MINAR International Journal of Applied Sciences and Technology
ISSN: 2717-8234
Article type: Research Article

Received: 02/07/2022 **Accepted:**19/07/2022 **Published:** 01/09/2022

INFLUENCE OF LASER ENERGY ON PHYSICAL PROPERTIES FOR CuO NANOPARTICLES PRODUCED BY LASER-INDUCED PLASMA AND THEIR ANTIBACTERIAL ACTIVITY

Marwa J. KETAN [1]
University of Baghdad, Iraq
Kadhim A. AADIM [2]
University of Baghdad, Iraq

Abstract

In this work, a pulsed laser ablation technique (PLA) was used to synthesize copper oxide nanoparticles by using A Q-switched Nd: YAG laser at a wavelength of 1064 nm and a frequency of 6 Hz. the number of pulses was 200 pulses at different laser energies (400, 500, 600, and 700) mJ to study the effect of these particles on the staphylococcus epidermidis bacteria isolated from acne, In addition, The properties of the prepared nanoparticles of CuO NPs were investigated by UV-Vis, XRD FE-SEM , EDX, and AFM analysis. The results showed that copper oxide nanoparticles had an apparent effect on bacteria, especially at energies (500, 600, and 700mJ) where the killing rate was perfect killing.

Keywords: Nd: YAG Laser, Antibacterial Activity, CuONPs XRD, CuONPs AFM, and FE-SEM

http://dx.doi.org/10.47832/2717-8234.12.4

[1] mrwhj983@gmail.com, https://orcid.org/0000-0002-3363-9631

[2] kadhim_adem@scbaghdad.edu.iq, https://orcid.org/0000-0003-4533-5309

Introduction

In the recent period, it has witnessed the spread of infectious diseases and bacteria that negatively affect public health. It's usually in the past that antibiotics (traditional Treatment) were used. Therefore, a great effort was made to find alternative solutions to the prevailing medicines for treatments [1,2]. One of the most famous types of bacteria is Staphylococcus epidermidis, which is considered a gram-positive bacteria and has an active role in various diseases of animals and humans, including wound infections and the main source of human suppurative infections and the skin, which is the first line of defense in the human body and the largest organ in it and the main contributor to protection in protecting The body of Canesten from external infection, pneumonia, enteritis, and osteitis [3,4,5]. Where nanoparticles of copper were prepared by the method of pulsed laser ablation in the liquid substance, this method has been recently considered one of the important methods due to its ease and the size, composition, and shape of the prepared nanomaterials. It can be changed and controlled by changing the laser parameters. Pulse width, laser power, repetition rate, wavelength, media. Liquid[6]. In general, nanoparticles have many advantages as they have unique optical, electronic, biological, chemical, and magnetic properties compared to bulk materials [7]. A clear difference was found in the physical properties of pure juices from their nanoparticles, as nanoparticles have many uses, including that they can be prepared with cosmetics and inhibit or kill bacteria[8]. In addition to that, the low production cost and their significant development to enter research fields such as the development of biosensors and experimental medicine [9]. Copper represents a three-dimensional transitional metal [10], and copper nanoparticles tend to oxidize rapidly in the presence of air, which leads to physical and chemical instability [11]. Copper oxide particles are the submissive member of the copper salt family, as they have a single crystal structure and semiconductor with optical, magnetic, and electrical properties Distinctive[12]. Specifically, CuO has been used for its ability to kill and restrict bacterial growth and its uses in biomedical applications [13]. In addition, it has many applications, including nanofluids and near-infrared filters. Preparation of inorganic and organic nanocomposites [14]. Cancer treatment[10].

2. Experimental Setup

Two methods were used in this research, where the first method is the preparation of CuO NPs nanoparticles by pulsed laser ablation, where the metal is placed in a beaker containing water 3 ml of deionized water as show in figure 1, and the second method is the preparation of CuO NPs nanoparticles By pulsed laser ablation but here the liquid is in the beaker is the bacteria used which is Gram-positive Staphylococcus epidermidis isolated from acne, which was activated 24 hours before (overnight). These bacteria are treated by pulsed laser ablation method by placing 4 ml of the liquid containing the bacteria in a beaker containing a copper sample, a pressed powder in the shape of a circular diameter with a thickness of 1cm. A Q-switched Nd:YAG laser with a wavelength of 1064 nm was applied to the sample immersed in liquid with a frequency of 6 Hz and different energies (400,500,600 and 700) mJ. The number of pulses is constant, 200 pulses, the spread between the sample and the source was 10 cm. at room temperature. Diffusion method was used to find out the effect of CuO NPs on bacteria. The cured liquid containing the bacteria is spread onto pre-prepared media in dishes and then placed. The plates are kept in a bacteria incubator for 24 hours at a temperature of 37°C, after which they are examined and the results revealed.

