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Preparation of molybdenum nanoparticles using cold plasma as antibacterial

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***Abstract*---**In this paper, molybdenum nanoparticles (Mo NPs) were prepared by cold plasma method with different concentrations and time constant. Some structural tests were performed using X-ray diffraction (XRD). and field emission scanning electron microscopy (FESEM). and energy-dispersive X-ray spectroscopy (EDX). Average crystal size is variable. Effect of the prepared nanomaterial on the growth of Pseudomonas aeruginosa bacteria. The results of those tests showed that the prepared substance at concentrations of (1.5 and 2) mM when exposed to plasma (12 min). As the results of their assays showed the polycrystalline structure of all samples of the cubic structure, the results also showed that the average crystal size changes directly with the change of concentration. On the other hand, the results of this research showed that Gram-negative bacteria (Pseudomonas aeruginosa) were resistant to Mo NPs prepared at a concentration of (1.5 and 2) mM at dilutions (0.5, 2, 4, 8, 16, 32).). But at dilution 64, there was little inhibition of its growth.

***Keywords*---**molybdenum, cold plasma, nanoparticles, pseudomonas aeruginosa.

Introduction

Nanomaterials are materials with external dimensions and/or internal structures with a nanometer (nanometer) intensity scale [1]. Metal nanoparticles are generating a lot of buzz because of their unique properties and potential applications in catalysis. [2, 3] magnetism [4] electronics [5] activity biological [6, 7] etc. The chemical and physical properties of most metallic nanoparticles are altered depending on their size. The study of molybdenum oxide and related

materials has received a lot of attention in recent years. Chemical synthesis, petroleum refining, recording media, and sensors could all benefit from molybdenum oxide's unique catalytic and electronic properties. [8, 9]. It is also used in the manufacture of optical devices [10,11]. and is a promising material for photovoltaic electrochemical energy generation with a large surface area and high photo-efficiency [12, 13]. Photochromic and electrophilic molybdenum oxides [14] whose color changes as a result of oxidation state changes caused by light absorption [15, 16]. Molybdenum oxide nanoparticles have antimicrobial activity, which can be attributed to their small size and high surface-to-volume ratio, which allows them to bind tightly to the microbial membrane and release a metal ion [17]. into the solution In bactericidal applications, molybdenum oxide nanoparticles have been shown to be useful and effective [18, 19].

Biomaterial

A non-viable substance that is used in a medical device and is designed to interact with biological systems. A biomaterial is any natural or synthetic substance that is intended to interact with tissues, blood, or biological fluids and to be used in synthetic, diagnostic, therapeutic, or storage applications without causing harm to the organism or its component [20, 21]. There are many types of biomaterials, polymeric biomaterials, bioceramic, mineral biomaterials, biocomposites and biological (derived) biomaterials. [22]. Exposure to bodily fluids usually means that the biological material is placed inside the body, and this places many strict restrictions on the materials that can be used as biological materials, they must be non-toxic and non-carcinogenic.

Plasma concept

Plasma is a (partially) ionized gas that contains the components of electrons and photons ions as well as radicals and particles that are excited. A glow discharge is a type of plasma that is defined as a partially ionized gas with approximately equal positive and negative charge concentrations [23,24]. Low pressure plasma technology has a wide range of applications in the microelectronics sector and material surface treatment. The field of glow-discharge plasmas has seen an increase of interest in recent years. Solid, gas, liquid and plasma are the four basic states of matter found in nature , Plasma can consist of a neutral ionized gas containing positively charged particles, negatively charged electrons, and neutral particles [25]. Plasma can be completely ionized, as in the sun and the ozone layer, or partially ionized, as in fluorescent lamps, which contain countless particles.

Uptake of molybdenum by cells

Organisms absorb molybdenum as the molybdate anion. Scavenging of molybdate in the presence of competing anions requires certain adsorption mechanisms. High-affinity molybdate transporters in bacteria have three protein components and work via ATP hydrolysis. Molybdate-binding proteins with up to eight anion binding sites [26]. Have been discovered in some bacteria and are in charge of storing molybdate until it is needed by the organism. Unlike the well-studied mechanisms of bacterial molybdate transport and homeostasis, the mechanisms

of eukaryotic molybdate transport remain unknown. Genetic evidence has revealed a separate molybdate uptake system in the alga Chlamydomonas rheinhardtii [27], and a molybdate vector has recently been cloned from this organism (E. Fernandez, personal communication). The molybdate vector was cloned and described in a plant model. Arabidopsis thaliana also.

