Khashaan et al. *Iraqi Journal of Science, 2021, Vol. 62, No. 7, pp: 2197-2203*
DOI: 10.24996/ijs.2021.62.7.9

ISSN: 0067-2904

Impact of Laser Energy on Features of Carbon Nanostructure Materials Prepared by A One-Step Pulsed Laser Ablation in Water

Ali Addie[1], Khawla Salah Khashaan[2], Jehan Saimon[2], Azhar Hassan[2]
[1]Center of Advanced Materials, Ministry of Science & Technology, Baghdad, Iraq
[2]Laser Science and Technology Division, Department of Applied Sciences, University of Technology - Iraq.

Received: 11/8/2020 Accepted: 16/1/2021

Abstract

Carbon nanoparticles (CNPs) formed by one-step laser ablation in deionized water were carefully studied. Scanning electron microscopy, atomic force microscopy, Raman spectroscopy, and U_V–V spectroscopy were used to obtain morphological, chemical, and optical properties of CNPs. SEM outcomes established that the synthesized nanoparticles are semi-spherical with a wide particle size distribution. Raman investigation showed two typical and expected peaks ~ (1300 - 2700) cm^{-1}, which are confirming to transverse and longitudinal modes of the carbon structure. The absorption spectra proved that the intensity of spectra increases as particle size and concentration increase.

Keywords: carbon nanomaterial, pulsed laser ablation in liquid, nanoparticles.

تأثير طاقة الليزر على خصائص مواد التراكيب النانوية الكربونية المحضرة بواسطة خطوة واحدة لاستئصال الليزر النبضي في الماء

علي جميل[1]،خولة خشان[2]، جيهان سيمون[2]،ازهار حسن[2]
[1] مركز المواد المتقدمة، وزارة العلوم والتكنولوجيا، بغداد، العراق.
[2] فرع علوم وتكنولوجيا الليزر، قسم العلوم التطبيقية، الجامعة التكنولوجية – العراق.

الخلاصة:

تم تشكيل جسيمات الكربون النانوية عن طريق الاستئصال بالليزر في خطوة واحدة في الماء منزوع الأيونات بعناية. تم استخدام الفحص المجهري الإلكتروني والفحص المجهري للقوة الذرية ومطياف رامان والتحليل الطيفي للأشعة فوق البنفسجية U_V–V للحصول على الخصائص المورفولوجية والكيميائية والبصرية لجسيمات الكربون النانوية CNPs. ثبتت نتائج SEM أن الجسيمات النانوية المحضرة شبه كروية مع توزيع واسع لحجم الجسيمات .أظهر قياس رامان قمتين نموذجيتين ومتوقعتين ~ (1300–2700) سم$^{-1}$ ، والتي تؤكد على الوضع العرضي والطولي لتركيب الكربون.تثبت أطياف الامتصاص أن شدة الأطياف تزداد مع زيادة حجم الجسيمات وتركيزها.

1. Introduction

The surrounding conditions of the process of pulsed laser ablation in liquid (PLAL) is an interesting way in the field of the generation of nanoparticles for different materials, such as pure metals, oxides, carbide, iodide, nitride, semiconductors, and nanocomposite materials that can be used

*Email: Khawla_salah@yahoo.com

in different fields [1-8]. Also, it can be used to produce different shapes of nanostructure materials, including nanotube, nanodisc, nanoflowers, and spherical nanoparticles [9-12]. PLAL technique has many benefits upon the other techniques, as it is easy and economical, with no substance necessary, no vacuum demanded, good purity for the product, and reasonable control on size and morphology of the product material. Otherwise, the features of nanoparticles produced via PLAL are powerfully depending on laser characteristics, such as wavelength, pulse duration, energy, and repetition rate. In the PLAL process, the objective is submerged in the solution medium and a high-fluence streak is focused on the surface. The interaction of the beam with the base results in the ablation plume, therefore a target material with few volumes of the embracing solution is vaporized to brew bubbles in the liquid. Then, the bubbles extend and collapse at a fixed condition, which results in the production of nanostructured materials [13-20]. Nanoparticles have a vast interest owing to their unique description contrast to the bulk material; therefore they are used in a very wide range of applications. Among these nanomaterials, carbon-based nanomaterial, including carbon nanotubes and fullerenes, have a high interest because of their excellent properties, such as high ability to let electricity flow, good germ-killing activity, large surface/volume ratio, low poisonous quality, good electron field emission, and biocompatibility [21-30]. Therefore, we study here the effects of laser energy on the qualities of carbon nanoparticles produced via one-step laser ablation of a graphite target in water.

