Iraqi Journal of Physics, 2019 *Vol.17, No.42, PP. 103-107*
DOI: 10.20723/ijp.17.42.103-107

Study of parameters of cadmium sulfide plasma produced by LIBS technique by using optical emission spectroscopy

Wadaa S. Hussein[1] and Ala' Fadhil Ahmed[2]

[1]Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq

[2]Department of Astronomy and Space, College of Science, University of Baghdad, Baghdad, Iraq

E-mail: ala.fadil77@gmail.com

Abstract

The current study was carried out to reveal the plasma parameters electron temperature (T_e), electron density (n_e), plasma frequency (f_p), Debye length (λ_D) and Debye number (N_D) for CdS using the laser induced breakdown spectroscopy LIBS for the purpose of analyzing and determining spectral emission lines. The valuable of electron temperature for CdS in the range (0.746-0.856) eV and the electron density (3.909-4.691)×10^{18} cm^{-3}. Finally, plasma parameters of CdS were discussed through nano second laser that generated plasma using different laser energy (500-1000) mJ.

Key words
Laser Induced Plasma Spectroscopic (LIPS), Optical Emission Spectroscopic (OES), diagnostic spectroscopy, cadmium telluride (CdS).

Article info.
Received: May. 2019
Accepted: Jun. 2019
Published: Sep. 2019

دراسة معلمات بلازما كبريتيد الكادميوم المنتجة بواسطة تقانة LIBS باستخدام التحليل الطيفي للانبعاثات الضوئية

وداع سدخان حسين[1]و الاء فاضل احمد[2]

[1]قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق

[2]قسم الفلك والفضاء، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

أجريت الدراسة الحالية للكشف عن معلمات البلازما مثل درجه حرارة الإلكترون (T_e) كثافة الإلكترون (n_e) و تردد البلازما (f_p) و طول ديباي (λ_D) وكذألك عدد الجسيمات في كرة ديباي (N_D) لمادة CdS بواسطة تحليل وتحديد خطوط الانبعاثات الطيفية باستخدام تقنية التحليل الطيفي. حيث كانت نتائج درجه حرارة الالكترون eV (0.746-0.856) و كثافة الإلكترون cm^{-3} 10^{18}×(3.909-4.691). وأخيرا تم مناقشة معلمات البلازما لمادة CdS المتولدة باستخدام ليزر النانوثانية المولد للبلازما باستخدام طاقات ليزر مختلفة.

Introduction

LIBS is define as an atomic emission spectroscopy technique which used high energy laser pulse to excite specimen. Lead the interaction between concentrated laser pulses with the sample for configure plasma plume [1]. Where they are considered plasma that were produced by laser beam interaction with the material is considered promising subject for many research [2]. The ablation process are by the laser beam reaction with the target leading to quick ionization of the sample surface to produce the plasma in a short time frame compare with pulse period. The laser light is efficiently absorbed by the plasma which expand isothermally [3]. Plasma is formed. Plasma is detected on using the spectral analysis technique of optical emissions. Some information , like the initial formation of the material can get from the plasma spectrum generated. Emission lines characteristics can supply information about plasma temperature (T_e) and electron density (n_e) [4]. The method utilized in the lab experiment is the Boltzmann plot method, were this way is widely utilized method for spectral measurements. It depended on measure the relative density for one lines from the same elemental nevertheless, to applied the Boltzmann method to the gauge of electron temperature, the level of excitement must be done arrive under local thermal equilibrium (LTE) stipulation .The last allows us to use the traditional Boltzmann plot technicality to calculate (T_e) using the following equation [5].

$$ln\left(\frac{\lambda_{ji}I_{ji}}{hcA_{ji}g_{ji}}\right) = \frac{-1}{KT}\left(E_j\right) + ln\left(\frac{N}{U(T)}\right) \quad (1)$$

where I_{ji} is the intensity, λ_{ji} its wavelength, g_i is statistical weight, A_{ji} is the transition probability for spontaneous radiative emission from the level i to the lower level j, E_j is the excitation energy (in electron volts), k is Boltzmann constant, N state population densities [6]. But regarding the density of the electron can be determine by stark broadening of an emission line or using the linear density ratio of different emissions for the same elemental [7]. In this experiment was used the stark-broadening method to calculated the electron density (in cm^{-3}) using equation [8].

$$n_e = \left(\frac{\Delta\lambda}{2\omega_s}\right) N_r \quad (2)$$

ω_s is the theoretical line full width Stark broadening parameter, calculated at the same reference electron density $N_r \approx 10^{17} cm^{-3}$.

