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Preparation and Characterization of Nickel Oxide for Antibacterial Properties

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ABSTRACT: NiO thin films of different preferred orientations have been growth successfully by sol-gel technique using methanol solvent. X-ray diffraction was used to assess the produced film. XRD analysis of the sample's phase reveals that the relative intensity of the peak (111) indicates a highly crystalline nickel oxide structure. In order to test a NiO-based film's antibacterial effectiveness against the gram-negative bacteria Escherichia coli (E. coli) and Staphylococcus aureus, the mac varland method was utilized (S. aureus). Colony-forming units per milliliter (CFU/mL), which are the number of colonies on each plate, were used to measure the antibacterial activity of the sample. The results demonstrated Nickel oxide is highly effective against (E. coli) and other bacteria (S. aureus).

Keywords: Nickel Oxide, sol-gel technique, antibacterial properties, E. coli, S. aureus.

1. INTRODUCTION

Nickel oxide (NiO) particles are important materials and NiO, a compound that is very chemically stable and has the right chemical, electrolytic, and optical properties has garnered considerable interest in which are extensively used for broad range of potential applications such as magnetic supercapacitor with antiferromagnetic material [1], gas sensors as a catalyst [2], electrochemical, antibacterial [3], electrochromic devices [4], catalysts [5], dye sensitized photocathode solar cells (DSSCs) [6], smart windows [7], fuel cells [8]. These particles have applications in the field of nanoscience as lithium-ion battery anode material [9]. While numerous uses and features of NiO-based materials have been examined, nickel oxide has not yet undergone a thorough investigation into the antibacterial capabilities mentioned in other metal oxides [10-11]. However, the necessity to control infections and increased antibiotic resistance make the antibacterial action of organics extremely important.

One of the most intriguing series of materials is the first-row transition-metal oxides, which show a wide range of physical characteristics connected to electronic structure. The vast array of applications is built on the specific optical and magnetic characteristics.

Thus, during the past few years, they have served as the subject of extensive experimental and theoretical investigation [12]. One of the most common anti-ferromagnets, NiO, is a model system for strong electronic correlations with high spin AF2 structure at low temperatures. It has a basic crystalline rock salt structure with a lattice constant of 0.417 nm [13]. Due to the non-local exchange interaction, spin configurations have two parts. The direct exchange contact between the Ni ions' closest neighbors encourages paring of spins to lower energy for the first

component. Another one exhibits a very potent interaction due to the super exchange between Ni ions and their next-closest neighbors. The ground state of NiO now has an antiferromagnetic spin structure.

With octahedral Ni (II) and O-2 sites, NiO adopts the NaCl structure [14]. Its name, the "rock salt structure," refers to its conceptual simplicity [15]. NiO is frequently not stoichiometric, like many other binary metal oxides [16], indicating that the Ni:O ratio is not quite 1:1. Having a strong photocatalyst and catalytic activation effectiveness against bacteria, nickel oxide's non-stoichiometry is accompanied by a color change, with the stoichiometrically correct NiO being green and the non-stoichiometric NiO being black. Antibacterial activity is related to substances that kill or retard the growth of bacteria locally while not generally being hazardous to nearby tissue. Most modern antibacterial substances are natural chemicals that have been chemically altered.

Bacteria can successfully spread over the world. However, bacteria are exposed to a wide range of environmental factors, including changes in temperature, radiation, toxins, and the availability of food sources. They must therefore create unique strategies in order to thrive in various surroundings. A significant concern for doctors is the rise of bacterial resistance to antibiotics [17].

One process by which this bacterial resistance can occur is the development of biofilms. Bacterial colonies that have formed biofilms are covered in a self-made hydrated polymer matrix. The inherent resilience of microbial biofilm to antibiotic and immune system-mediated eradication is a significant characteristic. Recent studies were undertaken to develop appropriate coatings with antibacterial activity employing nano-based approaches for altering the characteristics of surfaces in an effort to overcome the inherent resistance of bio films.

In recent years, nanotechnology has placed a special emphasis on the development of antibacterial agents that have minimal or no adverse effects on the environment [18–19]. Industrial effluents are susceptible to pollution from organic and microbial substances [20-44].

The aim of present work is to use sol-gel technique to prepare structured material of nickel oxide then tested its antibacterial activity.

2. METHOD EXPERIMENTAL DETAILS

The sol-gel technique is used to prepare NiO transparent solution. (20 gm) of nickel nitrate 60 mL of methanol were used to dissolve the $(NO_3)_2.6H_2O$. After that, the mixture was heated to 70 °C in a water bath for three hours (for indirect heating). The solution was cooled and filtered after the predetermined amount of time had passed. After that, (25 mL) of ethyl acetate was used to wash the filtrate. The tubes were then spun in a centrifuge to separate the solution, and the sample was then kept for 24 hours before being turned into a gel and digested at ambient temperature. The produced powder can be identified by (XRD). It was carried out utilizing a copper anode and a graphite monochromatic Shimadzu-6000 X-ray Diffraction using K radiation. The X-ray tube operates at 40 kV, 30 mA, and 1.54 A^o of wavelength. 20° to 80° is the scanning range, with steps of 0.02°.
Using XPert High Score software with automatic library search (ICDD PDF2/PDF4 choices) (International Centre for Diffraction Data) data files for comparison, patterns were gathered and phases were identified.

2.1. PREPARATION OF THE BACTERIAL CULTURE

A- MATERIALS AND BACTERIAL STRAINS

- Nutrient agar medium was acquired from (OXOID Company-England).
- S. aureus stain and (E. coli) (PTCC 1399) were obtained. S. aureus stain and E. coli (PTCC 1399) were obtained.