2. Materials and methods

CNPs were synthesized via laser ablation of pure graphite pellet (99.9%; Kurt J. Lesker Co., USA) in deionized water. The graphite pellet was immersed in a 3mL of deionized water (DIW) in the bottom of a vessel. The process was carried out using a 1064nm Nd: YAG laser with various laser energies (100, 200, 300, and 400mJ) at 10min ablation time. The characteristics of the CNPs were inspected using Senterra Raman from Bruker, Vegall scanning electron microscopy (SEM) from TESCAN, 1800 SHIMADZU double beam UV–visible spectrophotometer, and Ntegra Atomic force microscopy (AFM) from NT-MDT.

2. Results and Discussion

Figure-1 shows SEM images of the CNPs produced via the ablation of a graphite target in DIW, using several laser energy values (100,200,300, and 400mJ). The images show dense and fine structures with some collections of nanosized carbon, which are mostly semi-spherical in form. Also, the size and dense of NPs were increased as laser energy increased from 100 to 400 mJ, with the appearance of agglomerated large particles scattered on the surface. Raman spectroscopy is a very interesting non-destructive technique utilized to show the percentages of different chemicals within a substance of carbon-based nanomaterials. Figure-2 explains the Raman spectra of Carbon nanoparticles prepared at altered energy levels (100,200,300, & 400mJ). The spectra were obvious for the D-band at ~1300cm^{-1} and G-band at ~2700cm^{-1}. In general, the D-band involves scattering from a defect, while the G-band is characteristic of sp^2 carbon materials. The frequency changed toward a higher wavenumber as laser energy increased. Also, the strength was increased due to the high concentration of CNPs [31, 32].

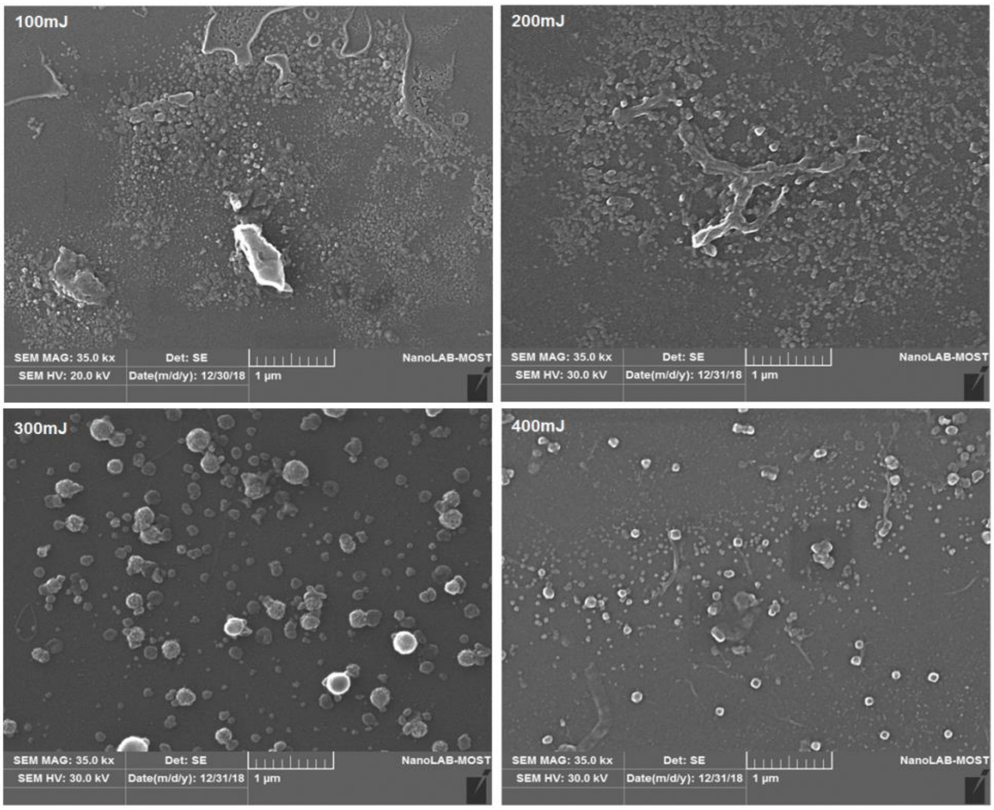

Figure 1-SEM images for CNPs prepared at different laser energy levels.

