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Study the optical and structure properties of CdTe nanoparticles prepared by pulsing laser ablation in distilled water

***Raad S. Alnaily** **Murtadha L. Sheqnab**

University of AL-Qadisiyah, College of Education, Department of Physics, Iraq.

*Corresponding Author E-mail: Raad.Alnayli@qu.edu.iq

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ABSTRACT:

In this paper, an easy and effective method to preparation of cadmium telluride nanoparticles with high purity and concentration have been presented. CdTe nanoparticles were synthesized by pulsed laser ablation in distilled water using Q-switched Nd-YAG laser at (100 mj, 1064 nm, 10ns, 6Hz) and with various laser pulses. The absorption spectra of the CdTe nanoparticles were measured using the UV-Vis spectrophotometer, and found to be affected by concentration of nanoparticles according to the number of applied laser pulses. Formation of the pure CdTe nanoparticles is confirmed using AFM image analysis whose showed that generated CdTe nanoparticles were a spherical shape whit average size in nanoscale. The structural and morphology properties of these nanoparticles were studied using X-ray diffraction analysis and SEM micrograph. Finally, the energy dispersive X-ray spectroscopy (EDX)was employed for the elemental analysis and chemical characterization of a prepared samples, it confirmed that prepared samples was high purity and presence of Cd and Te with high ratio.

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دراسة الخواص البصرية والتركيبة لجسيمات تيلوريد الكادميوم النانوية المحضرة بواسطة طريقة الاستئصال بالليزر النبضي في الماء المقطر

رعد شاكر عبيس **مرتضى لفته شغناب**

جامعة القادسية – كلية التربية – قسم الفيزياء - العراق

الكلمات المفتاحية:

الخصائص التركيبية والبصرية
جسيمات تيلوريد الكادميوم النانوية
الاستئصال بالليزر النبضي

الـــخُـــلاصــــة:

في هذه البحث ، تم عرض طريقة سهلة وفعالة لإعداد جسيماتشبه موصلة نانوية ذات نقاوة وتركيز عالي. أذ حضرت الجسيمات النانوية CdTe بواسطة الاجتثاث بالليزر النبضي في الماء المقطر باستخدام الليزر Nd-YAGالذي يعمل عند (100 mj، 1064 nm، 10 ns، 6 Hz)وبعدد نبضات ليزر مختلفة. تم قياس أطياف الامتصاص لجسيماتCdTe النانوية باستخدام مطياف الاشعة الفوق البنفسجية والمرئية ، ووجد ان اطياف الامتصاص تتأثر بتركيز الجسيمات النانوية وفقًا لعدد نبضات الليزر المطبقة. تم تأكيد تتشكل جسيماتCdTeالنانوية النقية بواسطةتحاليل صور AFM التي بينت أن الجسيمات النانوية الناتجة ذات اشكال كروية بمعدل حجم في المقياس النانوي. تمت دراسة الخواص التركيبية والمورفولوجية لهذه الجسيمات النانوية باستخدام تحليل حيود الأشعة السينية وصورة SEM المجهرية. أخيرا، تم توظيف مطياف تشتت الطاقة بالأشعة السينية (EDX) لتحليل العناصر والتوصيف الكيميائي للعينات المحظرة، اذ أكد أن العينات المحضرة تميزت بنقاوة عالية

بوجود عنصري Cdو Teبنسب عالية.

