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# An effective use of $VO_2$ and $Ag_2O$ thin films prepared by simple chemical method in different proportion as antibacterial

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In this research $Ag_2O$ and $Vo_2$ were prepared by using the simple chemical method in three different ratio S1$(VO_2)_{100\%}$, S2 $(VO_2)_{75\%}$ : $(Ag_2O)_{25\%}$ , S3$(VO_2)_{50\%}$ : $(Ag_2O)_{50\%}$, S4 $(VO_2)_{25\%}$ : $(Ag_2O)_{75\%}$ and S5$(Ag_2O)_{100\%}$ deposited on glasses substrate using the drop casting method . Both structural and optical examinations were conducted for these films, where the XRD examination confirmed the composition of each of the two prepared materials, with calculation of each of the crystalline size, micro strain and dislocation density. The AFM and SEM techniques showed that all the prepared films had smooth semi-spherical shapes with the presence of rough particles in very small quantity. The UV examination clearly showed that the two prepared films had a high transmission increases with increasing the wavelength with a very low absorbance within the range (200-1000) nm with calculation of the energy gap for both prepared films. The effective bonds of the two material $Ag_2O$ and $Vo_2$ were identified, which were different between stretching bonds and bending bonds using the FTIR technique. The two thin films were applied as antidotes to five different types of bacteria that are harmful to living organism. The effectiveness of these films in fighting these diverse bacteria was proven in this research.

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*Keywords:* Nano particals, Simple chemical method, Drop casting, Thin films, Antibacterial

## 1. Introduction

The study of thin films manufacturing technology has opened up many areas of scientific research, especially in the physics specialties, so this combination between technology and science of the material provides us a big foundation for the nanotechnology [1]. Also these films are suitable for many electronic, optical and medical application, as they represent the key to continuing technological process [2]. thin films which are a term used to describe a layer or several layers of atoms of matter whose thickness does not exceed one micron prepared by physical and chemical methods, have properties and characteristics that are not available in other material compositions. After the introduction of Nano materials that are prepared by specific methods and techniques such as silver oxide($Ag_2$ o) and vanadium oxide (Vo2) which are called semiconductor to metal transition [3] and they found in nature in the form of minerals and in a crystalline structure cubic (FCC) are considered important materials in films manufacturing applications because they possess many ideal physical and chemical features and properties[4,5] also in medical applications such as creating bio compatible , anti-corrosion protective coating and antibacterial agent that causes major health problems for organisms [6] with harmful effects on humans and animals[7] Ag2O NPs have been prepared by through several physical and chemical methods such as chemical reductions[8,9] microwave irradiation[10] laser ablation [11,12] Many methods have been used to prepare $VO_2$ nanoparticles, such as sol-gel method [13,14], the

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hydrothermal method [15,16], solid-phase method [17], the hydrothermal method is the most commonly used [18] .Silver and Vanadium oxide are new materials with antibacterial and properties as they are the strongest metal ions among many other materials that can be used safely for their non-toxic and wide -ranging properties . the mean objective of this research is to prepare thin films that are antibacterial from silver and vanadium oxide in different proportion by using the simple chemical methods to solve the problem of the bacteria which is considered one of the simplest and inexpensive methods which is summarized by mixing many materials together in different proportions until the required material is obtained.

## 2. Materials and method

### 2.1. Preparations of $Ag_2O$ nanoparticles by chemical method

Silver nitrate solution was prepared through a carefully controlled process to ensure optimal synthesis conditions. Initially, 0.89 g of silver nitrate (AgNO2) was accurately measured and dissolved in 100 mL of deionized water. The solution was stirred thoroughly and maintained at a temperature of 348 K (75 °C) for 30 minutes to facilitate complete dissolution and ensure uniform mixing. Subsequently, 15 mL of sodium hydroxide (NaOH) solution, prepared at a concentration of 0.1 M (equivalent to 4 g of NaOH per 100 mL of deionized water), was gradually introduced into the silver nitrate solution. The addition was done slowly and with continuous stirring to ensure controlled reaction kinetics and to avoid localized precipitation. The reaction was carried out under these conditions to optimize the interaction between $Ag^+$ ions and $OH^-$ ions. The appearance of a brown color in the solution indicated the formation of a silver oxide intermediate, which is a precursor to various silver-based nanoparticles. The brown coloration is characteristic of the reduction and transformation processes occurring in the system, signaling the initial stages of nanoparticle synthesis or compound formation. This controlled method lays the groundwork for further steps in the synthesis of silver nanoparticles or related materials.