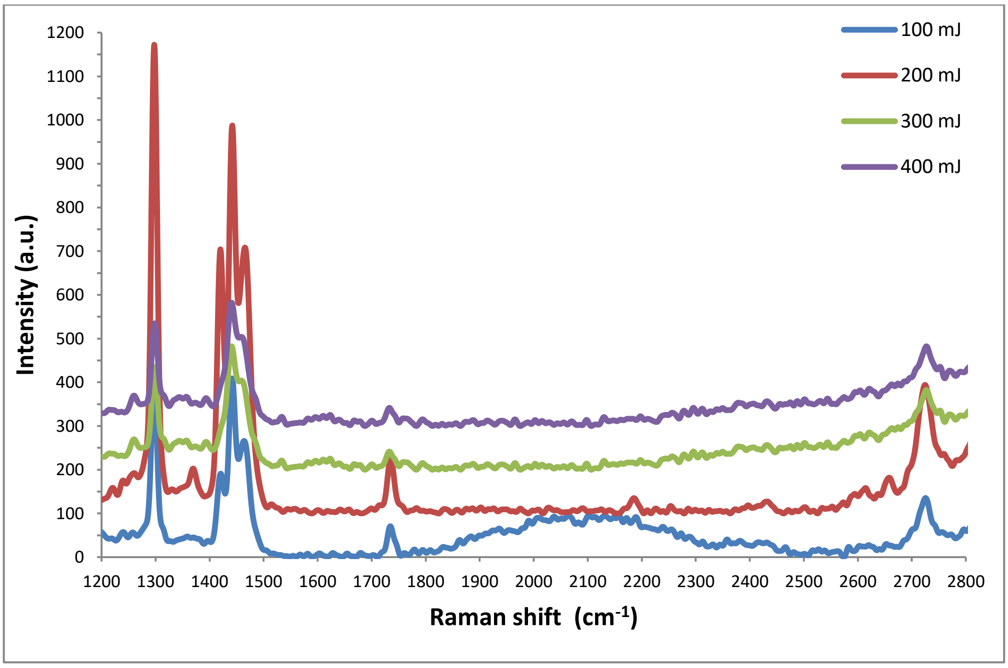

Figure 2- Raman spectra of CNPs as a function of laser energy.

Figure-3 shows the absorption spectra of CNPs produced via laser ablation at different energies (100, 200,300 & 400mJ). The chart of CNPs indicated an absorption peak at ~275nm, resulting from C=O band of $\pi - \pi^*$ transition, with a high peak intensity for the carbon nanostructure sample, produced at 400mJ/pulse, which means that the concentration produced was higher than that using the other energy values [23].