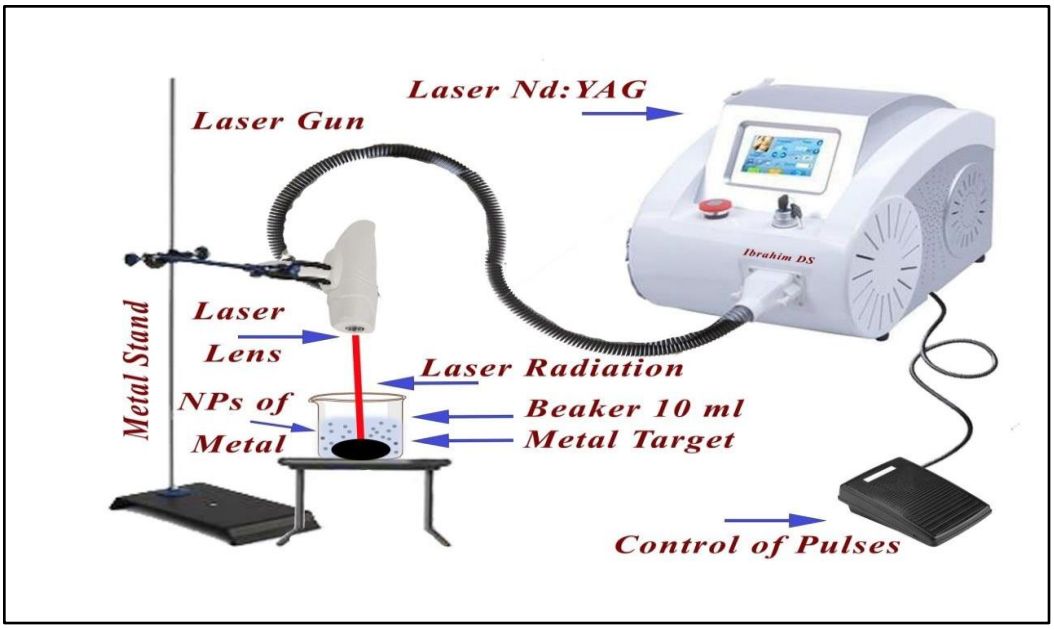


Figure -1 Experimental setup Laser ablation in liquid using Nd: YAG with λ=1064 nm.

3. Results and Discussions

3.1. Ultraviolet-Visible Spectroscopy analysis (UV-Visible)

Ultraviolet-visible spectroscopy has been used to detect the optical properties of nanoparticles and to calculate the energy gap CuO NPs, where a figure 2 shows the optical absorption spectra of copper oxide nanoparticles at different energies (400, 500, 600, and 700 mJ) and as it is clear that the absorption peak is at wavelength 308nm. We will note that with an increase in energy, the value of the absorbance increases due to the increase of ablation (skimming the material), which leads to an increase in the surface roughness of the material, thus increasing the absorbance[15].It is also essential to calculate the energy gap, through tauc relation .by using the following formula:

$$(\alpha h\nu)^2 = A\,(h\nu - Eg) \ldots\ldots\ldots (1)$$

and plotting the relationship of hυ versus $(\alpha h\upsilon)^2$ And obtaining an On an extrapolation line of the linear relationship, where, h is the Planck constant α is the absorbance coefficient, Eg is the optical band gap energy A is a characteristic constant, and ν is the frequency [6], as we will notice in figure 3 where the energy gap was determined, and it was 3 eV at energy 400 mJ, 2.9 eV at energy 500 mJ, 2.85 eV at energy 600 mJ, and 2.8 eV at energy 700mJ, and this agrees With[16].