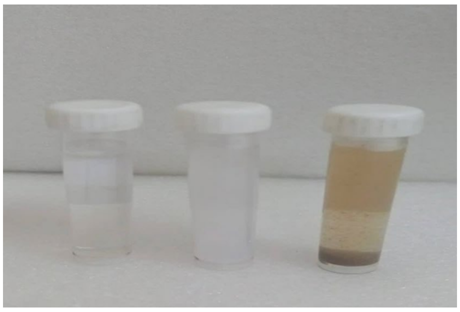

*Fig. 1. The materials from left in orders are NaOH, $AgNO_3$ and $Ag_2O$.*

### 2.2. Preparations of $Vo_2$ nanoparticles by chemical method

The preparation of vanadium involved dissolving 1 g of vanadium compound in 100 mL of deionized water under controlled conditions to ensure uniform solubility and proper mixing. The process was carried out at an elevated temperature of 343 K (70 °C), maintained consistently for 30 minutes. The elevated temperature was chosen to enhance the solubility of the vanadium compound in water, ensuring complete dissolution and preventing the formation of insoluble particles or aggregates. The solution was continuously stirred during this period to facilitate homogeneous mixing and to accelerate the dissolution process. This preparation method resulted in a clear and uniformly distributed vanadium solution, which serves as a precursor for various applications, such as catalytic reactions, synthesis of vanadium-based nanomaterial's, or as an additive in chemical processes. The controlled conditions ensured the stability of the vanadium ions in solution, minimizing the risk of precipitation or unwanted side reactions.

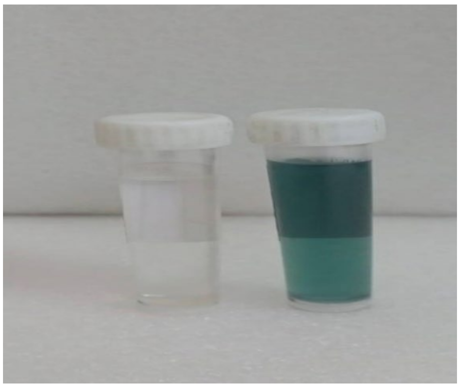

*Fig. 2. The material from the left in order are water and vanadium.*

After the two materials are prepared, the $Ag_2O$ and $VO_2$ are mixed in three different proportions to obtained the following proportions of the samples as it shown in figure (3), 5 drops of the two prepared material are deposited on glasses substrate at 323K temperature using the drop casting method with a special syringe and left to dry for a half an hour.

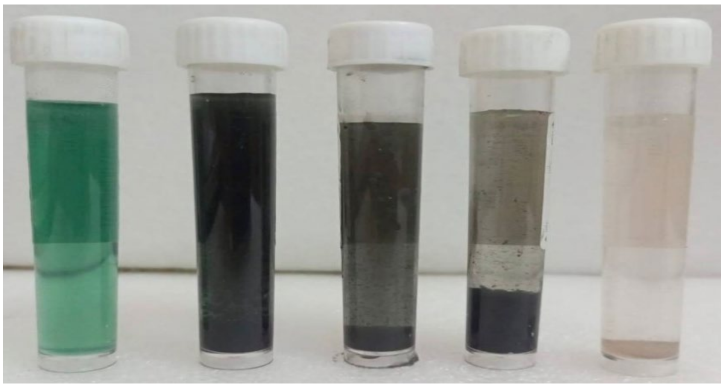

*Fig. 3. The mixed materials from left in order S1$(VO_2)_{100\%}$, S2 $(VO_2)_{75\%}$ : $(Ag_2O)_{25\%}$ , S3$(VO_2)_{50\%}$ : $(Ag_2O)_{50\%}$ ,S4 $(VO_2)_{25\%}$ : $(Ag_2O)_{75\%}$ and S5$(Ag_2O)_{100\%}$..*

$VO_2$ and $Ag_2O$ nanoparticals were characterized by the following important testes such as the x-ray diffraction (XRD) to ensure the crystalline structure of the two prepared materials, UV-visible spectrophotometer to calculate both of energy gap, absorbance and transmittance also the atomic force microscope (AFM), FTIR to show the functional groups of $VO_2$ and $Ag_2O$ and the scanning electron microscopy (SEM) to explain the topographic nature of the surface of the two prepared materials.

### 3. Result and discussion

The X-Ray diffraction patterns of $Ag_2O$ and $VO_2$ thin films are shown in figure 4(a,b) by using the XRD6100 shimadzu device. We can notice that the prepared $Ag_2O$ thin film is cubic with appearance of three peaks (110), (111) and (200) at different angles (26.62), (32.76) and (38.1) respectively as it shows in fig(4)(a), all the peaks of diffraction can be assigned to Ag2O (JCPDS No. 41-1104). while in fig (4)(b) for the $VO_2$ we can notice several peaks (111),(201),(310),(002),and(202) at different angles (25.5),(28.19),(33.1),(38.5), and (44.95) which is agreed with the card XRD (JCPDS No. 33-1441). The crystalline size of each of the prepared films was calculated using Scherrer's equations $G.S = 0.9\lambda / \beta \ cos$ [19-20] while other equations $\delta = 1/GS\ 2$ , $\eta = \beta \ cos\theta/4$ [21] were used to calculate both the dislocation density and the micro strain conformity as shown in tables (1)and(2),the simple chemical method proved to be very suitable for preparing $Ag_2O$ and $VO_2$ , in addition to the suitability of the drop casting method for oxidation $Ag_2O$ and $VO_2$.

