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### introduction

Nanotechnology is going to be a main pushing factor behind the continuing technological revolution in the 21st century. Today, modernization is not limited to the tech sector development and its infrastructure, but also to the numbers of researchers, applications of nanoscience, in addition to Nanotechnology Characterization Laboratories (NCL), which have the potential of producing new materials and products that may revolutionize all areas of life. Iraq, as a developing country, has suffered, for decades, from war and international isolation that have caused research and publication to fall behind in publishing high-quality academic articles, particularly in the cutting-edge area of nanotechnology, compared to other countries.

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- Synthesis and Self-Assembly of Nanostructured Materials, Films Functionalization, Size-Dependent Properties of Nanocrystals, and Quantum Dots and Nanowires.

- Processing and Templating of Nanotubes and Nanoporous Materials.

- Tailoring of Polymeric Nanoparticles, Organic-Inorganic Nanocomposites and Biohybrids.

- Fabrication of Nano and Micro Electro Mechanical Systems.

- Design and Engineering of Structural and Functional Nanomaterials.

- Nanosystems for Biological, Medical, Chemical, Catalytic, Energy and Environmental Applications.

- Nanodevices for Electronic, Photonic, Magnetic, Imaging, Diagnostic and Sensor Applications.

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- Design and Engineering of Structural and Functional Nanomaterials.

- Nanosystems for Biological, Medical, Chemical, Catalytic, Energy and Environmental Applications.

- Nanodevices for Electronic, Photonic, Magnetic, Imaging, Diagnostic and Sensor Applications.

### Aims & Scope

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# Procedures For Dealing With Unethical Behavior, count.

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#### The Application of Nanomaterials to Increase Solar Cell Efficiency: A Review

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#### **Keywords:** Abstract Nanomaterials; The findings demonstrated that nanoparticles have significant Solar cells; Plasma method; potential for use in improving photovoltaic cell performance, (CVD); particularly in the area of thin film PV systems. Compared to Nanoparticles (NPs). conventional wafer-based or thin-film systems, nanomaterials of solar cells may offer advantages in terms of cost, innovative charge separation methods, strain relaxation effects, and optical, electrical, and mechanical properties. All findings point to the possibility of successfully enhancing solar cell performance through the use of ultrawide band gap oxide semiconductor nanomaterials. At the TiO2/hole conductor contact, gold and silver nanoparticles (NPs) produce sustained plasmonic photocurrents as well.

#### Introduction

Nanotechnology is one of the hottest areas of research and development right now, and this is true across the board in the technical sphere [1]. Nanotechnology can be utilised to generate new materials, allowing for the design and construction of new buildings and assets with improved functionality, higher performance, lower maintenance costs, and novel optoelectronic/magnetic material properties [2]. A nanometer measures down to the billionth of a metre (nm). For a material to be considered nanoscale, its smallest component must be between one and one thousand nanometers in size. Nanomaterials study takes a materials science perspective on nanotechnology. These materials often have distinctive qualities because of their size, shape, and chemical composition [3].

Methods like chemical vapour deposition and laser ablation are two (CVD) [4], these nanostructures are produced by using various techniques. The increased surface area of nanoparticles and the

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associated quantum effects set them apart from more traditional materials. Nanomaterials are filled into the nanopores of the templates and, by etching the template, nanowires or nanotubes with similar diameter and length as the template nanopores are obtained. Because the size and shape of the nanomaterial that depends on the nanoholes of the template, fabricating a template with uniform pore diameters is very important.[5]. Solar cells, commonly known as photovoltaic cells, are electronic devices that convert solar radiation directly into usable electricity. The photovoltaic effect can be either natural or manufactured [6]. ZnO NPs and other oxide semiconductors were used to construct the porous electrode, however porous anatase TiO2 nanoparticles (NPs) sheets in a solar cell yield the highest efficiency. In thin films it has been reported that the anatase structure has higher mobility for charge carriers versus the rutile structure. For photocatalytic processes, anatase is the preferred structure, although all three forms have shown to be photocatalytic. The electronic structure of brookite is similar to anatase, based on minor differences in the local crystal environment [7]. ZnO NPs, with a band gap of 3.37 eV and electrical properties similar to TiO2, can be used as an electrode material in solar cells [8].

