مجلة كلية التربية الاساسية
كلية التربية الاساسية – الجامعة المستنصرية

Journal of the College of Basic Education Vol.30 (NO. 126) 2024, pp. 1-9

Synthesized Cu nanoparticles by the Electric Wire Explosion Method for Anti-Candida Albicans application

Sawsan T. Jumaa[1*], Baha'a A. M. Al Hilli[2], Ausama I. Khudia[3]
[1,2]Mustansiriyah University, College of Education, Physics Department, Iraq
[3]Ministry of Science and Technology, Material Science Directorate, Iraq, Baghdad.
*E-mail:- sawsentalal1995@uomustansiriyah.edu.iq

Abstract:

The copper nanoparticles Cu NPs were successfully prepared via laser triggering wire explosion technique at different explosion voltages (4, 5 and 7 KV). It was observed through atomic force microscopy examinations that the prepared powders are highly homogeneous and contain agglomerations resembling regularly distributed protrusions and that the homogeneity increases with increasing explosion voltage. The examination of the fourier transform infrared spectroscopy showed bonds and functional groups belong to CuO and Cu_2O. Antifungal activity tests showed the efficiency of the prepared powders in eliminating Candida albicans, especially the Cu nanopowder prepared at 7KV and a concentration 200 µg/mL.

Keywords: Electric wire explosion, copper, nano-particles, Antifungal

Introduction:

A particle with all three dimensions and a nanometer size between 1 and 100 nm is referred to as a nanoparticle because it has some atoms or molecules with different characteristics from the original substance. Among other shapes, they can be found in spherical, triangular, cubic, or pentagonal forms. An atomic or molecular aggregate of a few thousand to a million atoms joined together in a roughly spherical form is called a nanoparticle. The radius is less than 100 nm, and a quantitative restriction (also known as quantitative confinement) effect manifests when the size of the nanoparticles approaches the nanoscale [1]. The dominance of surface characteristics over material volumetric qualities is the most significant feature of nanoparticles. Another feature of nanoparticles is their ability to be suspended inside of solution without becoming disoriented or overpowered. One of the vapor-phase techniques, Electron Wires Explosion (EWE), produces particles by evaporating a thin metal wire by running a high current through it [2]. When it comes to producing nanopowders EWE combines the advantages of two different approaches: "top-down" and "bottom-up." The "top-down" method entails breaking down bulk material into nanoscale structures or particles; an electric pulse current passing through a wire breaks down the substance of the wire. The "bottom-up" method is predicated on the idea that particles arise from atoms, molecules, and clusters; in the event of an electric explosion, a sizable portion of the wire material first evaporates and then condenses back into particles [3]. The exploding wire, if the explosion chamber electrodes are made of the same material as the wire, will determine the purity of the synthesized powders. The EWE technique can be used effectively to fabricate metal nano powders, namely Ni, Fe, Al, Cu, Ag, or alloys such as Pt-Ni, Cu-Ni, and Cu-Ni-P [4, 5]. Due to their surface to volume ratio, copper nanoparticles have recently drawn a lot of interest for their catalytic activity, which is noticeably higher than that of their bulk counterparts. The particle shape and organization, as discrete spherical particles have the highest catalyst activity as compared to honey comb packed hexagonal nanoparticles; Cu nano powders are particularly attractive for applications in cancer cell killing, anti-microbial, and germicides, and also show quite high toxicities (for bacteria and humans) at a very small particle size [6,7]. Nanoparticles have significant potential for a wide range of practical applications [8,9]. This research aims to prepare copper nanoparticles by EWE technique and apply it as an antifungal.

Experimental

The copper nanoparticles were produced via the EWE method, as shown in Figure 1. The high quality 99% copper wire, which was inserted between the electrodes in lengths of 30 mm and with a radius of 0.2 mm, was supplied by a feeding roller that was set above the bursting vessel. A nozzle was used to guide the wires through the wall of the vessel. The copper wire was submerged in a container filled with water to collect the copper nanoparticles that were created when the wire exploded. The explosion process is switched using a high-power spark gap switch that is fired by a Nd-YAG laser. The wire was explosion using different voltages 4, 5 and 7 KV.