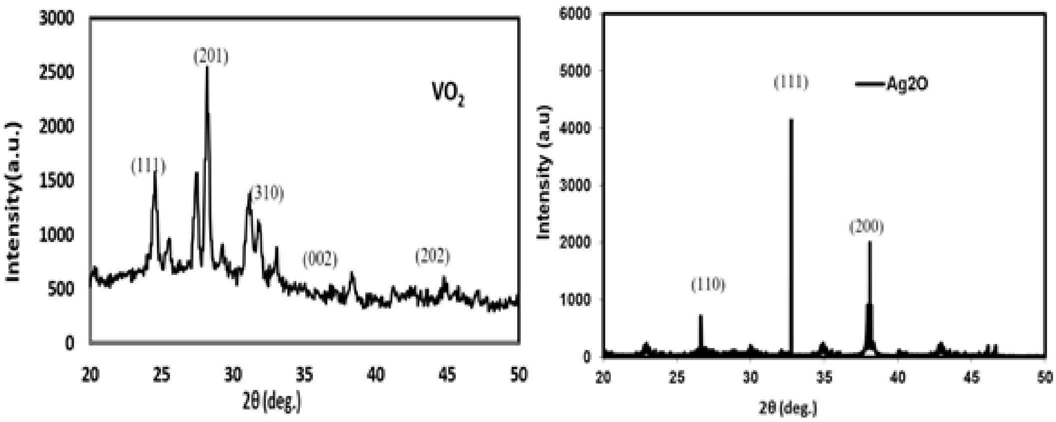


*Fig. 4. X-Ray diffraction (a) of the $Ag_2O$ and(b) of the VO2.*

*Table 1. XRD parameters of the $Ag_2O$.*

| Pos. [°2Th.] | (hkl) | $G.S$ (nm) | $\eta * 10^{-2}$ | $\delta * 10^{15}$ (lines/$m^2$) |
|---|---|---|---|---|
| 26.62 | 110 | 42.66 | 4.86 | 0.549 |
| 32.76 | 111 | 56.89 | 3.64 | 0.308 |
| 38.1 | 200 | 47.41 | 4.37 | 0.447 |

*Table. 2. XRD parameters of the $VO_2$.*

| Pos. [°2Th.] | (hkl) | $G.S$ (nm) | $\eta * 10^{-2}$ | $\delta * 10^{15}$ (lines/$m^2$) |
|---|---|---|---|---|
| 25.5 | 111 | 44.90903 | 4.6 | 0.495 |
| 28.19 | 201 | 56.89429 | 3.6 | 0.308 |
| 33.1 | 310 | 34.1423 | 6.07 | 0.857 |
| 38.5 | 002 | 30.46383 | 6.8 | 1.07 |
| 44.95 | 202 | 28.43764 | 7.2 | 1.23 |

Figure 5(a, b) presents the scanning electron microscopy (SEM) images of the prepared $Ag_2O$ and $VO_2$ thin films synthesized using a simple chemical method. The images revealed that the thin films exhibit surfaces composed of uniformly distributed clusters with an average size of approximately 1 μm. These clusters are indicative of the aggregation of smaller grains, which coalesce to form a larger morphological structure. The observed morphology suggests a high degree of surface roughness, which can significantly influence the films' optical, electrical, and catalytic properties, making them suitable for various applications such as sensors, photovoltaic, or photocatalysis.