#### Solar cells

The use of photovoltaic cells to generate electricity is a hotly debated topic in the context of renewable energy. After O'Regan and Graetze discovered the solar cell, they developed nanocrystalline TiO2 solar cells. High conversion efficiency, low part costs, simple production, and plentiful availability are only a few of solar cells' many benefits. [10]. The solar cell has four main components: a counter electrode, an electrode formed of nanomaterials (like TiO2, SnO2, or ZnO), a transparent conducting oxide substrate (like FTO or ITO), and an electrolyte that acts as a redox mediator [11]. Research was conducted by Kei Muraoshi and others to test the impact of TiO2 nanoparticles on solar cell efficiency, pyrrole was photoelectrochemically polymerized on a porous nanocrystalline TiO2 electrode that had been sensitised by the Gratzel dye [12]. Research comparing ZnO nanoparticle layers produced by two different technical techniques was proposed by Znajdek et al. They looked at how a thin film of zinc oxide (ZnO) nanoparticles may perform in a solar cell. The findings indicated that ZnO nanoparticles could be employed to improve solar cell efficiency, particularly in thin film PV systems, thanks to their promising potential as down converting layers, especially in thin-film PV systems that can be used to improve the efficiency of solar cells [13].

#### Working methods

#### 1. Some of the chemical methods

#### a. Thermal decomposition

Thermolysis, also known as thermal breakdown, is the chemical breakdown brought on by heat. Since this technique is endothermic, energy must be supplied in the form of heat in order to break the chemical bonds in the target substance. If the heat released during decomposition is high enough, the system may enter a runaway thermal state due to a positive feedback loop. In order to create TiO<sub>2</sub> nanoparticles, Chin et al. utilised a tubular electric boiler and TTIP, breaking down the TTIP thermally at different synthesis temperatures (700-1300 °C). The photocatalytic activity of the manufactured TiO2 nanoparticles was determined by measuring the rate at which methylene blue is decomposed in the presence of high temperatures (80-110 °C). The material was characterised with X-ray diffraction (XRD), Brunauer-Emmett-Teller (BET) studies, and transmission electron microscopy (TEM) [14]. Several experimental results suggest that as catalysts, nanometals far outperform their nanosized metal oxide counterparts. When oxygen-containing species are produced during metal breakdown, they can mix with the metal. In comparison to nanoparticles of metal oxide, the catalytic activity of metals is enhanced due to the high temperatures required for their generation [15].

#### b. Electrochemical synthesis

An electrochemical cell can be used for a process known as electrochemical synthesis. The capacity to carefully regulate the selected voltage and the rejection of potentially wasteful alternative half-reactions are the key advantages of electrochemical synthesis over conventional chemical techniques. Recently, there has been a lot of interest in the electrochemical method of creating nanoparticles. This electrochemical process involved dissolving a metallic anode in an aprotic solution [16]. Electrochemical synthesis allows for the rapid production of nanostructured energy materials with benefits including cheap cost, high purity, simplicity, and environmental friendliness. One may easily produce many different types of nanostructures, such as nanorods, nanowires, nanotubes, nanosheets, dendritic nanostructures, and composite nanostructures [17].

#### 2. Physical techniques

a. Plasma

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Nanoparticles are fabricated using a plasma process. To generate plasma, electric current is passed through radio frequency (RF) heating coils. The first metal is sealed in a pestle inside of an airtight container. High voltage RF coils are wrapped around the hoover chamber, heating the metal until it evaporates. The gas employed in the process, enters into the system and produces a hot plasma in the area around the coils. When metal vapour rises to a cold collecting rod, metal atoms form on the helium gas atoms, and the vapour is collected and passivated by oxygen gas to create nanoparticles [18]. The generation of nanoparticles in ionic liquids by using unrestrained electrodes of constant glow discharge plasmas was studied by Höfft et al. Many different aspects of plasma electrochemistry, including the basics, are covered. One area of research examines how collisions between plasma and ionic liquid affect the development of particles. It has been suggested that plasma, formed from ionic liquids, could provide an explanation for nanoparticle [19].

#### b. Deposition of chemical vapor

The process of chemical vapour deposition involves a chemical reaction (CVD). Thin films of a wide variety of materials are often created using the CVD method when semiconductors are being produced. An ideal deposit is produced when a volatile precursor or precursors are applied to a substrate and then decay. Precursors are vaporised and then introduced to a deposition of chemical vapour receptacle, where they react with a heated substance at a high temperature. Chemical processes take place or molecules breakdown to create crystals after being adsorbed. The CVD process consists of these three steps:

- 3. Above the forming surface, reactants are carried by a border layer.
- 4. A growing thing's surface is the site of many chemical interactions.
- 5. Phase gas reaction byproducts must be innocuous on the surface.

