Antibacterial by Zn/ZnOcore/shell prepare in laser ablation method

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Abstract:

-In this research, Zinc and Zinc Oxide nanoparticles was synthesized using pulsed laser ablation in liquid technique. This gives very simple, cheap, the long period of stability, less aggregation, non-toxic and non-contamination method. Noble metals; Zinc was synthesized by pulsed (Q-switched, Nd: YAG) 1064 nm by applying energy 800 mJ and frequency 6 Hz and 100 laser pulses at room temperature. laser ablation metal plates immersed in ethanol, acetone and distilled water. Respectively, indicating the production of pure and spherical Zn and ZnO NPs. All the size measurements have been confirmed by TEM. The study also focused on the applications of Zn and ZnO nanoparticles via a method to increase the activity and the efficacy of the antibacterial activity of nanoparticles which were produced by the laser ablation of 1064 nm wavelength with an energy power 800 mJ and applied pulses 100 to produce nanoparticles in different sizes on the Gram-positive isolate (Staphylococcus aureus) and Gram-negative isolate (Escherichia coli). The results and images of inhibition zones show that nanoparticles have synergistic effects on the studied bacteria Up to 22 mm at the highest value and 15 mm at the lowest value.

Keywords: -Pulsed laser ablation, Zn and ZnO nanoparticles, Core-shell nanoparticles, Antibacterial, E.coli, S.aureus, Nanoparticles, Ethanol, Acetone, Distilled water.

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1.Introduction

Nanoparticles are of large scientific advantage as they are effectively a bridge between bulk materials and atomic or molecular structures [1]. A bulk material should have constant physical characteristic regardless of its size, but at the Nano scale this is often not the case. Size-dependent properties are observed such as quantum confinement in semiconductor particles, surface plasmon resonance in some metal particles [2]. The formation of nanoparticles can be mainly attributed to the combination of ultrafast cooling of the hot plasma resulting from the evaporation of the molten thin layer and its interaction with the surrounding media [3]. When a laser pulse reaches the surface of a sample, some energy is reflected back to the surface. It is noted that the reflectivity depends on the material and the wavelength of the laser. The energy absorbed by the sample is transferred from the light photons to the electrons and then to the lattice, which then diffuses the energy into the material. The high-energy pulses may cause photochemical reactions that remove atoms and molecules from the surface. The heated surface can reach temperatures close to the critical temperature and cause a rapid vaporization process. The evaporation from the plasma consists of ionized atoms and electrons. Some of the incident laser energy thus only allows a fraction of the laser energy to reach the surface (plasma shielding) [4]. The plasma expands and is heated by photon absorption. Later the vapor cools down and aerosol particles begin to form. The rest of the energy in the material is spread by heat transfer. Depending on the applied laser energy, the surface may be melted into a liquid with a moving solid-liquid interface. Nanoparticles of noble metals, usually zinc, have strong interactions with visible light through resonant excitation of collective oscillations of conductive electrons within the molecule [5]. As a result, the local electromagnetic fields around the particles can be much higher than the fields present. The wavelength of the incident light is strongly scattered around the resonance peak [6].

2. Experiment setup

Figure 1. Shown the Colloidal of (Zn and ZnO) nanoparticles were produced by the pulsed laser ablation technique. The focused energy was 800 mJ and the wave length 1064 nm Nd: YAG laser and the number of applied pulses 100 pulses. The pieces of high purity (Zn) plates was placed on the bottom of Pyrex vessel containing 3 ml of ethanol, acetone and distilled water and the distance between the target and laser source is 10 cm at room temperature.Antibacterial Activity Experiment**,** Both of Staphylococcus aureus and Escherichia coli clinical isolates were used as bacterial model for evaluating the antibacterial activity of (Zn and ZnO) nanoparticles.