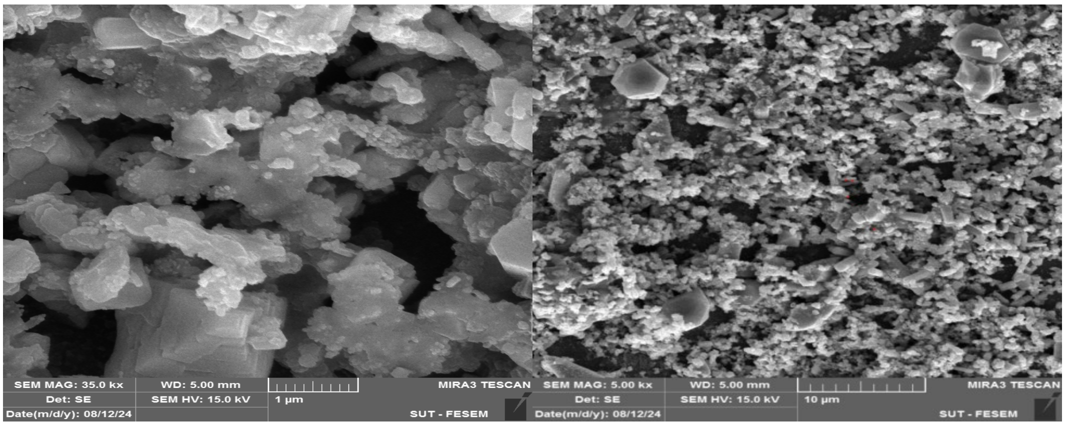


*Fig. 5. (a) SEM image of $Ag_2o$.*

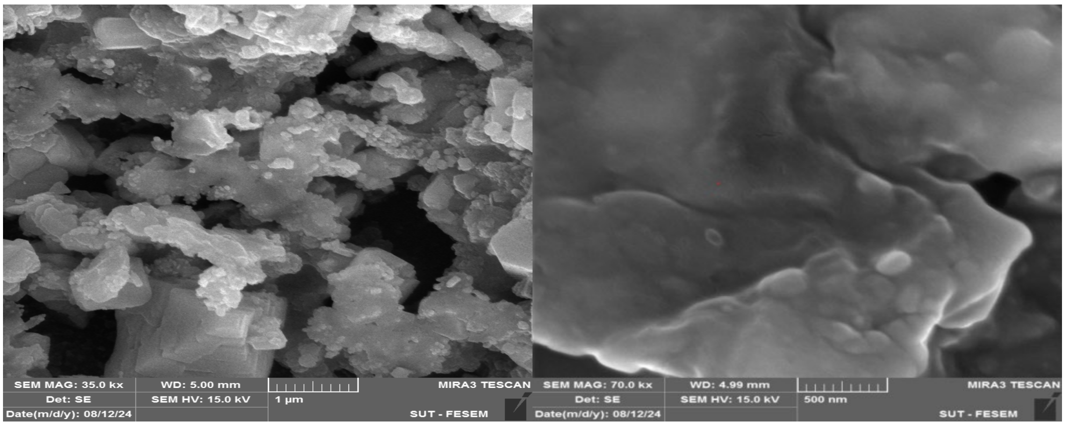


*Fig. 5. (b) SEM image of $VO_2$.*

Figure 6(a,b) shows the dimensional spherical images of the both thin films by using the atomic force microscopy (AFM) technique . the average diameter of the prepared $Ag_2O$ thin film by the chemical simple method is 19.6nm while in $VO_2$ thin film is 14.9nm also the figure shows that the two membranes have Nano scale particles that are homogeneous on the surface, with the greatest accumulation of atoms or the greatest homogeneity of the two membranes at the surface being within the range (1.0-2.0)μm, with the presence of large particles on the surface in a very small quantity of about 2μm.