1. INTRODUCTION

In the past few decades, synthesis of semiconductor nanoparticles have been attractive and interesting by many researchers due to their unique optical and electronic properties which differ from their properties as a bulk materials [1-4]. When the size of semiconductors materials in nanoscale, their physical and chemical properties change dramatically, resulting in unique properties due to their large surface area or the effect of their quantum size. [5] Semiconductor nanomaterials and devices are still in the research stage at present, but they are promising for applications in many fields, such as solar cells, nanoscale devices, nano-emitting devices, laser technology, waveguides, chemicals and biological sensors. Further development of nanotechnology will certainly lead to significant breakthroughs in the semiconductor industry [6-8]. CdTe nanoparticles (NPs) is one of the II-VI semiconductors nanomaterials attracts the interest of many researchers because of their unique optical properties, especially their potential applications in the manufacture of solar cells, chemical sensors, IR Detectors, optical switches, display devices and biological labels [9-11].Several methods were discovered to synthesis of nanoparticles with a shape and size controlled such as pulse laser deposition (PLD) [12], pulse laser ablation in liquid (PLAL) [13], flame metal combustion [14], chemical reduction [15], solvothermal [16], and etc. Most of these synthetic techniques are based on the isolation of small amounts of matter. Pulsed laser ablation in liquid environmental (PLAL), one of the newest techniques, offers an alternative method for synthetic nanostructures compared to chemical or other methods. In general it is a promising technique, offering novel opportunities to solve the problems of agglomeration and impurities [17, 18]. Additionally, the production system is easy, simple, and cheap, and does not require costly vacuum chambers. The ejected nanostructures are completely collected in solutions, thus forming a colloidal solution, which makes them very easy to handle as suspension or powder. Besides that, this alternative physical nanofabrication method opened new routes for materials processing based on the PLA of solids in various liquids to produce a wide range of novel materials, such as nanodiamond [19,20].In this work, we proposed a novel technique to obtain CdTe colloidal nanoparticles in one step using laser ablation method and characterize of the structure, morphology, particles size, absorption spectroscopy of obtained colloids and nanoparticles have been analyzed by UV-VIS spectrophotometer and X-ray diffraction, atomic force microscope AFM, scanning electron microscope SEM and energy-dispersive X-ray spectroscopy (EDX).

2. EXPERIMENTAL WORK

Figure 1 display the experimental set-up for preparation of cadmium telluride nanoparticles by laser ablation in liquid. At the first, A cadmium telluride (purity of 99.99%) immersed in distilled water were carried out by laser ablation using Nd:YAG laser type is (HUAFEI) with 10 ns pulse duration, 6Hz reparation rate, 1064 nm wavelength, 100 mj pulse energy, and with number of applied laser pulse of (100, 200, 300) pulse. Laser beam was focused by a 100 mm focal length lens in order to achieve high laser fluence on the target. The CdTe target was placed at the bottom of a glass vessel containing 2mL distilled water. Thus, three samples of colloid solutions has been produced according to Irradiation of solid target under different laser pulses. In the second stage, these a colloid solutions have been deposited on a clean glass substrate by drop casting method, in order to investigation of nanoparticles properties.

Finally, the optical and structure properties of these nanoparticles produced under laser ablation have been Characterized using UV-Visble spectrophotometer model (SP-3000 Plus, OPTIMA) within the spectral range (200-1100 nm), X-ray diffraction pattern with system specifications (Shimadzu-XRD-6000, Company /Japa) with CuKα radiation at 1.5406 Å wavelength in the range from (20° - 80°), the atomic force microscopy (AFM) type (scanning probe microscope SPM-AA 3000, Angstrom Advanced Inc., USA), scanning electron microscopy (SEM) type- S-1640 HITACHI company (Japan) with the energy-dispersive X-ray spectroscopy (EDX).

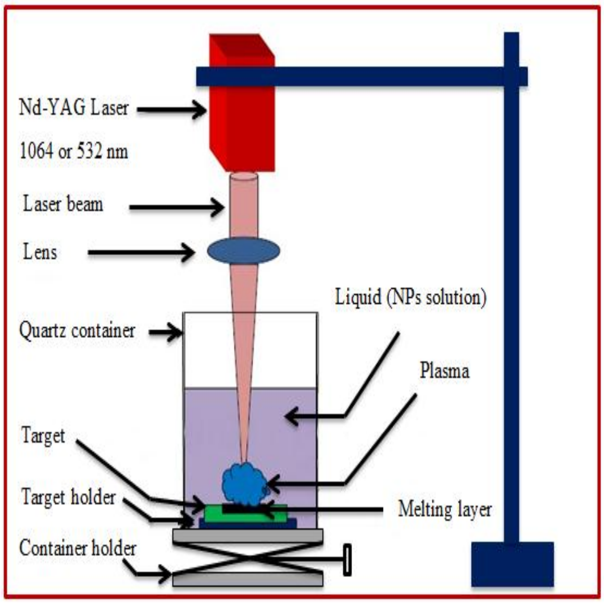

Figure 1: Experimental set-up to preparation of NPs by PLAL.