Heterogeneous nucleation occurs on the substrate, while regular nucleation occurs in the gas phase. By taking use of a chemical reaction that takes place in the gaseous phase, the CVD technique has the potential to create ultrafine particles with a size of less than 1 m. When the process is under control, nanoparticles between 10 and 100 nm in size can be created [20]. To create a durable silica membrane with a good H2/N2 permeance ratio, Nomura et al. used TMOS and O2 as reactants in a counter diffusion chemical vapour deposition method at 873 K (above 1000). By introducing TMOS and O2 into the substrates' opposing geometries, a silica layer was formed within the substrate pores. As the deposition temperatures rise, the apparent activation energies across the silica membranes rise too. The

activation energy for H2 to pass through the membrane was around 20 kJ mol-1. Pa1 H2 permeance measurements at 873 K were 1.5 107 mol m2 s1. Under normal methane steam-reforming circumstances, the H2/N2 permeance ratio was stable for 21 hours [21].

#### 3. Benefits of nanomaterial in solar cell

The last decade has seen a rise in the number of scientists and engineers interested in studying solar cells and nanomaterials. Solar cells made from nanmaterials may provide several benefits over traditional wafer-based or thin-film systems, including lower production costs, novel charge separation methods, strain relaxation effects, and improved optical, electrical, and mechanical characteristics. Nonetheless, there are situations in which planar solar cells do better than their axially connected or randomly arranged counterparts [22]. Dong and his associates looked into the interfacial charge dynamics controlled by producing a Ga2O3/SnO2 electron-transporting bilayer, with Ga2O3 inserted between fluorine-doped tin oxide and SnO2 NPs. This research suggests that the ultrawide band gap oxide semiconductor Ga2O3 might be used as a nanomaterial to boost solar cell efficiency [23]. Recent research has shown that the plasmonic properties of metallic nanoparticles can considerably boost the performance of solar cells because plasmonic nanoparticles can only be applied to a fraction of the surface area of solar systems (typically less than 30%). Increasing the Jsc of textured screen-printed solar cells by more than 2.5% through the use of plasmonic light-trapping is challenging. To go above and beyond the Jsc enhancement limit, a novel approach is needed to account for the parasitic absorption by the nanostructure [24]. Research was carried out by Reineck et al. to show that gold and silver nanoparticles (NPs) create persistent plasmonic photocurrents at the TiO2/hole conductor interface. The spectral photocurrent response closely follows the bands of surface plasmon absorption by the metal particles. Here, we present a straightforward method of using nanoparticle self-assembly in solar cell production [25].

#### 4. Nanomaterials

Substances having dimensions of 100 nm or less, at least one unique attribute that distinguishes them from bulk materials, and the potential to be used in a wide variety of applications, including nanoelectronics, are considered nanomaterials. Form, composition, and X, Y, and Z dimensions are only some of the ways according which nanomaterials may be sorted [26]. At least one of a material's dimensions must be on the nanoscale for it to be considered a nanomaterial. Quantum dots (or 0D), 1D and 2D (nanotube, nanowire, and nanorod), 2D (nanofilm), and 3D (such as bulk materials composited

with nanoparticles) are the most common dimensions used to categorise nanomaterials [27]. Singlewall nanotube (SWNT) or two-or-more termed multi-wall tubes multi-wall nanotube (MWNT) are the most common types of nanotubes, with one end open and the other closed in the shape of a hemisphere due to the possibility of individual atoms composing the tube's wall (MWNT). The tubes that make up the nanowire range in size from less than one nanometer to 100 nanometers in diameter and up to 100 micrometres in length, making them 50,000 times thinner than the width of a human hair. Nanotubes may be found in many different configurations, such as the straight, spiral, zigzag, bamboo, and conical tube. These tubes exhibit exceptional properties, like as strength, hardness, and electrical conductivity [28].



Figure 1 : Siegeli's definition of nanomaterials [29].

a.0D b.1D c.2D d.3D

A very high surface-to-volume ratio is required of nanoparticles. As a result of this unique quality of nanomaterials, novel quantum mechanical phenomena may emerge [29]. As was previously noted, nanomaterials may be sorted into distinct classes according to their chemical composition and shape (dimensionality) [27]. Finally, nanotechnology is one of the most important technologies of the present and future. Physicists, chemists, biologists, and engineers alike see this cutting-edge technology as a crucial research area because of its potential to revolutionise their respective disciplines and bring about positive change for all of mankind [30].