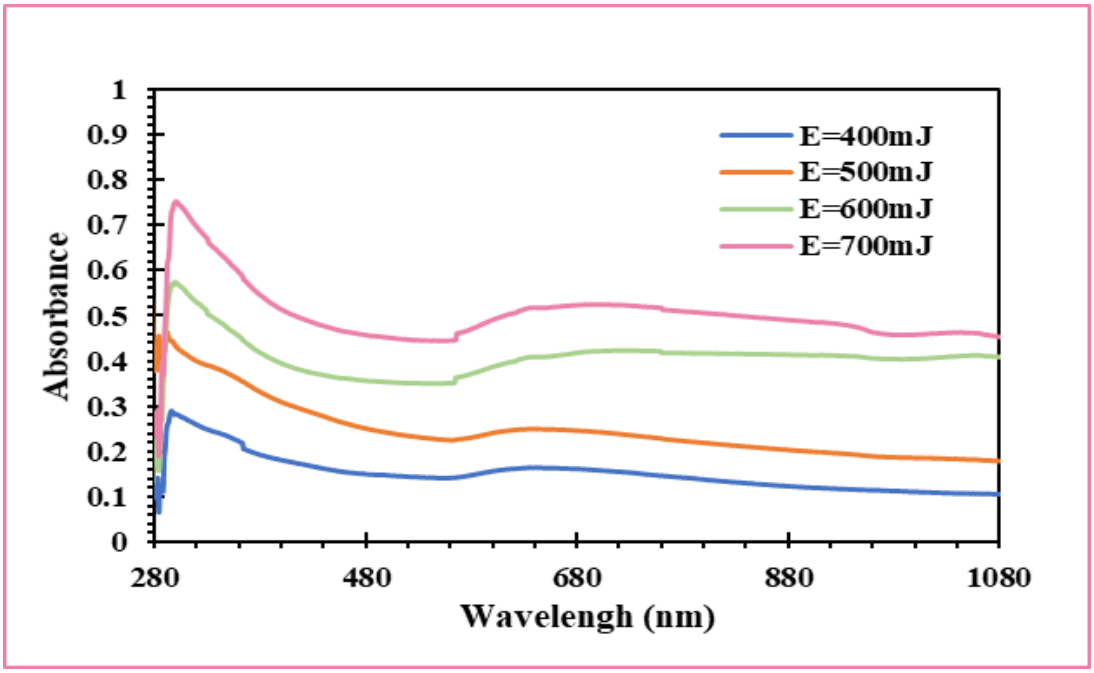


Figure -2 The absorbance spectrum as a function of the wavelength of the CuO NPs with different laser energy