3. RESULT AND DISCUSSION

A- Optical Properties

The absorption spectra of CdTe NPs produced by laser ablation in DIW are shown in Figure 2. We observe from Figure 2 the laser-ablated CdTe nanoparticles show an onset of the absorption edge slightly above the band gap energy of the bulk at near ≈550 nm for CdTe, unlike the bulk material of CdTe, which have steep absorption edges at ≈860 nm [21]. It also noticeable that all spectra of the samples prepared demonstrate an absorption peaks at near UV-Visble wavelengths positioned. These transitions in spectra towards the short wavelengths (blue shift) attributed to quantum size effect of NPs. On the other hand, increase of absorption peak intensity indicate to increasing of the NPs concentration in the colloid solution with increasing the number of applied laser pulse, as found that high absorbance peak at 300 pulse as illustrated in Figure 2. This result obtained through Uv-Vis spectroscopy confirm that high of peaks depond on the NPs concentration which related with number of laser pulses incident on target [22].

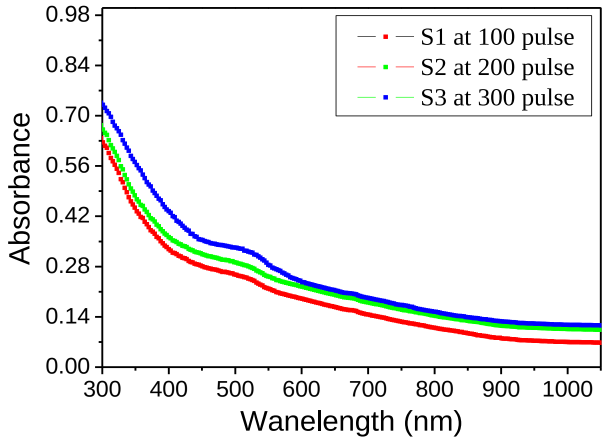

Figure 2: The absorbance spectra as of CdTe NPs synthesized by laser ablation in DIW at (E=100 mj, λ=1064 nm, F=6Hz) and different laser shots (100, 200, 300) pulse.

Figure 3. shows The transmittance spectra change as a function of the wavelength to CdTe NPs which prepared under laser ablation at various numbers of laser pulses at (100, 200, 300) pulse. It is noticeable that the transmittance spectrum behaves in opposite with absorbance and increasing density of the medium, where the transmittance increases with the wavelength of the electromagnetic spectrum of the visible-ultraviolet light and starts to decrease as towards the short wavelengths, a same of state is repeated for the prepared samples in two solutions. But there is a more drooping of transmittance, whenever increase of laser shots number, lead to increase concentration of absorbent nanoparticles abundantly in the solution, resulting in absorption energy of the incident electromagnetic radiation, and thus less value of transmittance.

The optical band gap of CdTe NPs was estimated from absorption coefficient data as a function of wavelength using the Tauc relation[23,24]:

$$\alpha h\nu = \beta\,(h\nu - E_g)^r \qquad (1)$$

where hν is the photon energy, β is band-tailing.

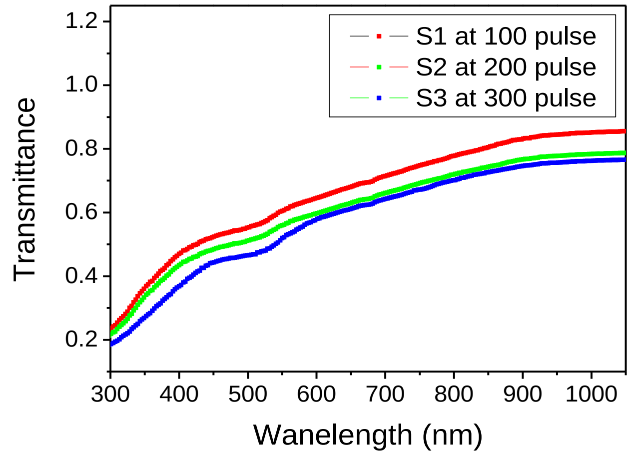

Figure 3: The transmittance spectra of CdTe NPs synthesized by laser ablation in DIW at different laser shots (100, 200, 300) pulse.