#### Conclusion

The use of nanomaterials in solar cell technology is only one example. Increasing the Jsc of textured screen-printed solar cells by more than 2.5% through the use of plasmonic light-trapping is challenging.

When trying to beat the Jsc enhancement limit, a novel approach that takes into account the nanostructure's parasitic absorption is required. Solar cells may also benefit greatly from the incorporation of ultrawide band gap oxide semiconductor nanoparticles.

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#### Using ZnO/PMMA Nanocomposite Coating to Improve the Polycrystalline Solar Cell in Hot Weather Conditions

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#### **Keywords:**

Polycrystalline silicon PV solar cell; ZnO/PMMA nanocomposite coating; Anti-reflection coating (ARC); Thin film thermal regulation; UV-mask; Zinc oxide (ZnO).

#### Abstract

Solar energy is the most significant future energy source as the world keeps working to minimize emissions caused by the use of fossil fuels. The most popular method for transforming sunlight into electrical energy is the photovoltaic solar cell (PV). The main two problems with PV solar cells highlighted in this paper are the high solar cell surface temperature and the high reflection light of PV solar cells. Because each 1 °C increase in surface temperature reduces efficiency by 0.45%, and approximately 35% of total sunlight reflected in crystalline silicon solar cells. In this experimental work, the sol-gel process was used to prepare different concentrations of zinc oxide/polymethyl methacrylate (ZnO/PMMA) nanocomposite coatings and apply them to the top side of the polycrystalline solar cell in order to increase the solar cell efficiency. The results demonstrate a maximum temperature drop of 8.6 °C and light reflection reduced up to 5.6%, so this led to an increase in solar cell efficiency from (11.33%)to (15.22%), where the results of the electrical properties after one hour (test time) showed that the uncoated cell was ( $I_{SC} = 0.33$  A,  $V_{OC} = 0.38$ V, and  $P_{max} = 97$  mW), while the results of the coated cell with the best concentration (3.875 wt%) were ( $I_{SC} = 0.36 \text{ A}$ ,  $V_{OC} = 0.43 \text{ V}$ , and  $P_{max}$ = 130 mW).

#### Introduction

One of the most significant renewable sources of energy sources is solar energy because of its minimal environmental effect and worldwide accessibility. In comparison to carbon-emitting fossil resources, solar energy is renewable and readily available to the general public, making it a critical green power source [1]. Solar cells have comprised of semiconductors which utilize photons from the sun to excite the electrons, resulting in a direct electric current and the conversion of energy from the sunlight,

whenever a PV solar cell is exposed to light, voltage - current are produced [2]. Photovoltaic systems (PVs) are one of the most potential solar energy harvesting approaches. The PV technology power generation system does have certain basic issues, such as snow, dust, high reflection light and the operating temperature, that can reduce the generator system's efficiency [3]. Solar cells usually operate in a temperature range of 50 °C to 55 °C or higher. Not all solar radiation absorbed by PV solar cell is converted into electricity, a large part of it converts into heat that causes the solar cell to heat up [4]. For example, solar cells are made of crystalline silicon, each increase in surface temperature by 1 °C leads to about 0.45% reduction in efficiency, as a result, the heat dissipation of a solar module is critical to lowering its temperature, which has a severe impact on energy output [5]. Normally PV solar cells are comprised of silicon (Si), which may be the second most prevalent substance found on the earth's mantle and has a high surface reflection characteristic. As a result, after striking the PV panel, approximately 35% of the entire amount of sunlight reflects, according to recent developments, either micro coating or nano-composite coating of antireflection compounds on the PV panel improves solar energy conversion and compounds that are fluorescent to lower the conversion rate capabilities that can be used to solve the high temperature problem [6]. The sun is located 150 million kilometers away with a solar constant of 1367 w/m<sup>2</sup>, this number changes by  $\pm 3\%$  depending on how far the Earth is from the Sun. The light we see every day is only a small part of the total energy generated by the sun. It is an electromagnetic wave that extends from gamma rays to radio rays, among which are X-rays, ultraviolet, visible, infrared, and microwave rays, the photon's energy and the wavelength of light are inversely related [7]. The sunlight in ground level consists of 44% visible light, 3% ultraviolet light and the remaining is infrared light. Since the atmosphere blocks 77% of the sun's UV-radiation [2].