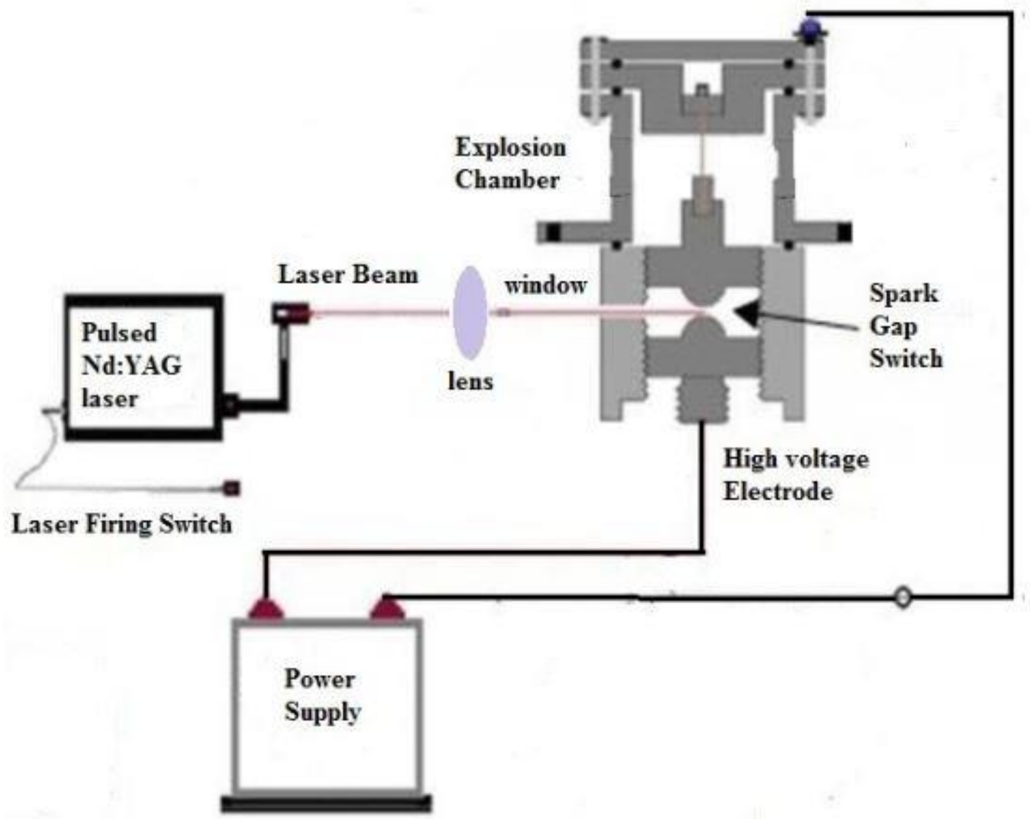

Figure 1. Schematic diagram of the experimental EWE setup.

The morphology and topography imaging of samples was done by the atomic force microscope (AFM) type of Angstrom AFM AA-3000A. Molecular bonds and vibrations were identified through Fourier Transform Infrared Spectroscopy type PerkinElmer for the prepared samples. The standard isolate of Candida albicans fungal was obtained to study the effect of the prepared Cu NPs on their survival outside the living body. This isolate was grown on a Nutrient Agar medium. The Well Diffusion Method was used to study the effect of Cu NPs at concentrations of (0.0, 25, 50, 75, 100, 150 and 200) µg/mL to study its effect on the Candida albicans.

Results and Discussion

Figure 2 shows the Atomic Force Microscopy images of the prepared Cu NPs via laser-triggering wire explosion technique at different explosion voltages (4, 5 and 7 KV). From this figure, it is noted that the surfaces of the prepared NPs are highly homogeneous and contain agglomerations resembling regularly distributed protrusions, and that the homogeneity increases with increasing explosion voltage, and the protrusions are more prominent at explosion voltages 7 KV. Table 1 illustrates the AFM parameters for all samples, this table shows the decreasing of particle size and roughness average with explosion and this agree with [10,11, 12].