Methods and Materials

The nanomaterial's preparation

Cold plasma method was used to preparation nano-molybdenum by dissolving molybdenum salts (Mo) in distilled water with different concentrations (1.5, 2) mM. After mixing the substance with distilled water by a device (magnetic stirrer), the mixture or solution is exposed to plasma per 10 ml at different concentrations; and a time (12 min) of exposure to plasma. Then the solute turns into nano-size after being exposed to cold plasma. A number of structural tests (FESEM and EDX) have been performed for the purpose of characterizing the as-prepared nanomaterial in terms of nanosize, internal composition and factors affecting it, such as plasma exposure time and concentration difference. Then, the prepared nanomaterial is ready for the purpose of handling bacteria.

Preparation of the Medium (Muller Huntington Broth)

Five ml of the medium was added to each tube, and it was inoculated with bacteria and the prepared nanomaterial was added at a concentration of (2 and 1.5) mM, and the plasma exposure time was (12 min) and at dilutions (0.5, 2,4,8,16,32,64), the Put them in the incubator for (24 hours), after which the results related to the effect of the nanomaterial on the inhibition of bacteria were observed.

Results and Discussion

Diffraction of X-rays

X-ray diffraction (XRD) patterns were shown for Mo NPs prepared at different concentrations at a fixed time (12 min) and deposited on glass slides were Figure (1) polycrystalline composition of all samples of the cubic composition was shown according to Standard Card No. 21-1272. The wide peaks are located at diffraction angles 2θ = 40.650º, 58.770º and 73.851º corresponding to the Miller indices (100), (200) and (211), respectively. Smaller peaks corresponding to molybdenum oxide appeared in all samples [28]. The oxidation of water results in [29]. Due to stress in the crystal lattice as a result of increased lattice defects due to increased growth rate, there is a slight deviation in the diffraction angles as the initial concentration of precursors increases [30]. The peaks' broad appearance is due to the crystal structure's nanoscale size. The intensity of the peaks also increases as the precursor concentration increases, indicating enhanced crystallization. The width of the peaks, on the other hand, decreases with increasing concentration due to the increase in average crystal size, which is consistent with [31]. The crystal size (C.S) was calculated using Sherrer's formula

(AB+BC= 2d Sin**θ**) and the d_{hkl} intermolecular plane distance for the diffraction peaks was calculated using Bragg's law (AB+BC=nλ) as shown in Table (1).

Table 1
XRD parameters for MoNPs prepared at same time of 12 min and at different concentrations

Conc. (mM)	2θ (Deg.)	d_{hkl} (Å)	FWHM (Deg.)	C.S (nm)	hkl
1.5	40.672	2.2166	0.4017	21.1	(110)
	58.796	1.5693	0.4292	21.2	(200)
	73.867	1.2819	0.4110	24.2	(211)
2	40.650	2.2177	0.4156	20.39	(110)
	58.770	1.5699	0.4017	22.70	(200)
	73.851	1.2822	0.4134	24.04	(211)

