Hui, and Y.G .son," structural and optical properties of ZnS thin films deposition by RF manetron Sputtering "*Nanoscale research Letters*, Vol. 7 article 26,pp.13,2012.

[11] S. Yano, R. Schoder, H. Sakai, and B. Ullrich, "High- electric- field photo current in thin –film ZnS formed by pulsed-laser deposition," *Applied physics Letters*, Vol.82.no.13, pp, 2026- 2028,2003.

[12] M.W. Huang, Y.W. cheng, K. Y. .pan, c.Cchang, F.S. Shieu, and H.C. Shih, "The preparation and cathodoluminecsence of ZnS nanowires grown by chemical Vapor deposition, "*Applied surface sciences*, Vol.261, pp.665-670,2012.

[13] G.Xu , S,Ji, and C.Ye," Efect of ZnS and CdS coating on the photo voltaic properties of CuLnS2 –Sensitized photoelectrodes," *Journal of materials chemistry*, Vol.22, no. 11 , pp. 4890-4896, 2012.

[14] K.Nagamani, N.Revathi, P.Prathap, Y. Ling appa, and K. T. Reddy, "AL-doped ZnS layers synthesied by solution growth method," *Current Applied Physics*, Vol1.12, no.2, pp.380-384, 2012.

[15] G.L. Agawane, S. W. Shin, and M.S. Kim et al, "Green route fast synthesis and charaterization of chemical bath deposited nano crystalline ZnS buffer Layers, ," *Current Applied Physics*, Vol. 13, no. 5, 850-856, 2013.

[16] F. Peng, S.Ou, P. Chuan, B. Wu, and D.Wuu, "Structural, Surface Morphology and optical properties of ZnS film by chemical bath Deposition at Various Zn/S Molar Rations," *Journal of nanomaterials* Article ID 594952, 2014.

[17] H.Harutyunyan, S. Palomba J. Renger, R. Quident, and L. Novotny," *NanoLett*, Vol .10,pp. 5076-5079, 2010.

[18] C.J. Barrelet, H.S. Ee, S.H Kwon, and H.G. park ,"non linear mixing in nanowire subwavelenght wave guide,"*NanoLett*. Vol. 11, pp. 3022-3025,2011.

[19] W. Liu, K. Wang, Z.liu, G. Shen and P. Lu," laterally Emitted surface Second harmonic Generation in a single ZnTe nanowire, "*NanoLetters*, Vol. 13, pp. 4224-4229, 2013.

[20] Y. Zhang, N.K. grady C.O. Ayla, and N.J. Halas, "Three- dimenstional nanostructure of second- harmonic light," *NanoLett*. Vol 11, pp.5519-5523,2011.

[21] N.Talebi, and M.J. Shahabadi, "photonics application and technology world market series" pp. 42-47. Business briefing.

[22] M.L. Ren, and Z. Y. Li, "Giant enhacement of Second Harmonic generation in distributed Bragg reflector mirror," *Opt. Express*, Vol. 17, pp.14502-14510, 2009.

[23] P.Dong J. Upham A. Jugessure, and A. G. Kirk, "Second harmonic generation in Semiconductor wave guide directional couplers," *Opt. Express*, Vol 14, pp. 2256-2262, 2006.

[24] P. B. Mehl, L.R. House, A.Uppal, J.A. Reams , and J.R. Kirschlbrown, "room temperature excitonic whispering gallery mood lasing" *advanced materials*, 441, 489. 2006

[25] J.P. Long, B.S. Simpkins, D. J. Rowen horst, and P.E. Pehrsson, " Far-Field imaging of Optical second harmonic Generation in a single GaN nanowires ," *Nanolett*, vol7, pp. 831-836, 2007.

[26] M. M. Lee, J T.Miyasaka, T.N. Murakami, H.J. Snaith, "optical properties of ZnS nanowire lasers and waveguids" *Science*, 338,643, 2012

[27] B.G. Ibert B. H. Frazer , and H.Zhang et al, " X-ray absorption spectroscopy of the cubic and hexagonal poly types of Zinc sulfied ," physical Review, *Advanced material*, Vol. 66. No.24, Article ID 245205, 2002.

[28] Z.Gang, L. Cheng, J.Zou, X. Yao, and, H. Cheng," Zinc sulfied nanowire array on Silicon Wafers for field emitters "*Nano technology*, Vol.21, Article ID 065701, 2010.

[29] S. Kumar, N. D, Govinda, R. G, thirumala" Synthesis, Structure and morphological studies of CdS nano powder" Int. *J. Chem. SCI*. Vol.14, No.1, 2017.

دراسة التولد التوافقي الثاني للحزام النانوي لكبريتد الكاديوم الهجين

ندى عبد الهادي كريم
جامعة القادسية/ كلية التربية/ قسم الفيزياء

الخلاصة :

في هذا العمل ، تمت دراسة التولد التوافقي الثاني المتناسق لتحضير CdS عالي الجودة بما في ذلك CdS (مسحوق الكاديوم ، مسحوق ، أساس معادن التتبع 99.995٪) على ركيزة السيليكون في أشباه الموصلات CdS nanobelts المصنعة باستخدام ترسيب التبخر الكيميائي (CVD) ، التي تم الحصول عليها فحصت بحيود الأشعة السينية (XRD) ، المجهر الإلكتروني النافذ (TEM) ، المجهر الإلكتروني الماسح (SEM) ، دراسة الخواص البصرية غير الخطية باستخدام المجهر الضوئي ، القياسات البصرية المجهرية البؤرية ، ومقاييس التولد التوافقي الثاني باستخدام Ti: Sappire laser femto second (800 نانومتر) ، أظهر أن الحزام النانوي ل CdS المحضر، كان له انبعاث أزرق عند طول موجة 400 nm ، والذي يرجع إلى الانبعاثات العميقة الناتجة عن عيوب أو شوائب.

كلمات مفتاحية: التولد التوافقي الثاني, الليزر, الاحزمة النانوية, كاديوم سيلفايد