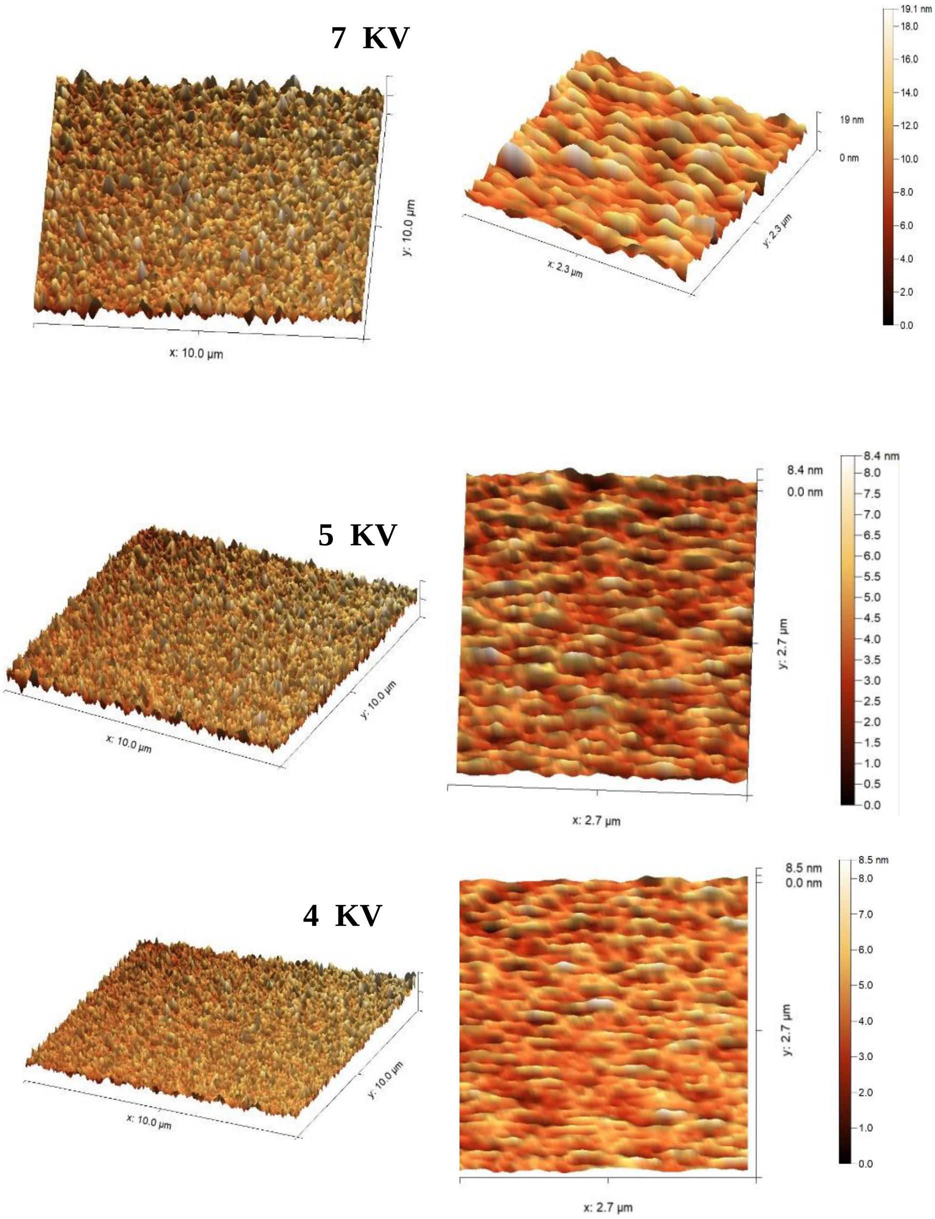

Figure 2 AFM images for the Cu NPs prepares via laser assisted electric wire explosion method at 4, 5 and 7 KV.

Table 1: The AFM parameters of samples

Explosion Voltage KV	Particle Size nm	Roughness nm
4	195.0	20.5
5	180.2	3.41
7	30.38	7.90

This type of test is usually used to examine organic samples, especially in the range of 400 to 4000 cm^{-1} FTIR test, as inorganic materials such as copper do not show prominent absorption peaks in the FTIR spectrum because they are unable to absorb infrared radiation effectively. But bonds formed between copper and oxygen or carbon will appear in this test to confirm that we have obtained copper oxide, since the vibrations related to Cu-O are usually in the range of 450-650 cm^{-1}. While the absorption peaks for CuO show the range 500-700 cm^{-1} and Cu_2O the range 1550-1750 cm^{-1}. If the peaks in the spectrum correspond to known absorption sites for CuO and Cu_2O, this indicates the presence of copper oxides in the sample. Figure 3 shows the fourier-transform infrared spectroscopy of the prepared Cu NPs via laser triggering wire explosion technique at different explosion voltages (4, 5 and 7 KV). In figure 4, it was observed that a broad peak appears at wavenumbers 3415 cm^{-1} belonging to the symmetric and asymmetric the stretching vibration of the O–H bond. The peak at wavenumbers 1630 cm^{-1} indicates stretching vibration of the Cu–O bond of copper(II) oxide, while the peak at 669 cm^{-1} refers Cu–O stretching vibration of copper oxide. [13, 14, 15].