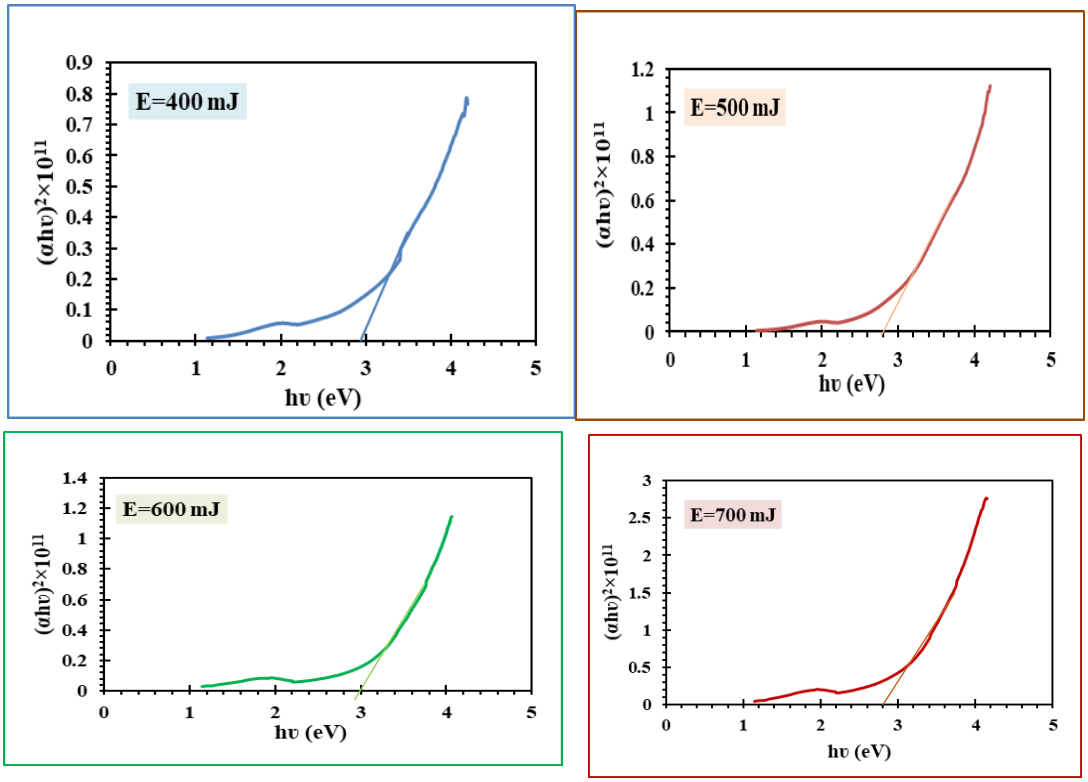


Figure -3 The relationship of (αhν)² as a function of the photon energy of the CuO NPs prepared by different laser energy.

3.2 X-ray Diffraction analysis (XRD)

The structural shape of the pure copper powder and copper oxide nanoparticles was studied by using the X-ray diffraction technique to characterize their crystal structure and calculate their crystalline size through the Scherrer's equation,

$$D = 0.9\lambda/(B\cos\theta_B).....(2)$$

where λ is the wavelength, B the full width at half maximum (FWHM) of the peak, and θ_B the Bragg angle[14]. Figure 4a shows the X-ray diffraction pattern of pure copper, where three clear peaks appeared at diffraction angles of 2θ = 43.28°, 50.40°, and 74.81°, corresponding to (111), (200), and (220). these results are in complete agreement with the standard model (JCPDS No. 040836) for pure face-centered cubic phase copper nanoparticles, which is agreed with[17,18]. Figure 4b represents the X-ray diffraction of copper oxide nanoparticles where we notice the emergence of a number of peaks that fall at 2θ ranging from 20° to 80°, whose locations correspond to the International Centre for Diffraction Data card No ‥-041-0254 in the XRD pattern of copper oxide with a=4.6850, b=3.4230, and c=5.1320 cell parameters.

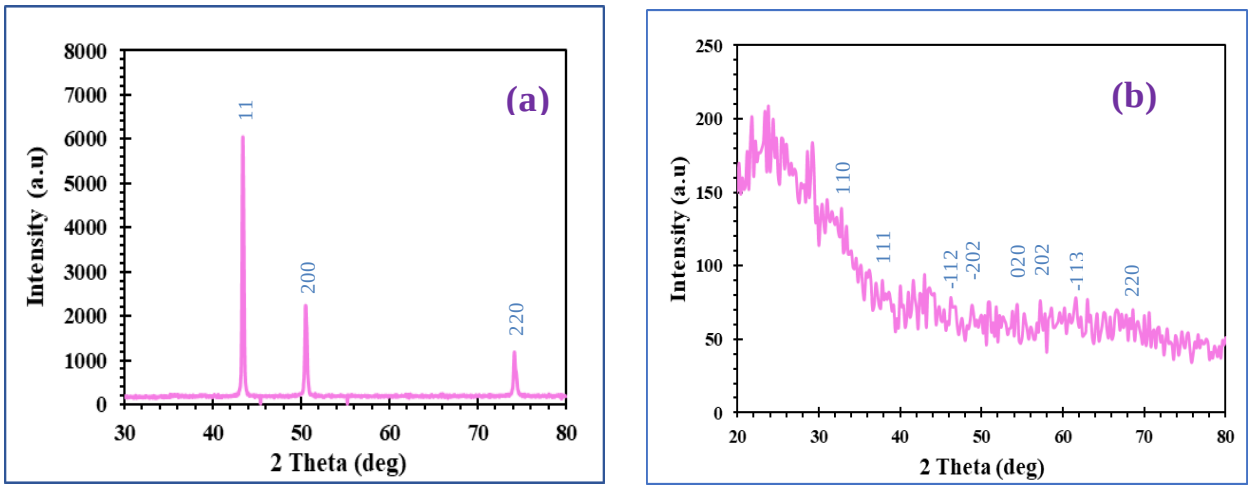


Figure -4 XRD patterns of (a) pure copper powder (b) XRD pattern of CuO

3.3 Scanning Electron Microscope Analysis(SEM)

SEM images of copper oxide nanoparticles prepared by pulsed laser ablation method at energy 700 mJ were made to analyze or reveal the surface morphology of the particles. The photos shown in figure 5 indicate the accumulation of nanoparticles due to the electrostatic attraction between the composite nanoparticles. And by the EDX test, the presence of elements in the samples is detected, as figure 6 shows the presence of oxidized copper in the sample, this agrees With [19].