The solar cells have comprised of semiconductors which utilize photons from the sun to excite the electrons, resulting in a direct electric current and the conversion of energy from the sun. Whenever a PV cell is exposed to light, voltage - current are produced. Although the connection between absorbed light and electricity generated production is linear, numerous factors influence the solar cell performance and, as a result, its output power. The operating temperature has a great impact on the efficiency of the PV cell. The photovoltaic cell's produce electrical current that passes across a P-N junction. As a result, only photons with energies equal to or greater than the band-gap energy are engaged, whenever the energy of a photon exceeds the energy bandgap, electrons are liberated, and the excess is transformed into heat, raising the temperature of the solar cell, so about 20% of overall light is transformed into electrical energy, and the remaining is wasted as light reflects, as heat in the silicon semiconductor, or light that passes along the photovoltaic cells without being absorbed or reflected. The formation of electrical charge and heat in solar cells are caused by the activation of the semiconducting of sunlight electrons, and these may maximize the efficiency by collecting the complete solar spectra inside that range's band without sacrificing any energy [8]. Therefore, the process of absorbing high-energy photons, such as ultraviolet photons, is one of the factors causing the rise in the temperature of the solar cell. Ultraviolet rays (UV) are divided into three regions based on their intensity (A, B, and C), where UVA (315-400) nm, UVB (280-315) nm, and UVC (100-280) nm where UV-C has the highest energy within the range of 100-280 nm, where it has electron energy of about 4.43 to 4.40 electron volts (eV), and it causes the most generating thermal energy that causes the heat of the solar cell [9]. The high transmittance of visible light in the wavelength rang (400-700) nm [10].

According to standard definitions, nanomaterials are those that "have structural or surface features with one or several dimensions in the range of sizes of 1–100 nm". Since their tiny size and high surface (area to volume ratio), nanoparticles are seen as different from their bulk counterparts and are made up of unique chemical and physical features. A new phase in the development of nanotechnology has emerged during the past two decades as a result of the obvious benefits of employing nanoparticles for many applications [11]. A practical way to integrate inorganic and organic elements to create a hybrid nanocomposite material is realized through inorganic and organic elements. Since organic-inorganic nanocomposites, sol-gel hybridization techniques have emerged as an exciting new field of research in material science. The creation of innovative organic-inorganic hybrid multi-purpose coating systems with intriguing physiochemical properties for potential application is the result of increased scientific research in this sector. Nanocomposite coating is used in a variety of applications, including corrosion protection, anti-fog coating, anti-reflective coating, self-cleaning coatings, anti-stain coatings, and water repellent anti-static coatings, etc. [12]. Vandana Kaler et al. [13] Polyvinyl alcohol (PVA) which had been dissolved in distilled water (DW), was combined with various amounts of titanium dioxide (TiO<sub>2</sub>) nanoparticles to create a nano-composite coating mixture. It was used on the solar cell's top surface to filter ultraviolet (UV) radiation and minimize visible light reflection, which improved the optical characteristics and increased efficiency. As a consequence of using 0.25 wt.% titanium dioxide in the TiO<sub>2</sub>/PVA nanocomposite, the maximum absorbance for the full UV spectrum (200-400 nm) was at wavelength 338 nm. And the melting point of the TiO<sub>2</sub>/PVA nanocomposite was substantially higher than that of pure PVA. The TiO<sub>2</sub>/PVA nanocomposite was found to have the maximum thermal stability. Jinsu Jung et al. [14] A double layer ARC of  $TiO_2/Al_2O_3$  was successfully produced by the experimental use of spin coating sol-gel precursors and applied to a silicon solar cell. The double-layer TiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> anti-reflective coating, which has an average reflection of 4.74 % in the 400-1000 nm wavelength area and a high refractive index (n = 2.89), proved the minimum reflectance result of 3.02 % at 970 nm when compared to single layers of titanium dioxide (TiO<sub>2</sub>) and aluminum oxide (Al<sub>2</sub>O<sub>3</sub>). This result shows that the double layer  $TiO_2/Al2O_3$  anti-reflection coating on silicon solar cells increased conversion efficiency by 13.95% compared to the single layer  $TiO_2$  and  $Al_2O_3$ anti-reflection coating. A. Kumar and A. Chowdhury [15] A selective radiative antireflective coating (SR-ARC) was created by combining SiO<sub>2</sub>, Si<sub>3</sub>N<sub>4</sub>, and Al<sub>2</sub>O<sub>3</sub>. They were used and tested to see how the (SR-ARC) affected the single and double Si<sub>3</sub>N<sub>4</sub>-coated layers of the crystalline silicon solar cell. At an ambient temperature of 30 °C, the results showed temperature reductions of 5.6 °C and 5.4 °C for double and triple ARC layers, respectively, and a maximum reduction of 6.8 °C found at an ambient temperature of 45 °C with double-layer ARC. Ali kadim et al. [16] The solvent casting method is utilized to conduct exploratory studies on the nanocomposite Titanium Dioxide/Polyvinyl Alcohol (TiO<sub>2</sub>/PVA), and nanoparticle concentration (10-20) nm, for coating on the top surface of the crystalline silicon solar cell. The aim is to investigate the impact of TiO<sub>2</sub>/PVA nanocomposite on the polycrystalline silicon solar cells. For the 0.2 wt% nanocomposite coating, it was discovered that the improvement in solar cell proficiency was (+2.3%), the reflection obtained was 3.9 %, and the solar cell showed the most significant temperature change is 9.7 °C when compared to a solar cell without a coating.