Antibiotic susceptibility was carried out for all isolates of bacteria isolated:

1. The tips of 4-5 isolated colonies of the bacteria were used to test tube containing 5 ml of sterile normal saline in a cell density equivalent to turbidity of McFarland tube No. (0.5) which approximately equal to bacterial cells density of $1.5x10^8$ cells/ml.
2. A sterile cotton swab was dipped into the standardized bacterial suspension. The excess fluid was removed by rotating the swab firmly against the inside of the tube above fluid level. The swab was then streaked onto the dried surface of a Muller-Hinton plate in 2 different planes to obtain an even distribution of the inoculums.
3. The plate lids were replaced and the inoculated plates were allowed to remain on a flat and level surface undisturbed for 3-5 min to allow for the absorption of excess moisture.
4. With the sterile forceps, the selected discs were placed on the inoculated plate and pressed gently into the agar. Within 15 min the inoculated plates were incubated at 37 ºC for 18 -24 hr in an inverted position.
5. After incubation, the diameters of the complete inhibition zone were noted and measured using reflected light and a ruler. The end point, measured to the nearest millimeter, was taken as the area showing no visible growth.
6. The results were interpreted the critical diameters and to the leaflet of antibiotics manufactures.

Fig. 1. The Colloidal of (Zn and ZnO) nanoparticles in ethanol, acetone and distilled water.

3. Results and discussion

3.1. Transmission Electron Microscope (TEM) Measurements

3.1.1. (Zn and ZnO) nanoparticles in ethanol

Figure 2. shown typical TEM image of (Zn and ZnO) nanoparticles in ethanol produced by the laser ablation of Zinc plate immersed in 3 ml of, ethanol at laser shots of 800 mJ and 100 pulses. The spherical shape of the produced Zn NPs is clearly seen in TEM images presented.

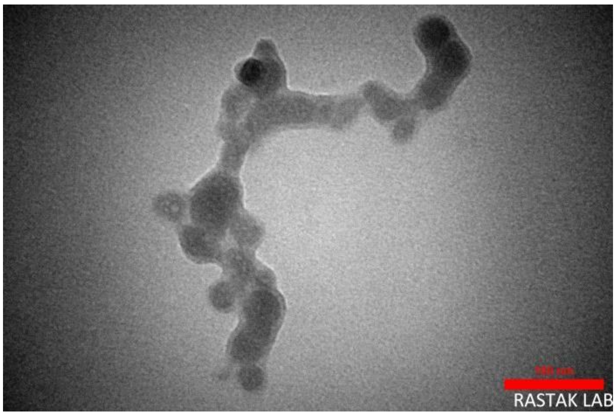

Fig. 2. TEM image of (Zn and ZnO) nanoparticles in ethanol.

3.1.2. (Zn and ZnO) nanoparticles in acetone

Figure3. shown typical TEM image of (Zn and ZnO) nanoparticles in acetone produced by the laser ablation of Zinc plate immersed in 3 ml of, acetone at laser shots of 800 mJ and 100 pulses. The spherical shape of the produced Zn NPs is clearly seen in TEM images presented.

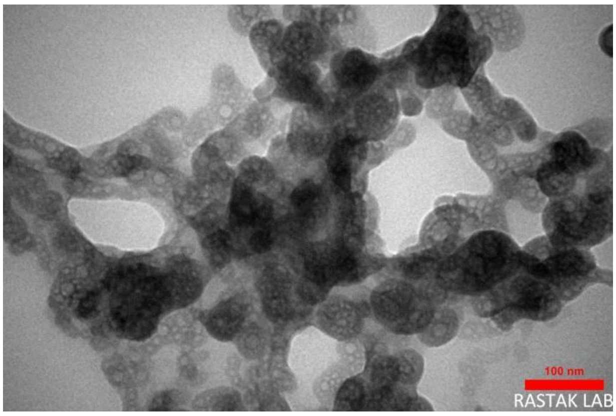

Fig. 3. TEM image of (Zn and ZnO) nanoparticles in acetone.

3.1.3. (Zn and ZnO) nanoparticles in distilled water

Figure 4. shown typical TEM image of (Zn and ZnO) nanoparticles in distilled water produced by the laser ablation of Zinc plate immersed in 3 ml of, distilled water at laser shots of 800 mJ and 100 pulses. The spherical shape of the produced Zn NPs is clearly seen in TEM images presented.