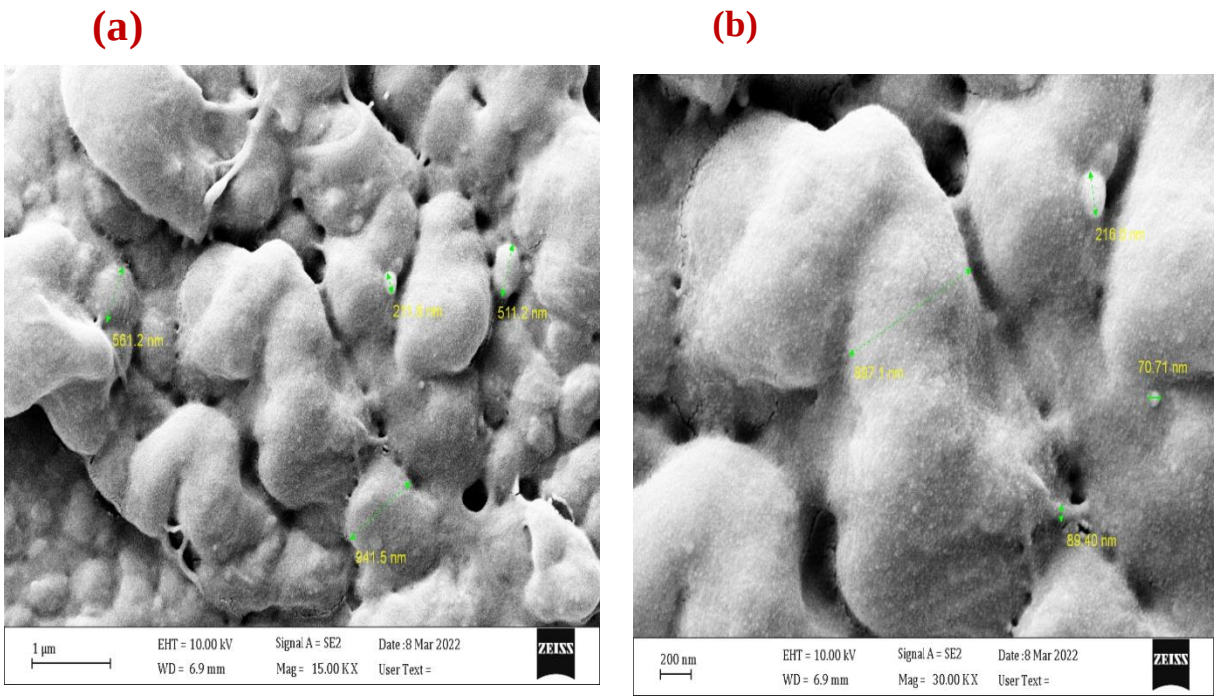


Figure -5 FE-SEM images of CuO NPs measurement at range (a) 1 µm (b) 200 nm with laser energy 700mJ.