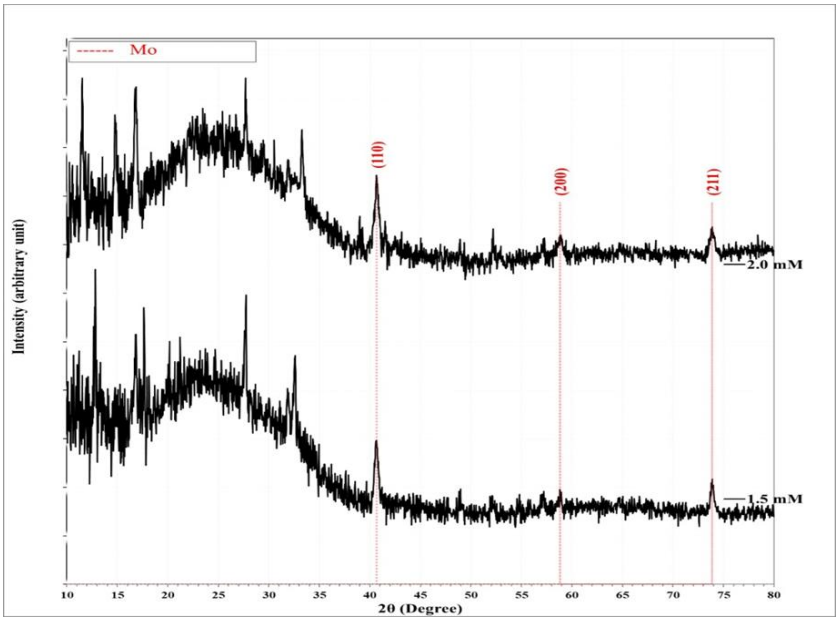

Figure 1. XRD patterns for Mo NPs prepared at same time of 12 min and at different concentrations

Microscopy measurement using FESEM

Figure (2) shows FESEM images of Mo NPs prepared at the same (1.5 and 2) mM concentrations and a plasma exposure time of (12 min) at two magnifications. The size of the particles grows as the concentration rises, and the seeds of the crystals that have begun to grow act as a catalyst for the growth of more atoms and the expansion of the NPs.

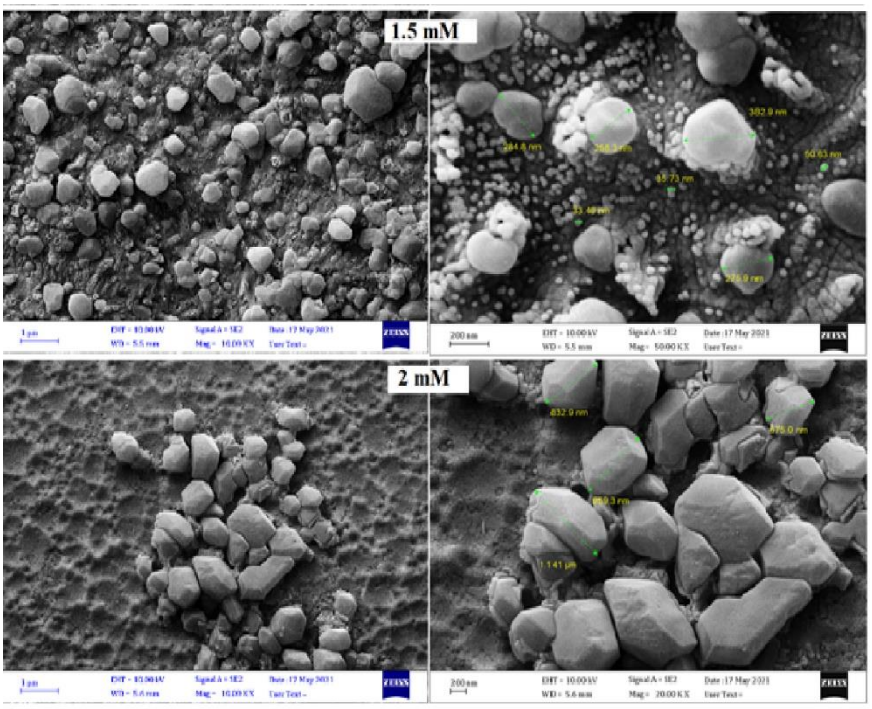

Figure 2. FESEM analysis at two magnifications for Mo NPs prepared at same time of 12 min and at different concentrations

Assays for EDX spectroscopy

The principle of energy-dispersive X-ray spectroscopy (EDX) is that after X-ray excitation, each element has a unique electromagnetic emission spectrum. Figure (3) shows the EDX spectra of Mo NPs samples prepared at different concentrations and with the same (12min) plasma exposure time. The measurement reveals several peaks corresponding to molybdenum (Mo) and oxygen (O) emission lines, as well as peaks corresponding to the glass substrate, such as silicon (at about 1.7 keV) and other trace elements, and the gold peak deposited on the surface of the samples to improve image resolution. FESEM. Peak intensity varies depending on the presence of the peaks in the samples. With increasing molybdenum concentrations, the peak intensity increased.