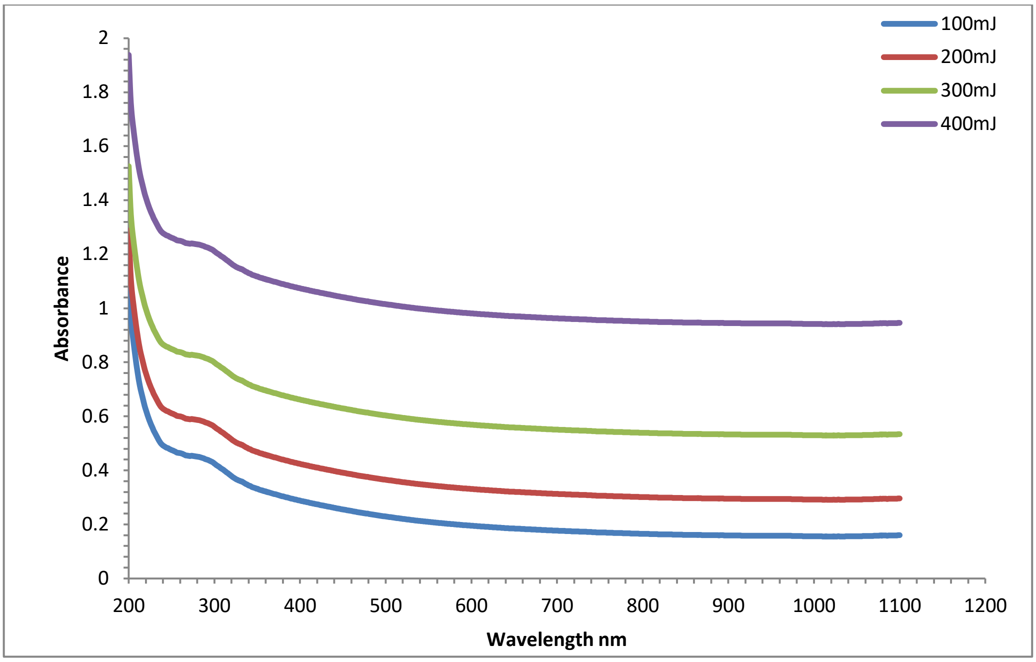

Figure 3-Absorbance spectra of CNPs at different laser energy

Figure-4 clarifies the AFM images for CNPs created at different laser energy values. It is obvious that the morphology and particle size are laser energy-dependent. Also, the distribution of particle size was evaluated from AFM realization, as given in Figure- 4, demonstrating a wide size distribution with an almost Gaussian model, where the size increased as the energy increased (Table-1).

Table 1-Average size range (nm) versus laser energy (mJ)

Laser energy(mJ)	Average size range (nm)
100	2-166
200	2-108
300	10-110
400	2-166

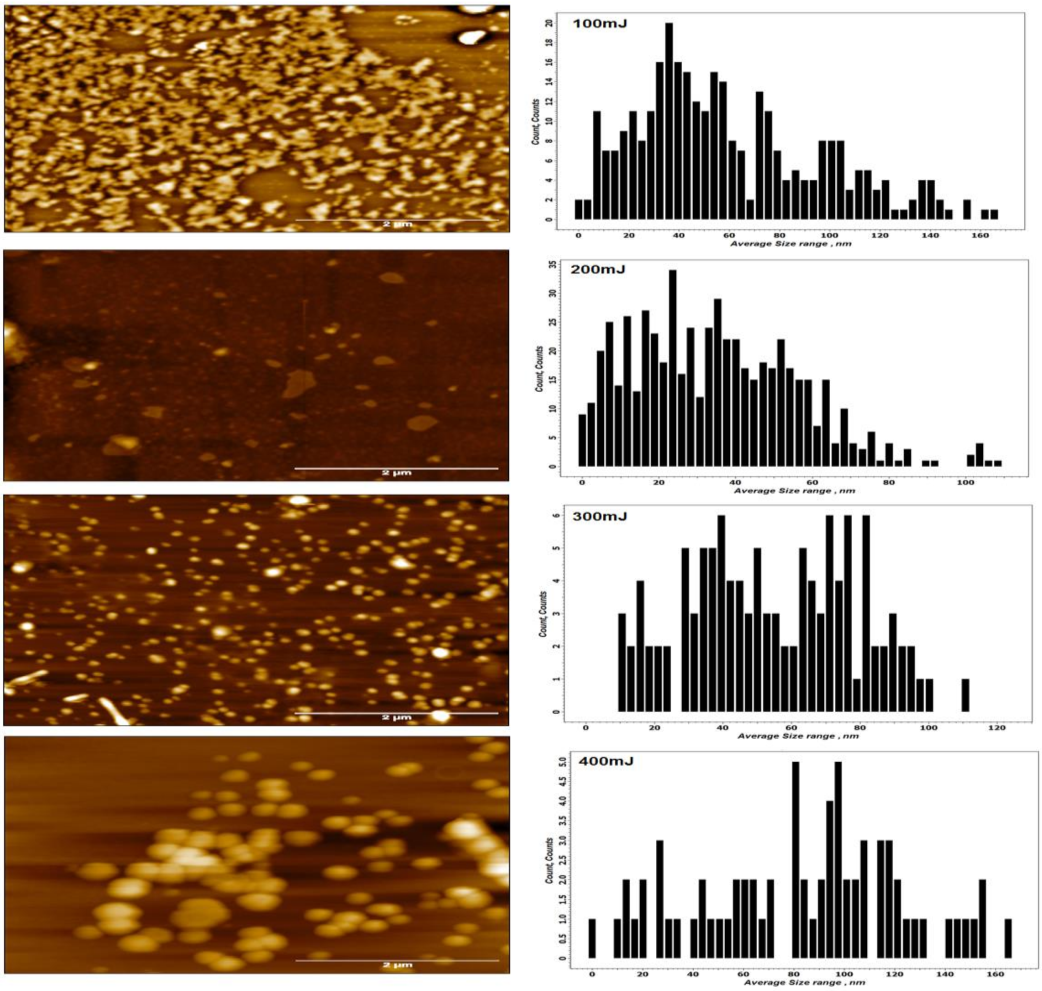

Figure 4-AFM images with size distribution of CNPs produced at various laser energy values.