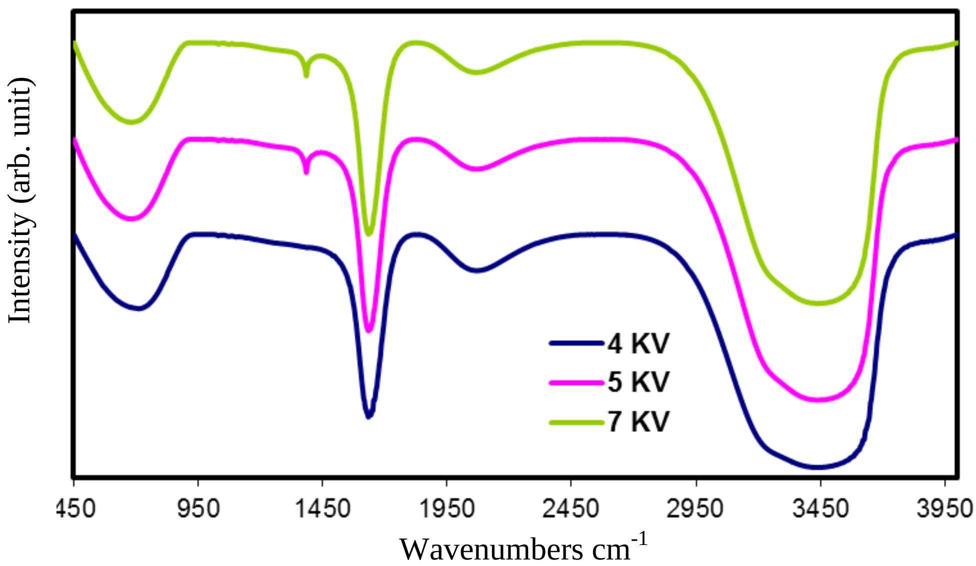

Figure 3 The FTIR spectra for the copper powders prepared at 4, 5 and 7 KV.

Cu NPs demonstrated antifungal activity against Candida albicans in the study; When the concentration of Cu NPs grew, the diameter of the Candida isolates' inhibitory zone also increased, reaching 19.4 mm at a 200:0% concentration at 7 KV. In contrast, Cu NPs prepared using the laser-induced exploding wire method at 4KV and 5KV, as well as standard Cu NPs, showed fewer signs of having an antifungal effect on Candida albicans. Tables 2 present the outcomes. Figure 4 shows the zones of death that were obtained. The literature also addresses Cu NPs' possible antifungal activity mechanisms. Cu NPs can enter a cell by either diffusion or endocytosis; once within the cytoplasm, they promote the release of ROS Cu^{+}, which disrupts mitochondrial activity [16]. These ions can cross the membrane and get to the DNA, which can lead to nuclear damage including irreversible chromosomal damage and cell death [17,18].