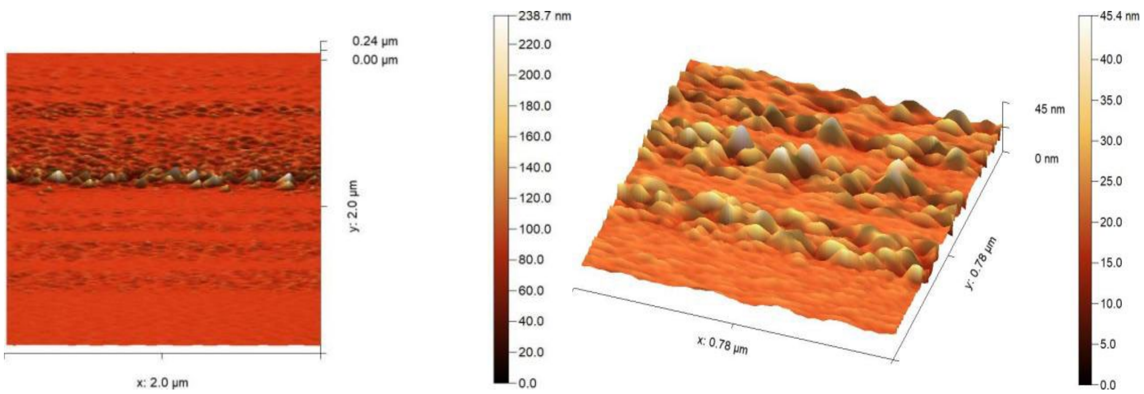


*Fig. 6. (a) AFM image of $Ag_2o$ thin film.*

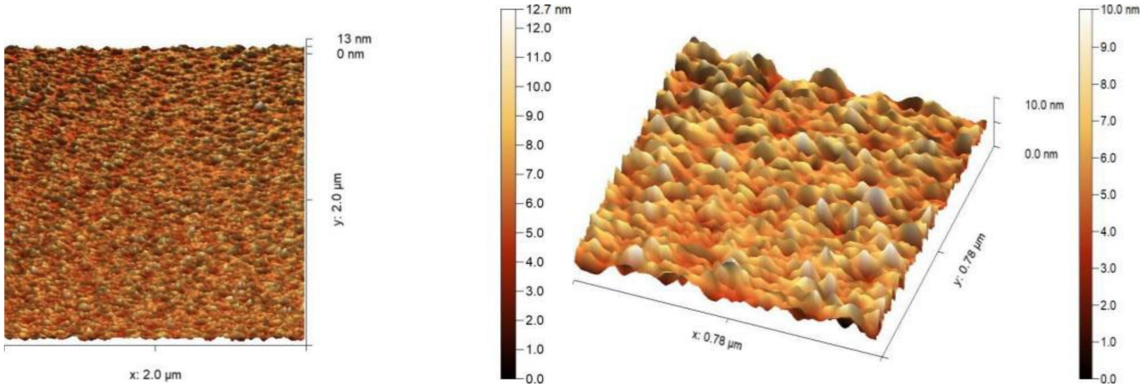


*Fig. 6. (b) AFM image of $VQ_2$ thin film.*

*Table 3. AFM parameters of the $Ag_2o$ and $Vo_2$ thin films.*

| Samples | Average value(nm) | RMS roughness (Sq)(nm) | Mean roughness (Sa) (nm) |
|---|---|---|---|
| $Ag_2O$ | 19.6 | 9.98 | 5.02 |
| $VO_2$ | 14.9 | 1.30 | 1.03 |

Figure7(a,b) shows the FTIR technique for both prepared films which is very important to provide valuable information about microbial cells and their differentiation from each other also to detect the bands that responsible from the stability of the nanoparticles thin films [22] .figure(7a) for the $Ag_2O$ material shows the appearance of several peaks for different bonds groups . the strongest peaks appears at 3395cm$^{-1}$ was assigned to the bending vibration of (O-H)group, while the peaks at 1075,1355 and 1662 cm$^{-1}$ were assigned to the stretching vibration of (C-O) , (C-H) and (C=C) groups respectively[23]. figure(7b) for the $VO_2$ material also have several peaks for different bonds groups , the strongest peaks appears at 3377cm$^{-1}$ was assigned to the bending vibration of (O-H)group, while the peaks at 2021 and 1628 cm$^{-1}$ were assigned to the stretching vibration of (C=C) group, the last peak at 1075cm$^{-1}$ was assigned to the stretching vibration of (C-O)group. The FTIR results showed that the two prepared thin films have mostly single inactive bonds of the (stretching) type. Accordingly, the absorbance is low and the transmittance is high with increasing wavelength, as shown in the UV test in figure(8).

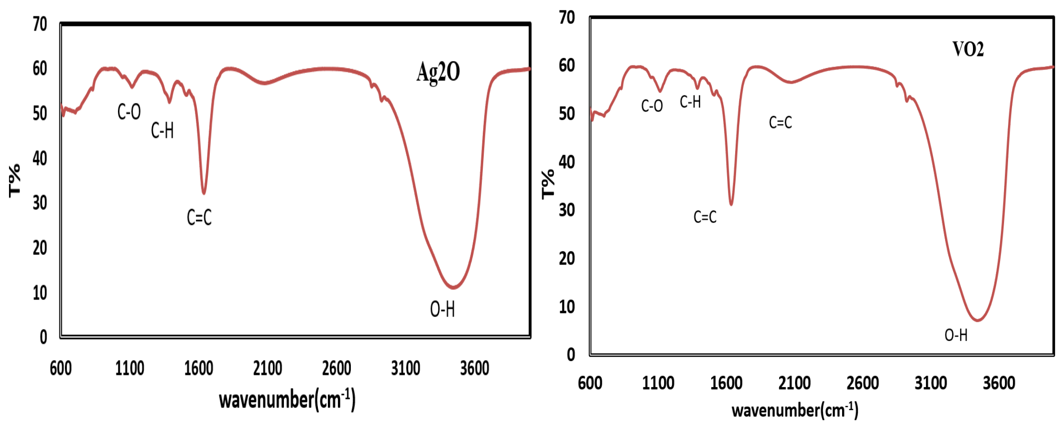


*Fig. 7. FTIR spectra (a) of the $Ag_2O$ thin film and (b) of the $VO_2$ thin film.*

The optical properties of the two films prepared by the simple chemical method were studied by using the UV- Visible 1800 spectrophotometer device. The figure8 (a) shows the transmittance spectrum of the $Ag_2O$ film within the range (200-1000) nm, as the transmittance increases with increasing wavelength to reach maximum at wavelength 1000nm. The optical properties of the two deposited films depend on the process time, the temperature of the substrates, and deposition condition. The optical energy gap rate was calculated by the absorbance of the prepared films [24-25]. The figure8 (b) shows the absorbance spectrum of the $Ag_2O$ film. the optical energy gap of the $Ag_2O$ also measured by applying tau's equation and it was equal to (3.05) eV as it shows in figure 8(c) these results were slimier to others researches [26].