In this experimental study, the polymethyl methacrylate (PMMA) polymer and zinc oxide (ZnO) nanoparticles were used to prepare different concentrations of ZnO/PMMA nanocomposite coating, which were then applied to the top surface of polycrystalline silicon solar cells to investigate its effect on solar cell efficiency in order to lower the polycrystalline silicon solar cells' surface temperature while working in hot weather conditions (blocking ultraviolet UV-rays), and reduce the amount of light that reflects intensely in polycrystalline silicon solar cells.

#### **Experimental procedure**

#### Materials used

#### Polymethyl Methacrylate (PMMA)

The Iraqi A white powder of PMMA (polymethyl methacrylate) has a  $1.18 \text{ g/cm}^3$  density and a  $160 \degree \text{C}$  melting point. Table 1, listing some of the physical and chemical properties of Poly (methyl methacrylate). PMMA is one of the most well-known and well-established polymers with the chemical formula (C<sub>5</sub>H<sub>8</sub>O<sub>2</sub>) n. PMMA was formerly thought to be a viable alternative to glass in a number of applications, and it is now widely utilized in glazing. The toughest polymers should be a stiff substance, transparent, and weather-resistant. PMMA is colorless and transparent by nature. Visible light transmittance is extremely great. PMMA matrix materials are well-known for their use in technological applications[17].

Property	Polymethyl methacrylate (PMMA)	Unit
Color	Colorless	-
Density	1.18	g/cm <sup>3</sup>
Melting point	160	°C
Thermal conductivity	0.12	w/m.k
Surface hardness	M90	Rockwell
Refractive index	1.4	-
Chemical formula	$(C_5H_8O_2)_n$	-
Organic solvents	Acetone, Chloroform and Toluene	-

Table 1. Spectro- Physical and chemical properties of polymethyl methacrylate (PMMA).

#### Zinc Oxide (ZnO)

Zinc oxide has the formula ZnO and is an inorganic substance. It is a white powder that is water insoluble. ZnO may be found in many different forms, including nanoengineered, nanoparticles, nanostructured, and nan-building materials. It is also simple to change the qualities of a nanostructure by changing its shape and size. Figure 4-2. Zinc oxide crystallizes mostly in wurtzite, zinc-blende, and rock salt cubic regimes [18]. They have outstanding optoelectronic characteristics and can be readily manufactured into various geometries, making them potential photovoltaic solar cell possibilities. ZnO nanoparticles have a low reflectivity, which increases optical absorption, table 2. Nanostructures of ZnO are commonly used as the anti-reflective coating in photovoltaic systems, in this study used ZnO nanoparticles of 40–50 nm size.

Property	Zinc Oxide	
Chemical formula	ZnO	
Color	White	
Molar mass	81.406 g/mol	
Melting point	1974 °C	
Density	5.606 g/cm <sup>3</sup>	
Band gap	3.3 eV	
Refractive index	2.013	

Table 2. Zinc Oxide general specifications.

#### Polycrystalline silicon solar cell

A commercial polycrystalline silicon solar cell was used with the specifications shown in table 3 and figure 1, to test the effect of the nanocomposite coating. The solar cell, with dimensions of (39\*22) mm, forms part of the solar module that contains several cells connected in series.



Figure 1. The commercial polycrystalline silicon solar cell.

Item	Description
Туре	Polycrystalline silicon
Size	(39×22) mm
Area	858 mm <sup>2</sup>
Maximum power (P <sub>max</sub> )	0.14 W
Rated Voltage	0.5 V
Rated Current	0.28 A
Standard test conditions (STC)	1000 w/m <sup>2</sup> , 25 °C

Table 4.3. Commercial Polycrystalline Silicon Solar Cell Properties.