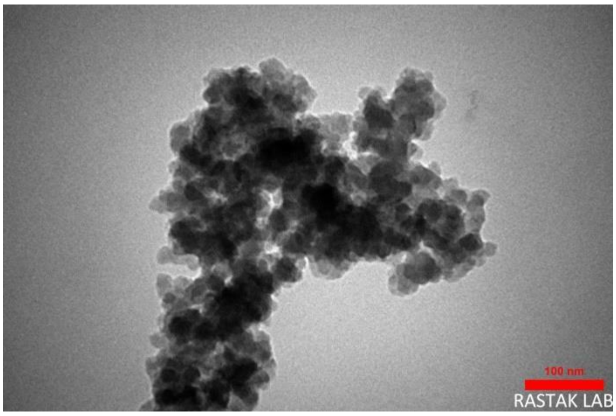

Fig. 4. TEM image of (Zn and ZnO) nanoparticles in distilled water.

3.2. Antibacterial Activity Experiment

Antibacterial activities of (Zn and ZnO) nanoparticles were studied against Escherichia coli Gram- negative bacteria and Staphylococcus aureus Gram- positive bacteria. The nanoparticles are synthesized by the laser energies of 800mJ pulse and 1064 nm Nd: YAG laser and the number of applied pulses 100 pulses which they have relatively small sizes. They applied to be tested against Staphylococcus aureus and Escherichia coli isolates which were illustrated shown figure 5. The results and images of the inhibition zones show that nanoparticles have synergistic effects on the studied Gram-positive isolate (Staphylococcus aureus) and on the Gram-negative isolate (Escherichia coli) that have low specific concentrations and relatively large sizes When the change medium, the concentration of the atoms ejected in solution increases, whereas the ejection rate decreases. The inhibition zone becomes 22 mm in the highest results and 15 mm in the lowest results. The inhibition zone depends on several factors: increase in time of exposure and increase in the concentration of nanoparticles in ethanol, acetone and distilled water. Nanoparticles generate holes in the cell wall due to surface ionization, resulting in the leakage of the cell contents and cell death. It is also possible that nanoparticles bind to the DNA of the bacteria and inhibit uncoiling and transcription of DNA. Gram-positive bacteria usually have much higher amount of peptidoglycan than gram-negative bacteria. The gram-negative cell wall is more complex in morphology because it contains outer membrane that surrounds a thin underlying peptidoglycan. It is constructed by specialized type of polysaccharide and protein. This outer membrane serves as an impermeable barrier to prevent or slow the entry of gold nanoparticles that kill bacteria. But the cell wall of the gram positive bacteria would be easily destroyed by nanoparticles because of the easy contact with cell membrane due to a lack of extra protective membrane.