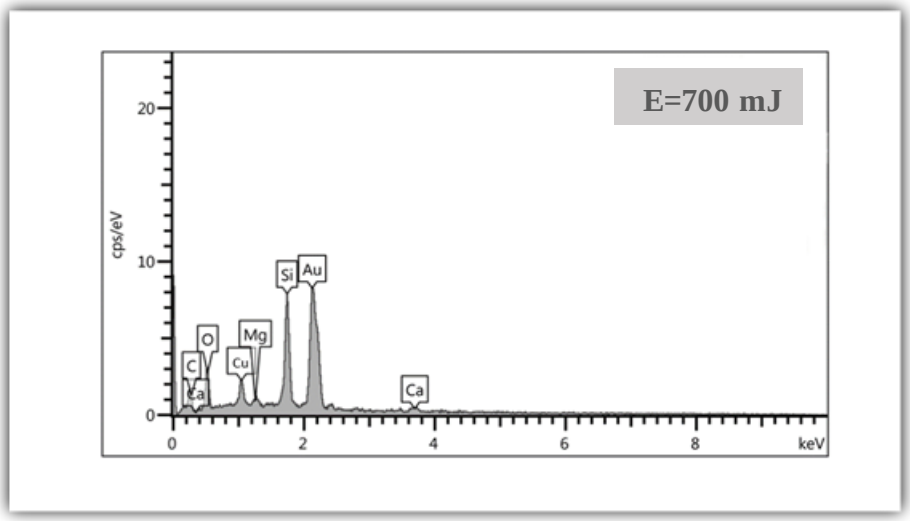


Figure -6 The EDX pattern of CuO NPs at 700 mJ laser energy

3.4 Atomic Force Microscope analysis (AFM)

Atomic Force Microscope (AFM) was used to study or identify the surface topography of the materials, as a figure 7 displays three-dimensional images of the dimensions of the homogeneous film of copper oxide nanoparticles, whose surface is similar to terrain or mountains, and the granularity accumulation distribution of grains, where the results showed that the membrane is homogeneous and that the values of the average diameter (22.80 nm), average roughness (1.680 nm), and root mean square (0.691nm) as it is clear from the results that the particle size of all atoms is in the nanoscale range, this agrees With [20].

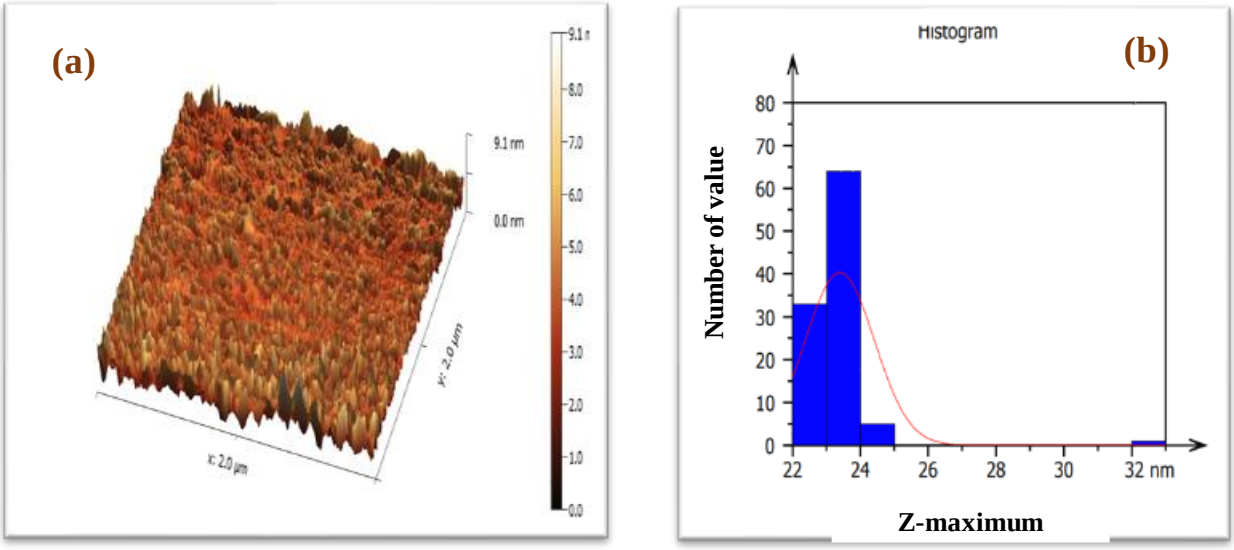


Figure -7 (a) 3D AFM for CuO NPs prepared by PLA with 700 mJ laser energy And (b)granularity accumulation distribution

3.5 Antibacterial Activity of CuO NPs

Copper oxide nanoparticles prepared by pulsed laser ablation method were used to see their effect on the Activity of Gram-positive Staphylococcus epidermidis bacteria taken from the acne by using the agar plate diffusion method. The number of bacteria colonies before Treatment, which amounted to (280×١٠^ colony/ml) was examined to compare with the results after Treatment. As shown in figure 8, at an energy of (400, 500 and 600mJ)and a concentration of (12.4, 18, 20.9ppm) nanoparticles, the killing rate was (3×10^9, 2.5×10^8, 1.1×10^8colony/ml), and the killing rate of 700mJ was perfect killing ,with concentration (34ppm) that mean total kill. The number of laser pulses was constant in all energies, which is 200 pulses. The killing process is due for several reasons. Including the deterioration of DNA and disruption of biochemical processes after entering nanoparticles whose particles are smaller than the cell wall or cell membrane morphology and its penetration into the cell system, taking into account the characteristics of bacteria[14,1]. Figure 9 that represents live images of bacteria colonies before and after Treatment.