#### Thin film preparation

PMMA amount (1.25 g) were weighed and added to the vial with 40 ml of acetone solvent and placed the PMMA solution on the magnetic stirrer at 400 RPM and a temperature of 60 °C for about an hour

until it is fully dissolved, this procedure used for 1.25 g PMMA amount to get the 3.125 wt% concentration.

In other hand four amounts of ZnO nanoparticles powder (0.1 g, 0.2 g, 0.3 g, and 0.4 g) were weighed by using a sensitive balance, and then 40 ml of the acetone solution was added to each weighted amount to prepare the four different concentrations as shown below.

- 0.1 gram ZnO powder +40 ml (acetone): 0.25 wt%
- 0.2 gram ZnO powder +40 ml (acetone): 0.5Wt%
- 0.3 gram ZnO powder +40 ml (acetone): 0.75 wt%
- 0.4 gram ZnO powder +40 ml (acetone): 1 wt%

The four different concentrations (0.25 wt%, 0.5 wt%, 0.75 wt%, and 1 wt%) were prepared by weighing four different amounts of ZnO nanoparticles, size 40-50 nm, (0.1 g, 0.2 g, 0.3 g, and 0.4 g), using a sensitive balance, and then adding 40 ml of the acetone solution to each weighted sample. To disperse the ZnO nanoparticles in the solution, the four created varied concentrations placed individually in the ultrasonic device, type NT-628, for six hours (total time for preparing one sample of nanocomposite). The preparation of ZnO/PMMA is shown in figure 2 and 3

The four ZnO concentrations prepared were doped with a 3.125 wt% PMMA (1.25 g) in order to prepare the four concentrations ZnO/PMMA (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%) as below listed.

- (1.25 g PMMA/40ml acetone)+(0.1 g ZnO /40 ml acetone):3.375 wt%
- (1.25 g PMMA/40ml acetone)+(0.2 g ZnO /40 ml acetone):3.625 wt%
- (1.25 g PMMA/40ml acetone)+(0.3 g ZnO /40 ml acetone):3.875 wt%
- (1.25 g PMMA/40ml acetone)+(0.4 g ZnO /40 ml acetone):4.125 wt%



Figure 2. The production of ZnO/PMMA nanocomposites coating.



Figure 3. Flowchart for the production of ZnO/PMMA nanocomposites coating.

#### **Coating process**

The first step of the coting process is the cleaning and surface preparation of commercial polycrystalline silicon solar cells of size  $(39 \times 22)$  mm. This is done by placing a number of cells in a beaker and adding 20 ml of distilled (DI) water, sonicating in the ultrasonic device, for 10 minutes, and repeating the procedure with acetone instead of DI water. The solar cells were then allowed to dry at an ambient temperature. As a result, the polycrystalline silicon solar cells are freed from dust and pollutants and are ready for coating. There were several techniques used to coat the silicon solar cells, but the casting procedure was the most economical and easiest one [13]. 0.5 ml of ZnO/PMMA nanocomposite coating was enough to coat one of the commercial polycrystalline silicon solar cells with a size of (39\*22) mm, so by using a pipe tube, 0.5 ml of coating was applied to the top surface of the solar cell. The coating was then moved to cover the entire solar cell, where the coating layer was formed with an almost even thickness, as conformed by measuring the coating thickness using a dry film thickness gauge (DFT). And then leave the solar cell at room temperature for about 30 minutes to dry the coating. See figure 4.

#### Dry film thickness measurement (DFT)

The most essential metric in protective coatings operations is dry film thickness, which is defined and monitored in almost every coating application. Modern digital gauges allow for the rapid and precise collection of readings, providing a full image of the coating job [19]. After the coating has been dried and cured, the thickness of the film has been measured by using a digital thickness gauge in different locations. The thickness of the coating layer was measured by the coating thickness gauge TT-260, shown in figure 4. The average reading for the ZnO/PMMA thin film coating was found to be about 2  $\mu$ m.



Figure 4. Coating application process and thickness measurement.