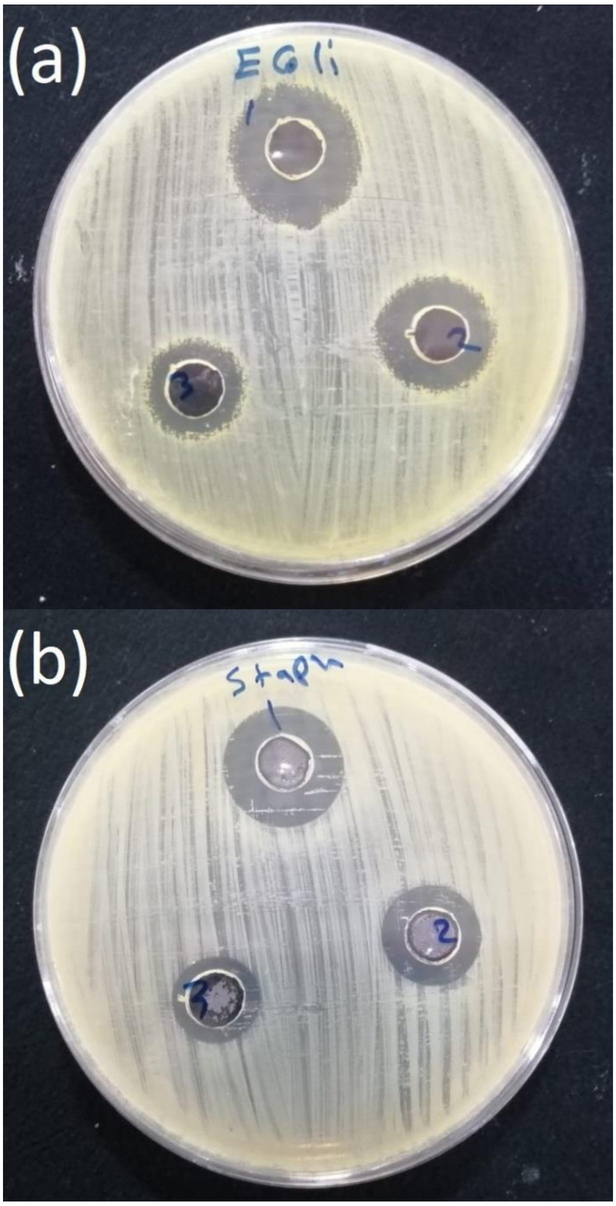

Fig. 5. Antibacterial Activity experiment for (a) Escherichia coli and (b) Staphylococcus aureus for (Zn and ZnO) nanoparticles applied pulses 100 pulses.

The following table shows diameter zone of inhibition for E.coli and S.aureus bacteria by using different colloidal nanoparticles.

Metal	**E.coli**	**S.aureus**
(Zn and ZnO) nanoparticles	Ethanol 2.2 cm	Ethanol 2 cm
	Acetone 2 cm	Acetone 1.7 cm

	Distilled water 1.6 cm	Distilled water 1.5 cm

From the table it can be seen that the diameter zone of inhibition for E.coli and S.aureus bacteria was changed by changing the medium. The largest diameter of the inhibition zone was 2.2 cm for Zn and ZnO nanoparticles synthesized at 100 pulses on E.coli bacteria and 2 cm on S.aureus bacteria.

4. Conclusions

It is a simple and controllable process with a low cost. The present work confirms the success of the ablation in liquid method to synthesized (Zn and ZnO) nanoparticles in ethanol, acetone and distilled water. The change in the medium have showed the change in the particle size. The results and images of inhibition zones show that nanoparticles have synergistic effect on the studied Gram-positive isolate (Staphylococcus aureus) and on the Gram-negative isolate (Escherichia coli) that have low specific concentrations and relatively large sizes.

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References:

[1] Mohammad Malik Abood, Adel H. OmranAlkhayatt. Au, Ag, Cu and Ag:Au:Cu Colloidal Nanoparticles Synthesized by Pulsed Laser Ablation, 2017.

[2] Hina Khalid, ShamailaShamaila, NosheenZafar, Rehana Sharif, Jawad Nazir, Mohammad Rafique, Sheeba Ghani, Hussain Saba. Antibacterial Behavior of Laser-Ablated Copper Nanoparticles MetallurgicaSinica (English Letters), 2016, 29(8): 748-754.

[3] Stefan Reich, Patrick Schönfeld, Philipp Wagener, Alexander Letzel, ShyjumonIbrahimkutt, Bilal Gökce, Stephan Barcikowski, Andreas Menzel, Tomy dos Santos Rolo, Anton Plech. (Pulsed laser ablation in liquids: Impact of the bubble dynamics on particle formation) Journal of Colloid and Interface Science 489 (2017) 106–113.

[4] Isam M. Ibrahim.Synthesis and Characteristics of Ag, Cu/Au Core/Shell Nanoparticles Produced by Pulse Laser Ablation, 2017.

[5] C. Abinaya, M. Marikkannan, M. Manikandan, J. Mayandi, P. Suresh, V. Shanmugaiah, C. Ekstrum, Joshua Pearce.Structural and optical characterization and efficacy of hydrothermal synthesized Cu and Ag doped zinc oxide nanoplate bactericides,Materials Chemistry and Physics, Elsevier, 2016, 184, 172-182.

[6] Paladini, M. Pollini, A. Sannino, L. Ambrosio, Metal-Based Antibacterial Substrates for Biomedical Applications, Biomacromolecules 16 (2015) 1873-1885.