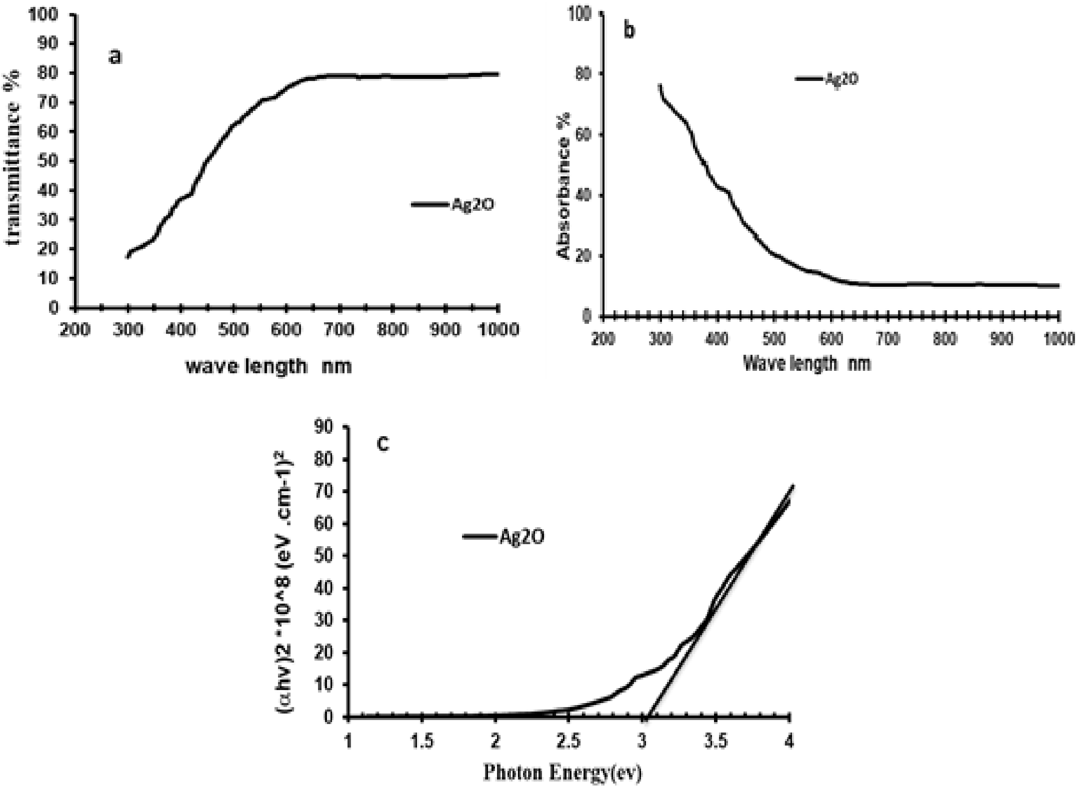


*Fig. 8. (a) Transmittance spectrum (b) Absorption spectrum (c) Eg gap of $Ag_2O$.*

The transmittance spectrum as a function of wavelength of the prepared thin film was examined in figure 9.(a)and it was found that the $VO_2$ thin film has a high transmittance that increase with increasing wavelength , with decreasing absorbance that decrease with increasing wavelength as shown in figure 9.(b) the optical energy gap of the $VO_2$ was calculated and it was equal to (2.65)eV as it shows in figure 9.( c ).

After studying the optical properties , we notice that the absorbance of the two prepared films decreases with increasing wavelength , which is attributed to several reasons , including the smoothness of the surface of the two films ,which is confirmed by the AFM technique in figure (6) , in addition to the fact that the incident photons can no longer excite the electrons and transfer them from one beam to another because the photon energy is less than the value of the optical energy gap of the two prepared films. the transmittance is high for the two prepared films considering that it behaves in the opposite direction to the absorbance spectrum [27], which makes these films suitable for many applications. these results were slimier to others researches in the same method and different substance [28]