3. Conclusions

One-step manufacturing of CNPs was verified utilizing laser ablation of graphite in water. AFM and SEM outcomes showed that the size distribution and morphology of the prepared CNPs can be organized via selecting suitable laser energy values. Raman analysis established the presence of two typical peaks that are associated with transverse and longitudinal modes of CNPs structures. The absorption data revealed that the intensity of spectra increased as laser energy increased, due to the increases in nanoparticles concentration linearly with energy.

References

1. Hamad, A.H., Khashan, K. S. and Hadi, A. A. **2016**. Laser ablation in different environments and generation of nanoparticles. *Applications of Laser Ablation: Thin Film Deposition, Nanomaterial Synthesis and Surface Modification*. Dongfang Yang, IntechOpen, **21**:177.
2. Varadan, V. K. , Pillai, A. S. , Mukherji, D., Dwivedi M. and Chen, L. **2010**. *Nanoscience and Nanotechnology in Engineering*, World Scientific Publishing, 71-74
3. Sadrolhosseini, A. R., Mahdi, M. A., Alizadeh F. and Rashid, S. A. **2018**. Laser Ablation Technique for Synthesis of Metal Nanoparticle in Liquid. *Laser Technology and its Applications*. Yufei Ma, DOI: 10.5772/intechopen.80374.
4. Ismail, R.A., Mousa, A.M., Khashan, K.S., Mohsin, M.H. and Hamid, M.K. **2016**. Synthesis of PbI_2 nanoparticles by laser ablation in methanol, *Journal of Materials Science: Materials in Electronics* **27** :10696-10700
5. Khashan, K.S. and Mohsin, M.H. **2015**. Characterization of carbon nitride nanoparticles prepared by laser ablation in liquid for optoelectronic application, *Surface Review and Letters* **22** :1550055

6. Khashan, K.S., and khlewee, M.M. **2018**. Structural and optical properties of colloidal InZnO NPs prepared by laser ablation in liquid, *Journal of Physics: Conference Series* **1003**: 012090

7. Khashan, K.S., Sulaiman, G.M., Hussain, S.A., Marzoog, T.R., and Jabir, M.S. **2020**. Synthesis, Characterization and Evaluation of Anti-bacterial, Anti-parasitic and Anti-cancer Activities of Aluminum-Doped Zinc Oxide Nanoparticles, *Journal of Inorganic and Organometallic Polymers and Materials* 1-17

8. Khashan, K.S. and Mahdi, F. **2017**. Synthesis of ZnO: Mg nanocomposite by pulsed laser ablation in liquid, *Surface Review and Letters,* **24**: 1750101

9. Sima, C., Viespe, C., Grigoriu, C., Prodan G. and Ciupina, V. 2008. Production of Oxide Nanoparticles by Pulsed Laser Ablation, *Journal of Optoelectronics and Advanced Materials,* **10** : 2631 – 2636

10. Thongpool, V., Denchitcharoen, S., Piyapong, A., and Pichet, L. **2011**. Preparation of Carbon Nanoparticles by Long Pulsed Laser Ablation in Water with Different Laser Energies, *Advanced Materials Research,* **214**: 402-405

11. khashan, K. S. and Mohsin, M. H. **2014**. Preparation of Carbon Nanotube by Pulse Laser Ablation of Graphite Target in Deionized Water, *Eng. &Tech. Journal,* **32**: 61

12. Khashan, K.S. , Ismail, R.A., and Mahdi, R.O. 2018. Synthesis of SiC nanoparticles by SHG 532 nm Nd: YAG laser ablation of silicon in ethanol, *Applied physics* A, **124**: 443

13. Yang, G. 2007 Laser Ablation in Liquids: Applications in the synthesis of Nanocrystals, *Progress in Materials Science*, **52**: 648-698

14. Sasak, K., and Takada, N. **2010**. Liquid-phase laser ablation, *Pure and Applied Chemistry,* **82** : 1317–1327

15. Hadi, A.A., Badr, B.A., Mahdi, R.O., and Khashan, K.S. **2020**. Rapid laser fabrication of Nickel oxide nanoparticles for UV detector, *Optik* 165019