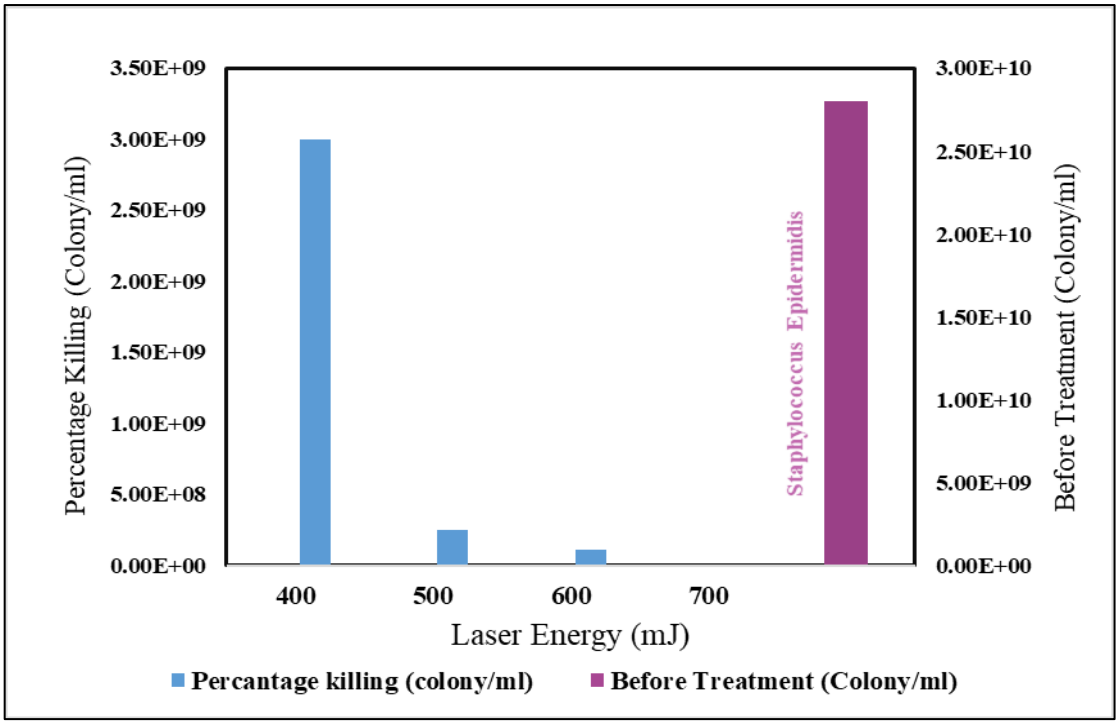
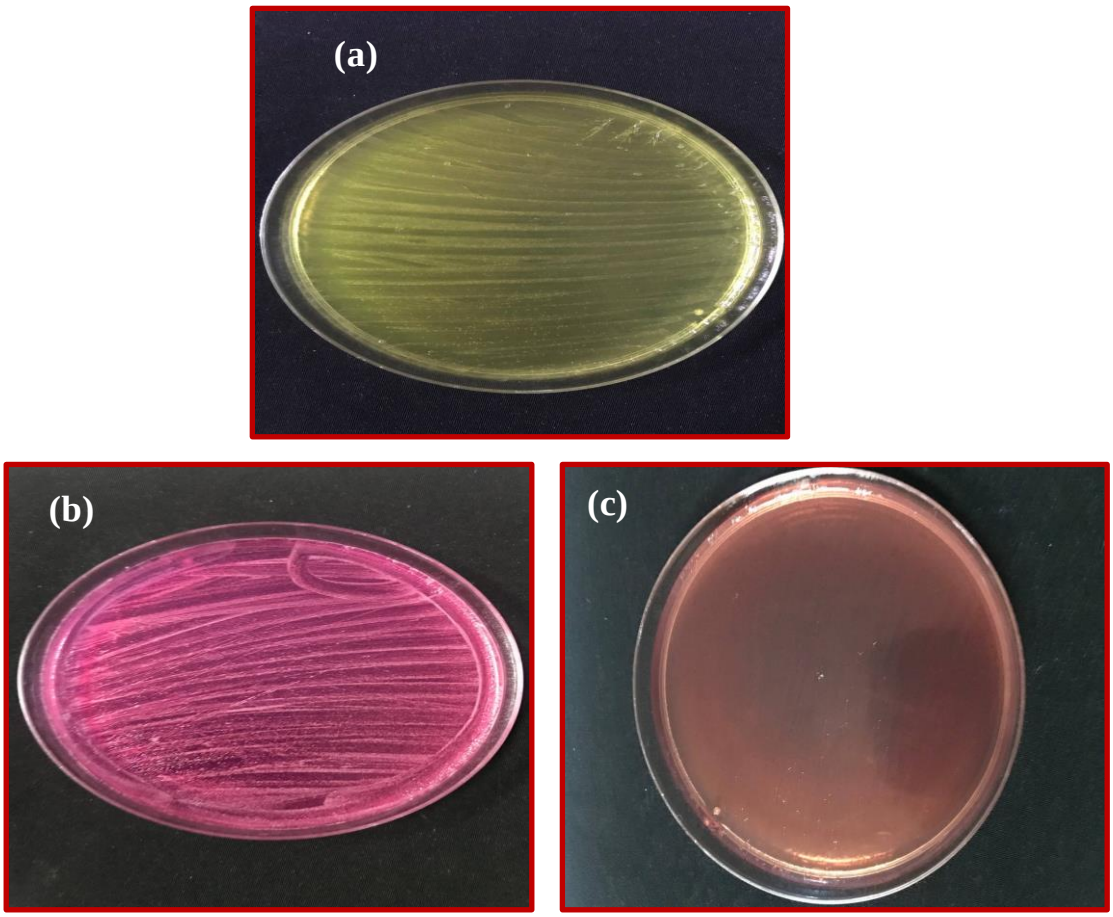