parameter, E_g is the optical band gap of thenanoparticles, and r is a constant which value is the values 1/2, 3/2, 2 and 3 depending on the nature of electronic transition. It is well known that CdTe is a direct band gap, so in this case value of r to be 1/2. Hence the direct band gap value is estimated from the absorption spectra by plotting $(\alpha h\nu)^2$ versus (hν) and extrapolating the straight line to the energy axis of the graph to the hν axis, that is, at α =0. Thus, these values of energy band gap of CdTe NPs are fund from 2.45, 2.54 and 2.68 eV for 100, 200 and 300 pulse, respectively as shown in figure. 4. The large values of band gap of CdTe NP compared to its value for bulk (1.46 eV) can be ascribed to the quantum size effect [25].Thus, the blue shift value of approximately 1.42 eV confirms the successful preparation of CdTe nanoparticles in this work.

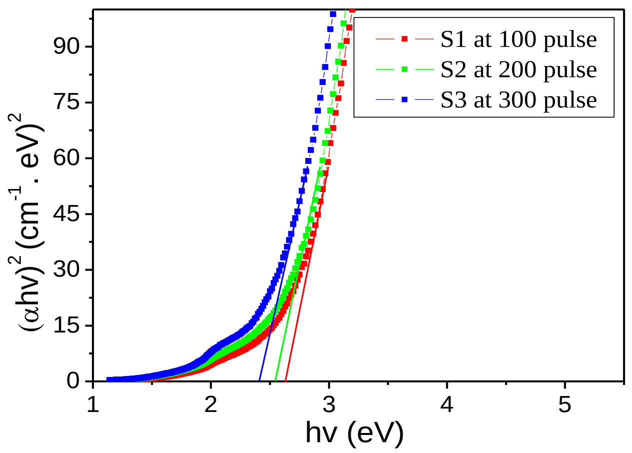

Figure 4: $(\alpha h\nu)^2$ versus photon energy gap varies of CdTe NPs synthesized by laser ablation in DIW at different laser pulses(100, 200, 300) pulse.

B- Structure Properties

The XRD pattern taken into CdTe colloid NPs deposited on clean glass substrate showed diffraction lines at 2θ = 23.47°, 39.16°, 46.39° and 62,24° corresponding to (111), (220), (311) and (331) planes, respectively as shown in figure.5. The XRD pattern shows the highest intensity diffraction peak at 2θ = 23.47°. The diffraction data was indexed to a cubic phase and the corresponding lattice cell parameter a = 0.659 nm. This results is agreement with [26]. The diffraction peaks at and 32.35° corresponds to CdO at the surface of the NPs [27]. The average crystallite size was calculated using the FWHM values of the high peak (111) according to Debye–Scherer formula in equation expressed as follows [28]:

$$D = \frac{0.94\,\lambda}{\beta\, COS\theta} \qquad (2)$$

Where λ is the wavelength (λ = 0.1542 nm) (CuKα), β is the full width at half maximum (FWHM) of the line, and θ is the diffraction angle. The crystallite size estimated using the relative intensity peak (111) for CdTe nanoparticles was found to be around 35 nm. Increase in sharpness of XRD peaks indicates that particles are in crystalline nature. The sharp XRD peaks indicate that the particles were of polycrystalline structure, and that the nanostructure grew with a random orientation.

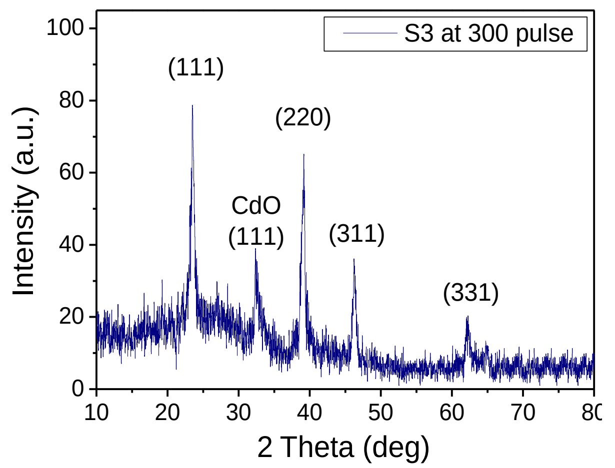

Figure 5: XRD pattern taken onto CdTe NPs films prepared laser ablation at 100 mj, 1064 nm, and 300 pulse