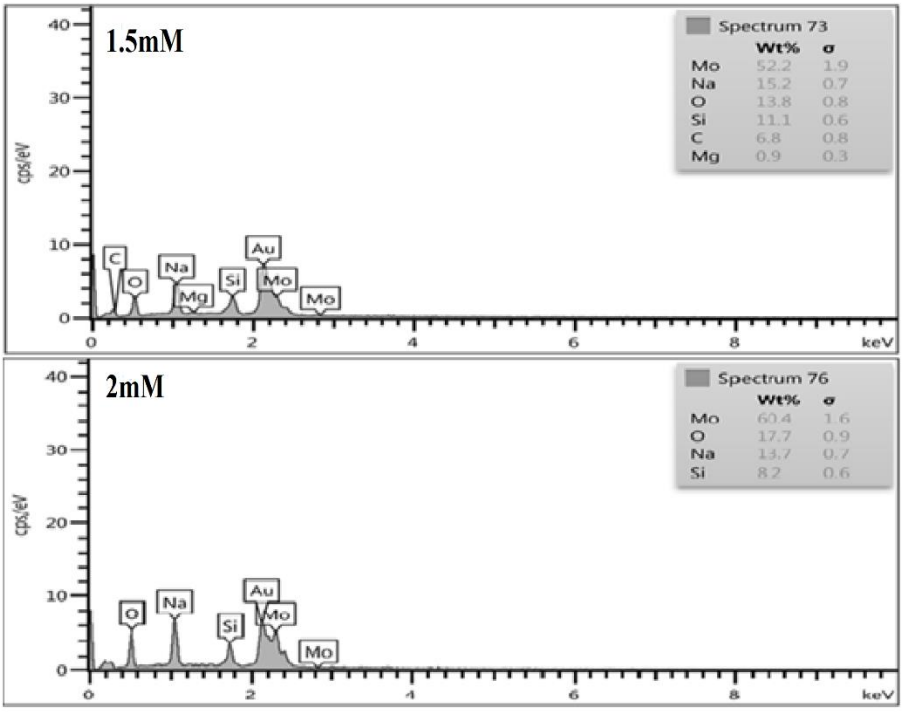

Figure 3. EDX analysis of Mo NPs prepared at concentrations of 1.5 and 2 mM and at a time of 12 min.

Minimum inhibitory concentration (MIC) assay

From Figure (4) the MIC was read optically after completing the incubation of a bacterium (*Pseudomonas aeruginosa*) and adding the prepared nanomaterial to the tubes inoculated with bacteria at a time (12 min) of plasma exposure at concentrations (1.5 and 2 mM) at dilutions of 0.5, 2, 4, 8, 16 and 32. Bacteria growth is clear and we observe in 64, the bacterial growth was more decreasing than others, where no complete inhibition of bacteria was observed.

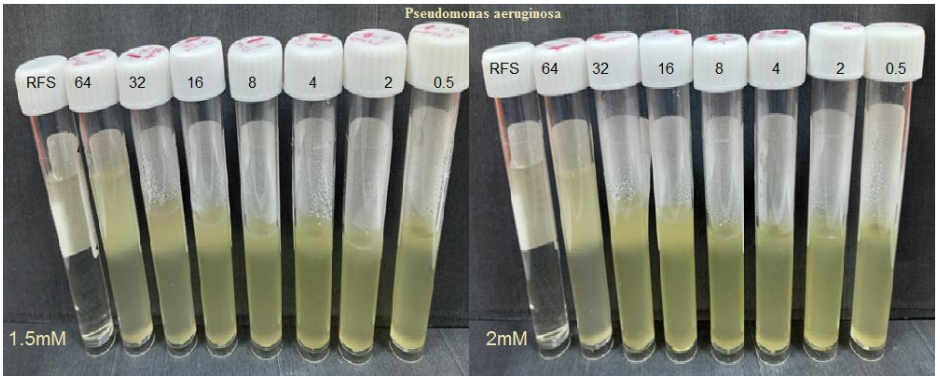

Figure 4. *Pseudomonas aeruginosa* bacteria where (a nanomaterial was added at a concentration of (1.5mM) and (2mM) exposed to the plasma for a time of (12 min) with different dilutions of the nanomaterial

Conclusions

- The average crystal size changes directly as the concentrations (1.5 and 2) mM change, while the plasma exposure time remains constant.
- The shape and size of the particles change as the concentration is increased.
- Gram-negative bacteria (Pseudomonas aeruginosa) showed clear resistance to the prepared molybdenum, but at dilution 64, there was very little inhibition.

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