The responses of charged particle (ions and electrons) for decrease impact of electric fields applied to it is called Debye shielding, the shielding which granted quasi-neutrality special property for, plasma. A distance (λ_D) which called the Debye length we can calculated from equation [9].

$$\lambda_D = \left(\frac{\varepsilon_o kT}{n_e e^2}\right)^{1/2} \quad (3)$$

where ε_o is permittivity of free space, and e the electron charge, T_e , the electron temperature.

Also we can found number of particles (N_D) in a Debye sphere using the equation [10].

$$N_D = \frac{4}{3}\pi\lambda_D^3 n_e = 1.38 \times 10^6 T^{3/2}/n_e^{1/2}$$

(T in K) (4)

Experimental setup

The emitted spectrum of the specimen was analyzed CdS after they were bombed using Nd: YAG laser of 1064 nm wavelength and 200 pulse laser, 6 Hz pulse repetition frequency using with various valuable of energy from (500 to 1000) mJ, where the laser is placed on a distance 10 cm for the sample. The process of the row occurs after the plasma column is produced and then the resulting light was collected from the plasma via the optical fiber where they were set at angle of 45^0 as shown in Fig.1.

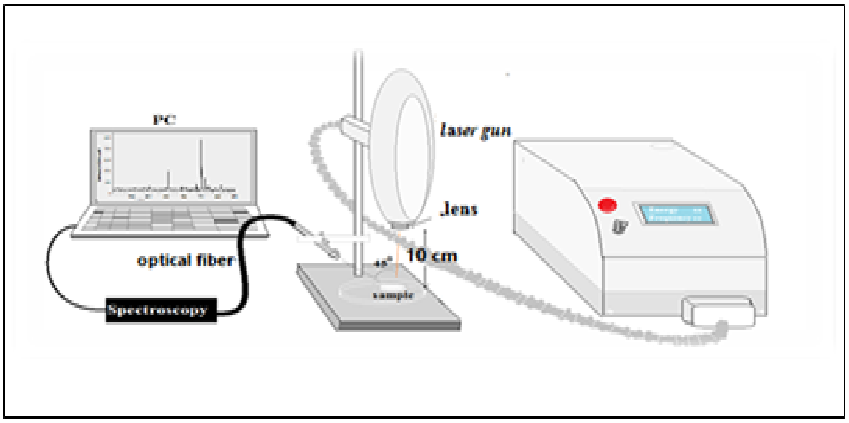

Fig .1: Schematic of the experimental setup for (LIBS).

The spectra emitted from cadmium sulfide plasma was by spectrum analyzer in within a spectral range of (300-800) nm. The data were discussed and compare with data from the (NIST) [11].

Results and discussion

Fig.2 shows the emission spectra for cadmium sulfide plasma produced in air at different laser energy E=(500 to 1000) mJ using the Optical Emission Spectroscopy (OES) technique. Emission spectra were recorded in the spectral range (300 to 800) nm.