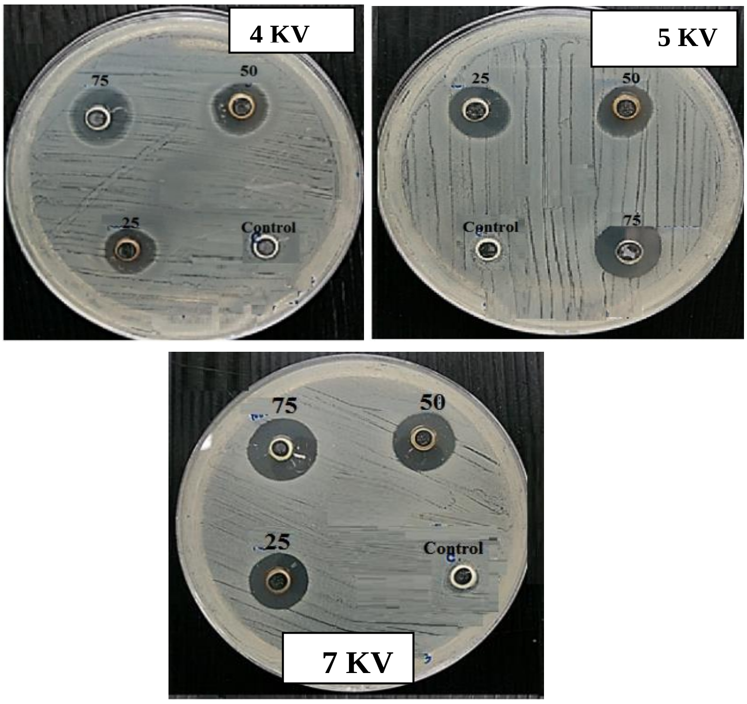

Figure 4 The anti-candida activity of Cu nanoparticles prepared at 4KV, 5KV and 7 KV.

Table 2 Antifungal activity of Cu nanoparticles prepared by laser induced exploding wire method at 4KV, 5KV and 7 KV against Candida albicans.

	Diameter inhibition zone (mm)		
Concentration µg/mL	7 KV	5 KV	4 KV
0.0	0.0	0.0	0.0
25	9.7	7.6	6.4
50	10.8	8.1	7.4
75	13.1	10.4	9.8
100	15.7	11.5	10.8
150	17.9	14.5	12.8
200	19.4	16.7	14.5

Conclusion

Copper nanopowders were successfully prepared using the EWE method and it was observed that increasing the explosion voltage improves the structural properties of the resulting nanoparticles. AFM examinations showed highly homogeneous and contained agglomerations resembling regularly distributed protrusions with particle size about 30.38 nm. While FTIR examinations show the presence of bonds dating back to oxidized copper. The copper NPs were effective against fungal isolates and the inhibitory zone for Candida albicans was 19.4 mm at a concentration of 200:0% and 7 kV.

References:

1. Satoshi Horikoshi, Nick Serpone, Microwaves in Nanoparticle Synthesis: Fundamentals and Applications, John Wiley & Sons, 2013.

2. R. Das, B. K. Das, R. Shukla, T. Prabaharan and A. Shyam, Analysis of Electrical Explosion of Wire Systems for the Production of Nanopowder, Indian Academy of Sciences, Vol. 37, No. 5, pp. 629- 635, 2012.

3. A. Gromov and U. Teipel, Metal Nanopowders Production, Characterization, and Energetic Applications, 1st Edition, WileyVCH, Germany, 2014.

4. Y. S. Lee, B. Bora, S. L. Yap, C. S. Wong, Effect of Ambient Air Pressure on Synthesis of Copper and Copper Oxide Nanoparticles by Wire Explosion Process, Current Applied Physics Journal, Vol. 12, No. 1, pp. 199-203, 2012.

5. J. W. Song, D. J. Lee, F. Yilmaz and S. J. Hong, Effect of Variation in Voltage on the Synthesis of Ag Nanopowder by Pulsed Wire Evaporation, Journal of Nanomaterials, Vol. 2012, No. 1, pp. 1-5, 2012.
6. Y.R. Uhm, J.H. Park, W.W Kim., C.H. Cho, C.K. Rhee, Magnetic properties of nano-size Ni synthesized by the pulsed wire evaporation (PWE) method, Materials Science and Engineering B, Vol. 106, No. 3, pp. 224–227, 2004.
7. A. K. Chatterjee, R. Chakraborty and T. Basu, Mechanism of Antibacterial Activity of Copper Nanoparticles, Journal of Nanotechnology, Vol. 25, No. 13, pp. 135101-135112, 2014
8. Y. He-long, X. Yi, S. Pei-jing, X. Bin-shi, W. Xiao-li and L. Qian, Tribological Properties and Lubricating Mechanisms of Cu Nanoparticles in Lubricant, Transactions of Nonferrous Metals Society of China Journal, Vol. 18, No.1, pp. 636-641, 2008
9. O. Nazarenko and A. p. Ilyin, Nanopowders Produced by Electrical Explosion of Aluminum Wires in Water, Conference of International Forum on Strategic Technology, Copenhagen, Vol. 2007, pp. 654-656, 2007
10. I.V. Beketov, A.P. Safronov, A.I. Medvedev, A.V. Bagazeev, A.D. Maksimov, A.M. Murzakaev, T.M. Demina, Synthesis of Carbon-Encapsulated Copper Nanoparticles by The Electrical Explosion of Wire Method, Diamond and Related Materials, Vol. 139, p. 110317, 2023.
11. Lerner M, Suliz K, Pervikov A, Tarasov S. Micron- and Nanosized Alloy Particles Made by Electric Explosion of W/Cu-Zn and W/Cu/Ni-Cr Intertwined Wires for 3D Extrusion Feedstock, Materials (Basel), Materials (Basel), vol.16(3), pp.1-14, 2023.
12. Sawsan T. Jumaa, Baha'a A. M. Al Hilli, Ausama I. Khudia, The Structural Properties of Nano-Coppers Synthesized via the Electric Wire Explosion Method and Application as Anti- Escherichia coli Bacterial International Journal of Scientific Research in Science, Engineering and Technology, Vol. 11 No. 3, pp. 231-236, 2024.
13. Prasanta Kumar Raul, Samarpita Senapati, Ashish K. Sahoo, Iohborlang M. Umlong, Rashmi R. Devi, Ashim Jyoti Thakurc, Vijay Veera , CuO Nanorods: A Potential and Efficient Adsorbent In Water Purification, RSC Adv., vol.4, no. 76, pp. 40580(1-7), 2014