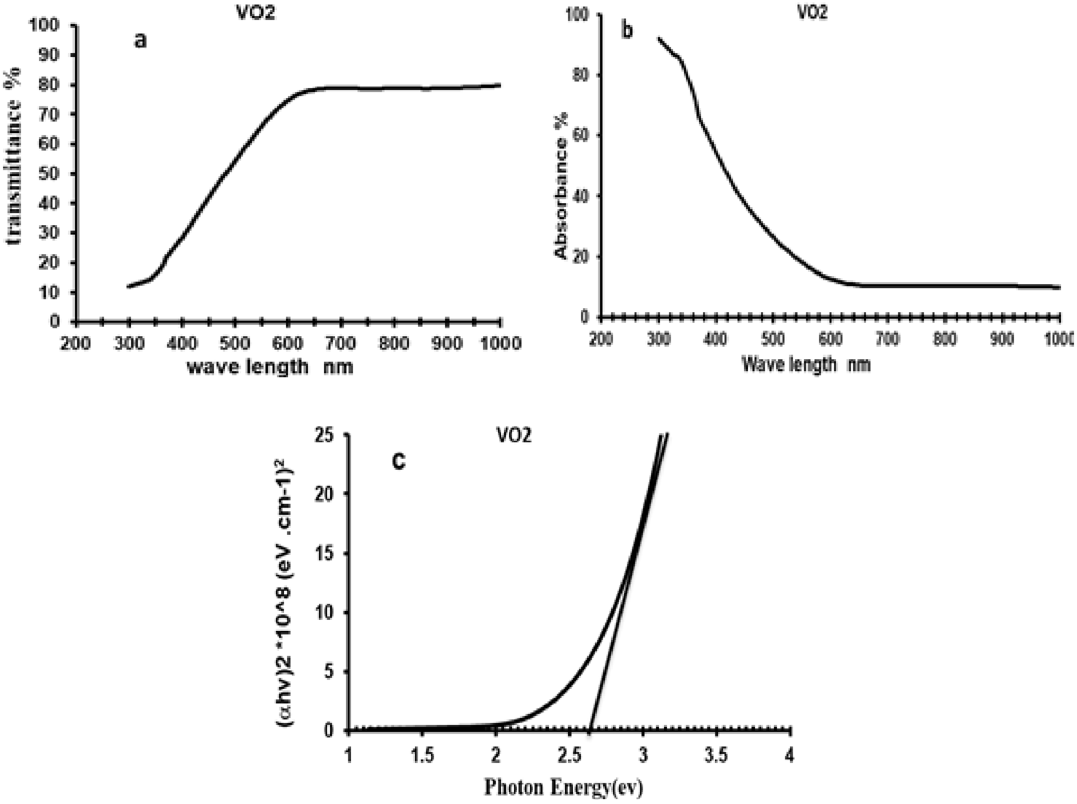


*Fig. 9. (a) Transmittance spectrum of $VO_2$ (b) Absorption spectrum of $VO_2$ (c) Eg gap of $VO_2$.*

Figure (10) shows a group of different types of bacteria and the effect of each of the two films $VO_2$ and $Ag_2O$ prepared by the simple chemical method on them. The figure shows that the two prepared material that mixed in different proportion have the stronger effect on the bacteria compared to the effect of the two material individually as a result the Nano bodies inters into the DNA structure of these type bacteria and creating a defect in this structure, the partials of these prepared material work by increasing the percentage of reactive oxygen , including the formation of free radicals in addition to their interaction with the enzymes of the respiratory chain of bacteria , this consistent with [29].And they also attack the surface of the these Bactria, thus inhibiting the growth of proteins and the work of the nuclear material and stopping the metabolic pathways inside the bacterial cell and thus hindering the growth of bacteria. Which gradually reduces the effect of these bacteria until they die . We note that the highest antibacterial effect is in Sample 3 ( $Vo_2)_{50\%}$ : $(Ag_2O)_{50\%}$ , against bacteria of type klebsiella SP and the lowest antibacterial effect is in sample 1 $(VO_2)_{100\%}$) against bacteria candida albicans. Other studies have used the electrolysis simple method to prepare special films to reduce the effect of the harmful bacteria , and have shown better results than this study against the bacteria of the type staphylococcus aureus, Escherichia coli [30] and Staphylococcus epidermis type as it shown in other research[31].

*Table 4. The activity of antibacterial of different concentrations of $Ag_2O$ and $VO_2$.*

| **Bacteria's types** | **S1** | **S2** | **S3** | **S4** | **S5** |
|---|---|---|---|---|---|
| Staphylococcus aureus | 15 | 16 | 16 | 16 | 16 |
| Staphylococcus epidermis's | 10 | 20 | 20 | 21 | 20 |
| Escherichia coli | 11 | 19 | 18 | 18 | 19 |
| Klebsiella sp | 9 | 20 | 28 | 21 | 21 |
| Candida albicans | 8 | 20 | 20 | 21 | 22 |