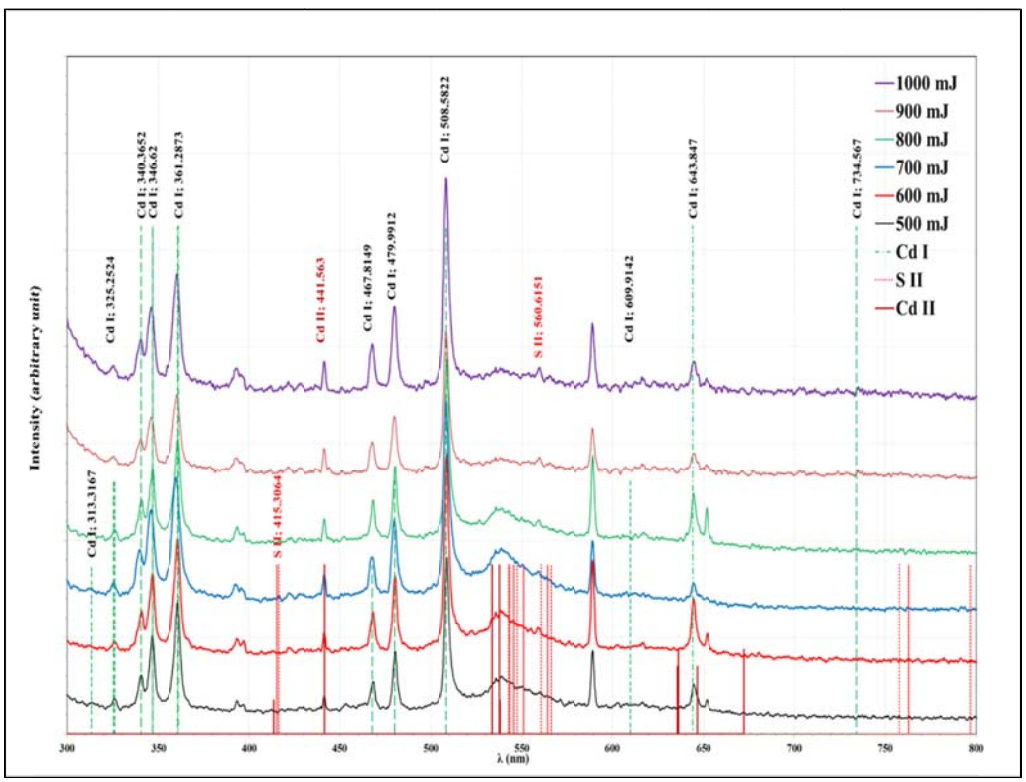

Fig.2: Optical emission spectra for cadmium sulfide plasma produced in the air with different laser energy.

The Boltzmann way require tops that originate from the same atomic species and the same ionization stage, (one peak was used at 441.5) nm for CdS powder (pellet) in the air as shown in Fig.3. (the slope of the fitted line equals to -1/ T). R^2 is a statistical coefficient indicate the goodness of the linear fit which takes a value between (0 and 1).

The fitting equations and the R^2 were shown in the figure for all fitting lines. The better one has R^2 value closer to 1.

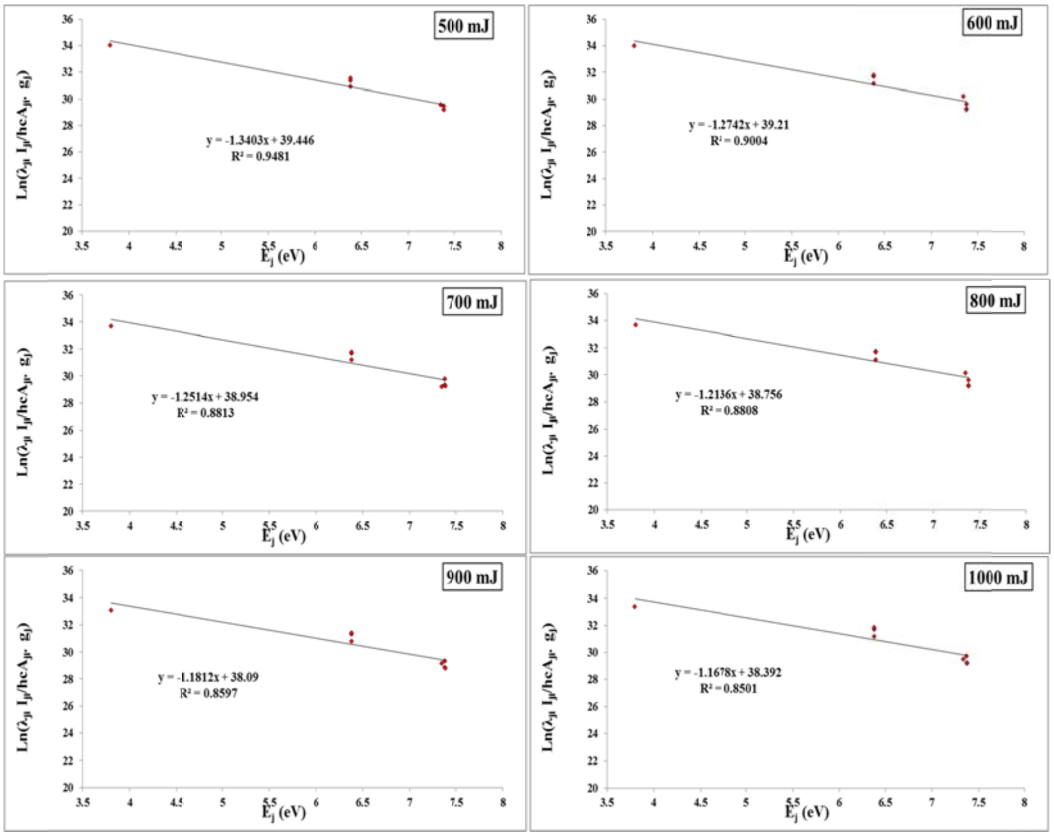

Fig.3: Boltzmann plots of CdS target with different laser energies in the air.