14. Nzilu, D.M., Madivoli, E.S., Makhanu, D.S. et al. Green Synthesis of Copper Oxide Nanoparticles and its Efficiency in Degradation of Rifampicin Antibiotic. Scientific Reports, Vol. 13, p.14030, 2023.
15. Ammu Varughese, Raminder Kaur, Poonam Singh, Green Synthesis and Characterization of Copper Oxide Nanoparticles Using Psidium guajava Leaf Extract, IOP Conf. Series: Materials Science and Engineering, Vol. 961, p. 012011, 2020
16. Sawai, Jun, Shinobu Shoji, Hideo Igarashi, Atsushi Hashimoto, Takao Kokugan, Masaru Shimizu, and Hiromitsu Kojima. Hydrogen Peroxide as an Antibacterial Factor in Zinc Oxide Powder Slurry, Journal of fermentation and bioengineering, vol. 86, no. 5, pp. 521-522, 1998
17. Applerot, Guy, Jonathan Lellouche, Nina Perkas, Yeshayahu Nitzan, Aharon Gedanken, and Ehud Banin. ZnO Nanoparticle-Coated Surfaces Inhibit Bacterial Biofilm Formation and Increase Antibiotic Susceptibility, Rsc. Advances, vol. 2, no. 6, pp. 2314-2321, 2012
18. Da Silva, B. L., Abuçafy M.P., Manaia E.B., Junior J. A.O., Chiari-Andréo B. G., Pietro R.C.R., Chiavacci L. A., Relationship Between Structure and Antimicrobial Activity of Zinc Oxide Nanoparticles: An Overview, International Journal of Nanomedicine, vol.14, p.9395, 2019

تصنيع جسيمات النحاس النانوية بطريقة انفجار السلك الكهربائية وتطبيقاتها كمضادات للمبيضة البيضاء

مستخلص البحث:
تم تحضير مساحيق النحاس النانوية النحاسية بنجاح باستخدام تقنية تفجير الأسلاك باستخدام مفاتح الليزر عند جهد انفجار مختلف (4، 5، 7 كيلو فولت). وقد لوحظ من خلال فحوصات مجهر القوى الذري أن المساحيق المحضرة ذات درجة عالية من التجانس وتحتوي على تكتلات تشبه النتوءات الموزعة بانتظام وأن التجانس يزداد مع زيادة جهد الانفجار. أظهر فحص اطياف الاشعة تحت الحمراء وجود روابط ومجموعات وظيفية تنتمي إلى احادي اوكسيد النحاس و ثنائي اوكسيد النحاس. أظهرت اختبارات فعالية كمضادات للفطريات كفاءة المساحيق المحضرة في القضاء على المبيضات البيضاء، وخاصة مسحوق النحاس النانوي المحضر عند جهد 7 كيلو فولت وتركيز 200 ميكروجرام/مل.
الكلمات المفتاحية : تقانة انفجار السلك ، مساحيق النحاس النانوية ، مضادات الفطريات .