B- CULTURE MEDIA

Nutrient agar medium (13 g/l) dissolved in distilled water has pH 7 and sterilized in autoclave at 121 °C for 15 minute and cooled to 45 °C then pour in plates under aseptic conditions.

C- CULTURE MEDIA

All grown strains incubated at 37 °C for 24 hour on Nutrient agar slants and plates. The plates were then kept at 4 oC and subcultured once every three months after that.

2.2. DETERMINATION ANTIBACTERIAL ACTIVITY

The antibacterial properties of samples, 100 mg/ml, was carried out by mixing (E. coli) and (S. aureus) bacteria suspensions (106 CFU/ml), separately. In buffer saline (NaCl of 1 mM with pH= 7). Under aerobic conditions, the mixture was incubated for 24 hours at 37 °C and 150 rpm of agitation. By applying 50 µl of suspension to the surface of a nutrient agar plate and incubating it at 37 °C for 24 hours, a viable count was performed in triplicate. Colony forming units (CFU/ml), which represent the colonies were counted, this ASTM-required test (E2149-10).

3. RESULTS AND DISCUSSION

XRD ghas been utilized to analyze the sample's phase using Cu K radiation with a 0.154 nm wavelength. From the peak height measurements of the individual peaks, the relative phase of the sample was estimated. Comparison of the International Centre for Diffraction Data's PDF-2 and PDF-4 reference data allowed for the identification of crystal phases (ICDD). Figure 2 illustrates the identification of the NiO sample using the XRD diagram. The peaks at the 2θ angles of 37.3°, 42.9° and 62.5° are pointed to the planes (1 1 1), (2 0 0), (2 2 0) respectively.

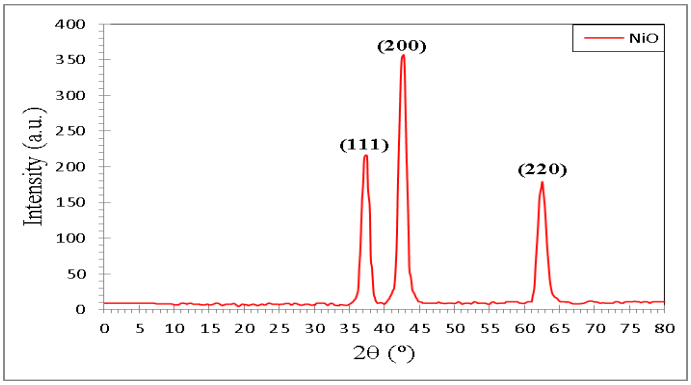

Figure 2.- Nickel oxide sample's X-ray diffraction (XRD) spectral data.

3.1 ANTIBACTERIAL ACTIVITY

This test's goal was to assess the sample's antibacterial activity against two highly prevalent oral bacteria (E. coli and (S. aureus). The tests were conducted at 37 °C, and the results revealed that the suspension of the sample has a significant antibacterial effect on these two strains of bacteria (E. coli) and (S. aureus).

Figure 3 (a & b) illustrates the control bacterial growth on the cultured media and the inhibitory effect of the specimen's suspension as determined after 24 hours of exposure to the bacterial suspensions. Temperature was a significant factor as well because, as shown in Figure 3, antibacterial activity was always more potent at 37 °C. The samples had a remarkable inhibitory effect, showing a reduction in the CFU of two oral bacteria when compared to the initial inoculum (106 cell/ml) and the controls, respectively, within two to four hours of exposure and increasing after 24 hours.

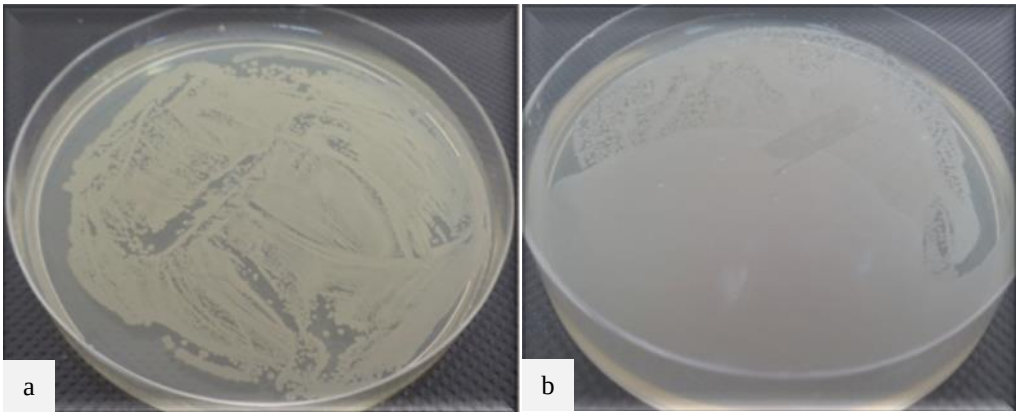

Figure 3. - E. coli and S. aureus bacteria growing on the nutrient agar medium (control).

The following mechanisms are proposed for nickel oxide's antibacterial action

1- When nickel particles come into contact with DNA and other substances containing sulfur and phosphorus, they destroy the bacterial cell.

2- After entering the bacteria, nickel particles interact with enzymes to make hydrogen peroxide, which causes the bacteria to die Ni^{+2} interacts with the bacterial respiratory chain enzymes, impairing respiration.

4. CONCLUSION

Other contaminants are not clearly visible peaks in the XRD data. The peak's relative severness (1 1 1) indicates that the nickel oxide crystal structure is very crystalline. The use of our sample would be especially beneficial to reduce the bacterial cross contamination brought on by bacterial infections like (E. coli) and (S. aureus).

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