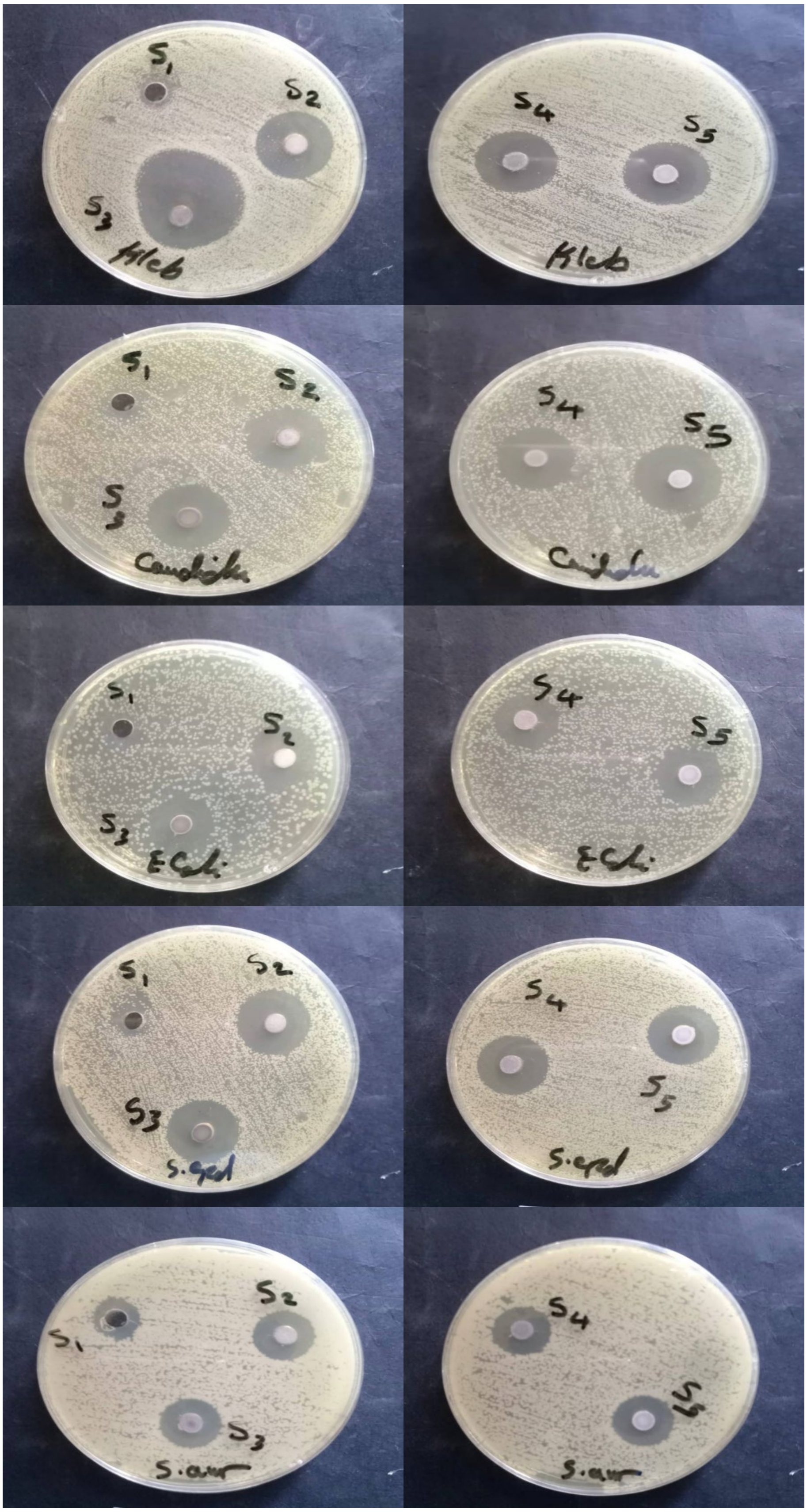


*Fig. 10. Biological activities of different concentrations of $Ag_2O$ and $VO_2$ against different type of bacterial.*

## 4. Conclusion

This research provides a comprehensive summary of the preparation and application of thin films of VO2 (vanadium dioxide) and Ag2O (silver oxide) using a simple chemical method. The chosen preparation method is characterized by being straightforward, cost-effective, fast, and highly accessible, making it ideal for producing nanostructured materials. The study explores the combination of these materials by mixing VO2 and Ag2O in three different proportions $(Vo_2)_{75\%}$ : $(Ag_2O)_{25\%}$, $(Vo_2)_{50\%}$ : $(Ag_2O)_{50\%}$, $(Vo_2)_{25\%}$ : $(Ag_2O)_{75}$. These mixed materials were then evaluated for their potential antimicrobial properties. Specifically, the prepared thin films were tested against five types of harmful bacteria known to negatively impact living organisms. The aim was to determine their effectiveness as antibacterial agents, assessing their ability to inhibit bacterial growth. This research highlights the potential of $VO_2$ and $Ag_2O$ nanostructures as promising candidates for developing antimicrobial coatings and treatments, contributing to advancements in combating bacterial infections.

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