Figure -8 Histogram of antibacterial Activity at (400-700 mJ) show the Percentage Killing



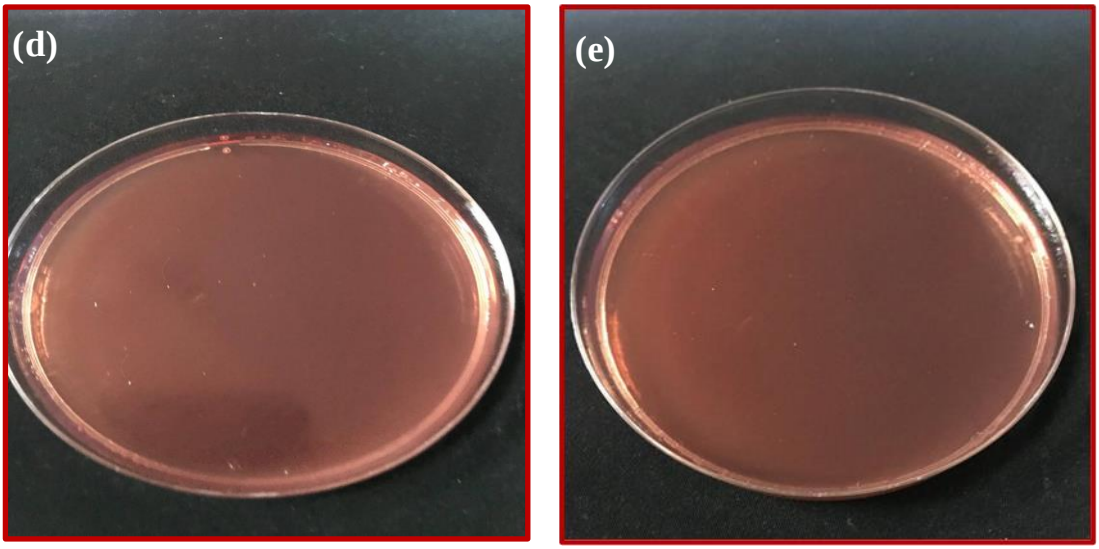


Figure -9 Antibacterial activity at (a) Before Treatment.
Aftar tretment at (b) 400 mJ (c) 500mJ (d) 600mJ (e) 700m

4. Conclusions

The ability to synthesize CuO NPs by the pulsed laser ablation (PLA) method in a liquid medium at a wavelength of 1064 nm at different laser energies was studied. The laser treatment led to the encoding of copper oxide nanoparticles, whose optical properties were studied, and the energy gap was deducted for them, which was in the range of (2.8eV-3eV). In addition, an examination (SEM, EDX, XRD, AFM) was conducted. The results of these tests showed that the copper element was purity and that the shape of the copper oxide nanoparticles is homogeneity, and that the size of CuO NPs does not exceed 22.8 nm. The results of Antibacterial Activity showed that the copper oxide nanoparticles have an apparent effect on Staphylococcus epidermidis bacteria, Gram-positive clusters, especially at energy (700mJ) where the killing rate was perfect killing.

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