Figure 6 displays images of the atomic force microscope in 3D and the cumulative statistical distribution of CdTe NPs produced in distilled water by PLAL method using Nd-YAG laser at (E=100mj, λ=1064nm) and different laser pulses (100, 200,

300) pulse. The AFM analyze showed that average grain size of particleswas

about (67.51, 68.39, 70.10) nm, this range refer to the good preparation and control of particle sizes by selecting appropriate variables in our work. The surface of the thin film have a vertically closely packed ball/haped, homogenous and a good roughness grains of CdTe nanostructure

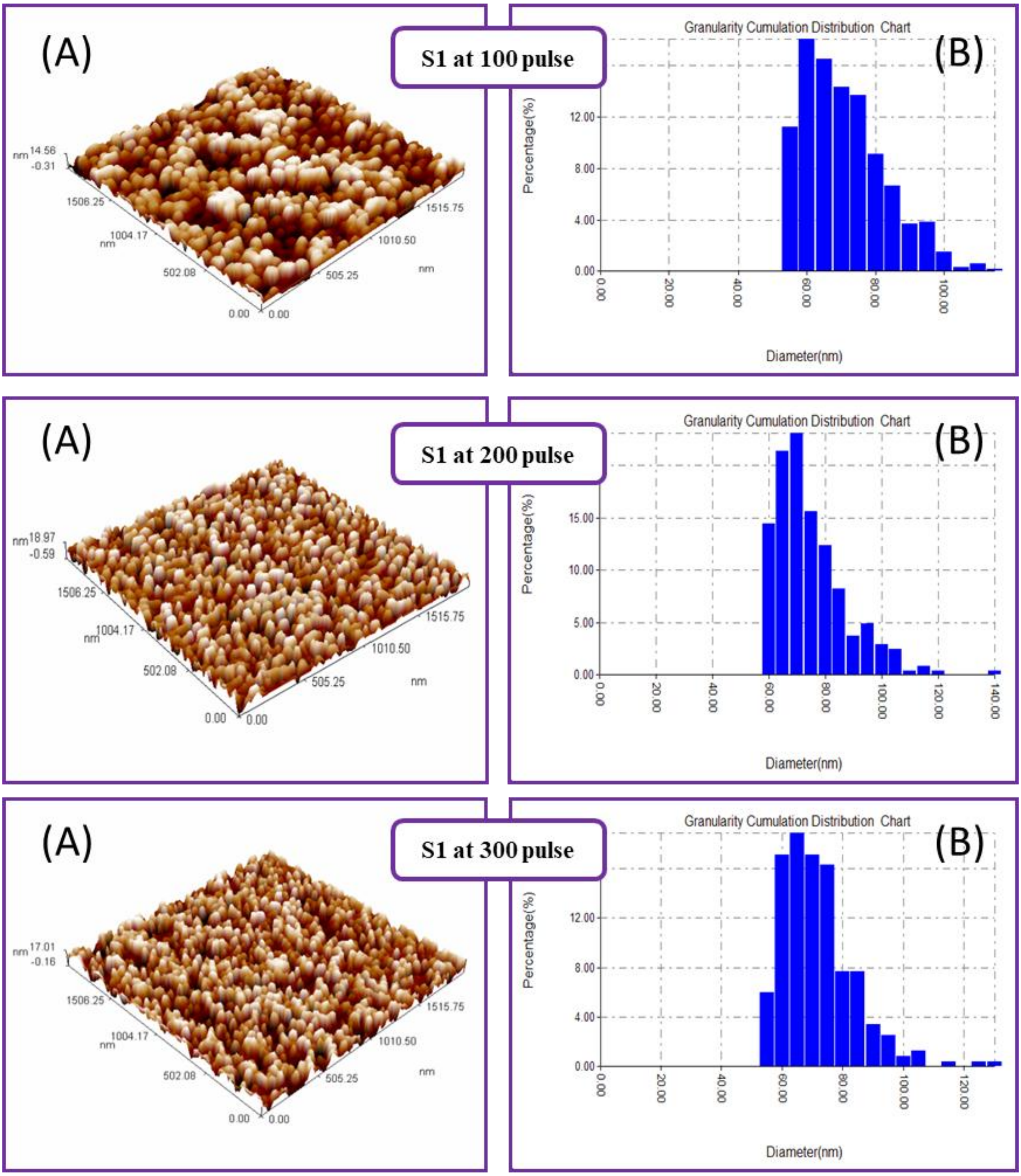

Figure 6: AFM images (A) 2D and (B) size distributions for the samples (S1, S2, S3) of CdTe NPsproduced in DIW at different laser pulses and assembled onto a clean glass substrate