16. Phipps, C.**2006**. *Laser Ablation and its Applications*, Springer 1-597

17. Khashan, K.S., Sulaiman, G.M., and Mahdi, R. **2018**. The effect of laser energy on the properties of carbon nanotube—iron oxide nanoparticles composite prepared via pulsed laser ablation in liquid, *Materials Research Express,* **5**: 105004

18. Khashan, K.S. and Abbas, S.F. 2019. Indium Nitride Nanoparticles Prepared by Laser Ablation in Liquid, *International Journal of Nanoscience,* **18**: 1850021

19. Bulgakova, N.M. and Bulgakov, A.V. **2001**. Pulsed Laser Ablation of Solids: Transition from Normal Vaporization to Phase Explosion, *Applied Physics* A, **73**: 199–208

20. Abbas Z. M. and Adnan Q. **2020**. Influence of Magnetic Field on Silver Nanoparticles Synthesized by Laser Ablation. *Iraqi Journal of Science,* **61**(2): 341-350.

21. Escobar-Alarcon, L., Espinosa-Pesqueira, M. E., Solis-Casados, D. A., Gonzalo, J., Solis, J., Martinez-Orts, M. and Haro-Poniatowski, E. **2018**. Two-dimensional Carbon Nanostructures Obtained by Laser Ablation in Liquid: Effect of an Ultrasonic Field, *Applied Physics* A, **124**:1-7

22. Khashan, K.S. and Mohsin, M.H. **2013**. Synthesis of polyynes by laser ablation of graphite in ethanol, *Iraqi Journal of Physics,* **11**:37

23. Tarasenka, N., Stupak, A., Tarasenko, N., Chakrabarti, S. and Mariotti, D. **2017**. Structure and Optical Properties of Carbon Nanoparticles Generated by Laser Treatment of Graphite in Liquid, *Chem. Phys. Chem,* **18**:1074-1083

24. Khashan, K.S. , Jabir, M.S. and Abdulameer, F.A. **2019**. Carbon Nanoparticles Prepared by Laser Ablation in Liquid Environment, *Surface Review and Letters*, **26:** 1950078

25. Vaghri, E. and Dorranian, D. **2018**. Effects of Green Laser Fluence on the Characteristics of Graphene Nanosheets Synthesized by Laser Ablation Method in Liquid Nitrogen Medium, *Optical and Quantum Electronics,* **50**: 110

26. Reyes-Contreras, D., Camacho-López, M., Camacho-López, M.A., Camacho-López, S., Rodríguez-Beltrán, R. I. and Mayorga-Rojas, M. **2015**. Influence of the Per Pulse Laser Fluence on the Optical Properties of Carbon Nanoparticles Synthesized by Laser Ablation of solids in Liquids, *Optics & Laser Technology,* **74**: 48–52

27. Hameed, R., Khashan, K.S. and Sulaiman, G.M. **2020**. Preparation and characterization of graphene sheet prepared by laser ablation in liquid, *Materials Today: Proceedings,* **20**: 535-539

28. Saira, F., Razzaq, H., Mumtaz, M., Ahmad, S., Rafiq, M. A., Yaqub, A., Dilshad, N., Ihsan, A. and ulHasan, M. M. **2020**. Investigation of Glucose oxidation at Gold Nanoparticles deposited at

Carbon Nanotubes modified Glassy Carbon Electrode by Theoretical and Experimental Methods, *Karbala International Journal of Modern Science,* **6**: Article 10.

29. khashan, K.S. and Mohsin, M.H. **2013**. Carbon Nanotube Prepared by Pulse Laser Ablation of Graphite Target in Iso-Propanol solution, *Eng. & Tech. Journal,* **31:** 3078-3089

30. Jeryo A. K., and Abbas Q. A. **2020**. Synthesis of Graphene Oxide Nanoparticles by Laser Ablation System. *Iraqi Journal of Science,* **61**(9): 2241-2250.

31. Ismail, R. A., Mousa, A. M. and Hassan, M. A. **2014**. Synthesis and characterization of diamond-like carbon film on silicon by electrodeposition from solution of ethanol and methanol, *Materials Science in Semiconductor Processing*, **27**: 461–467

32. Ismail, R. A., Mousa, A. M. and Hussain, Z. T. **2017**. Effect of nitrogen pressure on the performance of a-C:N/p-Si photodetector prepared by pulsed laser deposition, *Optik*, **139**: 328–337