The calculated values of the electron temperatures (T_e) using Boltzmann plot equation show that the electron temperature (T_e), electron density (n_e) are increased with increase laser pulse energy, in the air as shown the Fig.4. At high laser peak energy (T_e) becomes almost stable.

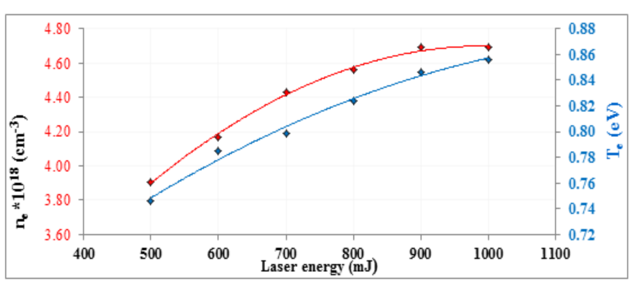

Fig.4: The variation of (T_e) and (n_e) versus the laser energies of CdS target.

Table1 shows the plasma parameter for CdS pellet at different laser energies (500-1000) mJ. We can notice the (f_p), (n_e) and (T_e) increase with laser energy, but λ_D decreases in the same operating conditions. Through the results we note that the values of N_D >>> 1 and is one of the conditions of the plasma.

Table 1: Plasma parameters for CdS with different laser energies in the air.

E(mJ)	Te (eV)	FWHM (nm)	n_e*10^{18} (cm^{-3})	f_p (Hz) *10^{12}	λ_D *10^{-7}(cm)	N_D
500	0.746	1.500	3.909	17.754	3.246	559.781767
600	0.785	1.600	4.169	18.337	3.223	584.6776021
700	0.799	1.700	4.430	18.901	3.156	582.8103906
800	0.824	1.750	4.560	19.177	3.158	601.4844634
900	0.847	1.800	4.691	19.449	3.156	617.6053261
1000	0.856	1.800	4.691	19.449	3.175	628.3250413

Conclusions

Laser was used Nd:YAG at wavelength (1064 nm) to produced cadmium sulfide plasma. The spectral lines intensities of the laser induced plasma emission exhibited a strong dependence on the ambient conditions. It was found that the intensities at different laser peak powers increase with increasing laser peak power and then decreases when the power continues to increase. Plasma parameters such as electron temperature, electron density, Debye length, number of particles in Debye sphere and plasma frequency are found to be strongly effective by the laser energy. The results showed that the (T_e, N_D and n_e) were increased with increase of laser energy .While λ_D values decreased in the same operating conditions.

References

[1] F. Anabitarte, A. Cobo, J. M. Lopez-Higuera, ISRN Spectroscopy, 2012 (2012) 1-12.

[2] A. A. I Khalil, Laser Physics, 23 (2012) 1-13.

[3] N. M. Shaikh, Y. Tao, R. A. Burdt, S. Yuspeh, N. Amin, M. S. Tillack , J. Phys. Conf. Ser., 244, 4 (2010) 2-5.

[4] David A. Cremers, Rosalie A. Multari, Andrew K. Knight, "Encyclopedia of Analytical Chemistry: Applications", Theory and Instrumentation, Wiley, 2006.

[5] Noriyasu Ohno, M. Abdur Razzak, Hiroshi Ukai, Shuichi Takamura, Yoshihiko Uesugi, Plasma and Fusion Research: Regular Articles, 1 (2006) 028-1_028-9.

[6] H. H. Ley, A. Yahaya, R. K. R. Ibrahim, J. Sci. Technol., 6, 1 (2014) 49-66.

[7] Tetsu Mieno, "Plasma Science and Technology-Progress in Physical States and Chemical Reactions", Shizuoka University, Intech Open, 2016.

[8] M.A. Ismail, H. Imam, A. Elhassan, W.T. Youniss, M.A. Harith, Journal of Analytical Atomic Spectrometry, 19 (2004) 489-495.

[9] K. Dobbyn, "Design and application of a plasma impedance monitor for RF plasma diagnostics", MSc. Thesis, Dublin City University, 2000.

[10] Francis F. Chen, "Introduction To Plasma Physics And Controlled Fusion" 2_{nd}, Volume 1. Los Angeles, California, 1983.

[11] “NIST National Institute of Standards and Technology USA, electronic database”.