Figure 7 shows the SEM micrographs of CdTe NPs that deposited on glass substrate. It can be clearly observed from the low resolution SEM images that the prepared sample shows shaped sphere and uniform size, with an average size around 42 nm. On the other hand, EDX measurements spectral taken onto the prepared samples confirmed that a samples was a high purity and containing on Cd and Te elements with high varying ratio as observed in Figure 8.

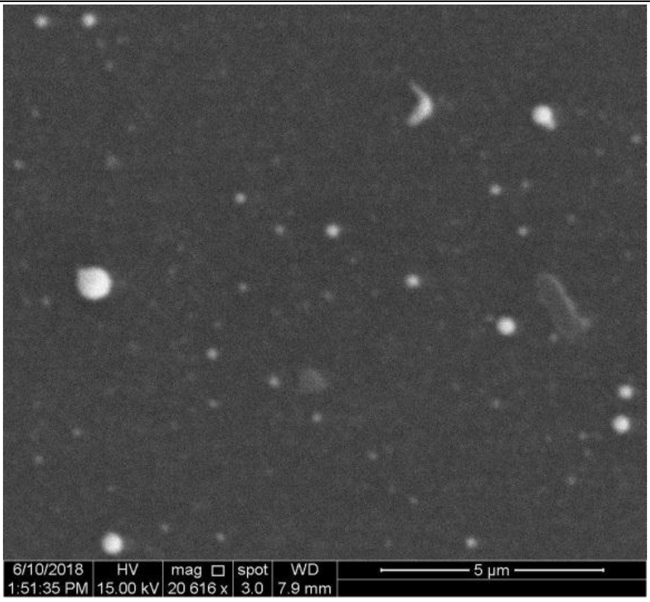

Figure 7: SEM images of CdTe NPs synthesized by laser ablation in DIW at 100mj, 1064nm, 300 pulse

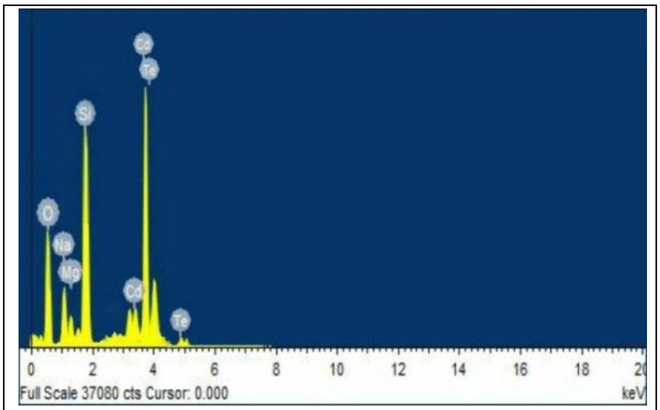

Figure 8: EDX spectra taken onto the CdTe nanoparticles synthesized by laser ablation in DIW at 100mj, 1064nm, and 300 pulse

4. CONCLUSION

We have successfully synthesized CdTe nanoparticles without using any capping agent, via simple and environmental friendly route by laser ablation method. Size and shape of particle was monitored with XRD and SEM showed about 35 nm and spherical shaped. XRD patterns also confirmed the formation of cubic cadmium telluride.Through the results of AFManalyze explained that the spherical particles with a regular shape and their diameter in nanoscales limit.The absorbance spectra of CdTe NPs was appeared in Uv-Visregion and found that absorbance peak increasing with increased NPs concentration. High absorption values along with increase in direct band gap of 2.45, 2.54 and 2.68 eV was observed for the nanoparticles prepared at 100 , 200 and 300 pulse, respectively. From EDX analyze showed that a samples generated was very high purity and rich of Cd and Te elements.At finally, we can see that effect of laser pulses plays an important role in the properties of the resulting nanoparticles by increasing their concentrations in addition to the slight effect on their sizes, which is increased by increasing the number of laser pulses due to increase in the number of particles produced in colloid solution, which leads to their convergence and coalescence.

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