#### **Results and discussion**

The results show the performance of the coated and un-coating polycrystalline solar cells which are used in this experiment to test the UV-visible absorbance, surface temperature, Current-Voltage (I-V) curve, power-voltage (P-V) curve, power and efficiency. The quantity of solar irradiation and the surface temperature degree of the solar cell change the value of electric power produced by photovoltage cells. If the solar radiation increases, the short circuit current ( $I_{SC}$ ) grows linearly, but open circuit voltage ( $V_{OC}$ ) increases marginally. But the temperature has the greatest impact on the I–

V characteristics and power efficiency of the PV solar cell unit [20]. The power and efficiency calculations has been calculated by [7]:

$$P_{max} = I_{sc} \times V_{oc} \times FF = I_{mp} \times V_{mp}$$
(1)

$$\eta(\%) = \frac{I_{mp} \times V_{mp}}{P_{in}} = \frac{P_{max}}{A \times G}$$
(2)

Where, (Pmax) is the maximum power output, (I<sub>SC</sub>) short circuit current, (V<sub>OC</sub>) open circuit voltage, (FF) fill factor, ( $\eta$ ) electrical efficiency, (G) overall irradiance (w/m<sup>2</sup>), and (A) the effectively illuminated region (m<sup>2</sup>).

#### UV-visible absorbance analysis

Four samples with different concentrations of the ZnO/PMMA nanocomposite coating were used (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%). An absorbance test UV-Vis was conducted to find out the effect of adding the ZnO nanomaterial to the PMMA polymer on the absorption of UV rays. The examination was carried out by the UV-visible spectrophotometer device (Mega-2100) at the University of Kufa, Science College.

The results show that the absorbance intensities (1.9 A.U, 2.2 A.U, 2.7 A.U, and 2.4 A.U) for the investigated concentrations (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%), respectively. Indicating that the nanomaterial increased the absorption area within the UV wavelength range (200-400) nm, with the higher concentration of the nanomaterial, the greater the ultraviolet ray absorption area, as shown in table 4 and figure 5.

ZnO/PMMA nanocomposite	Absorbance	Peak Absorption point
concentrations (weight percent)	( <b>A.U</b> )	( <b>nm</b> )
Without coating (WOC)	Full-transmittance	-
3.375 wt%	1.9	205
3.625 wt%	2.2	208
3.875 wt%	2.7	203
4.125 wt%	2.4	210


Figure 5. Comparison of the Absorption for ZnO/PMMA coating concentrations used (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%)

### **Energy bandgap analysis**

The band gap (energy gap  $E_g$ ) is the energy difference between the conduction and valence (P-region), commonly given in electron volts (eV). The band gap is particularly important in insulation materials and semiconductors, where even a small gap value controls several of the material body's electrical and optical characteristics[21]. Therefore, the bandgap energy of polymethyl methacrylate (PMMA) and ZnO/PMMA nanocomposite was measured using the Tauc plot relation through the absorbance data that were extracted when examining the UV-Visible absorbance. The results shown in figure 6 showed that the examined PMMA polymer at a concentration of 3.125 wt% obtained a band gap of 4.55 eV, while the examined ZnO/PMMA nanocomposite concentrations (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%) recorded higher results (5.16 eV, 5.23 eV, 5.60 eV, and 5.50 eV) respectively.

As it is mentioned earlier, the value of the energy bandgap has increased by increasing the concentration of the ZnO nano-material until it reaches the steady state point. Compared with the value of the band gap of silicon (Si), the main component of the polycrystalline solar cell, at 1.1 eV, it is low, as raising the band-gap value of the nanocomposite coating works to reduce the reflection light experienced by the silicon cell, so it works as an antireflective coating.



Figure 6. The energy band gap (Eg) of the ZnO/PMMA nanocomposite, Tauc plot relation.

#### **Reflection losses analysis**

The reflection test was carry out by using the UV-Visible spectrometer, type (UV-1800) double beam device for the coated polycrystalline solar cells and compared with the reflectance on the uncoated polycrystalline solar cell that has reflected light 35%, where the results of visible light reflection ratio showed in figure 7 was (13.2%, 10.3%, 5.6%, 8.7%) at 600 nm wavelength for the tested ZnO/PMMA concentrations (3.375wt%, 3.625wt%, 3.875wt%, and 4.125wt%) respectively, the best result was obtained for visible light transmission and low reflection (5.6%) at 3.875 wt% of ZnO/PMMA concentrations. Depending on the above, the light reflection is reduced from 35% to 5.6% for the polycrystalline solar cell coated with ZnO/PMMA nanocomposite coating, 3.875 wt% concentration.



Figure 7. Comparison of the reflections for ZnO/PMMA coating concentrations used (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%)

### Thermal and temperature reduction

One of the objectives of this work is to reduce the surface temperature of polycrystalline silicon solar cells by applying ZnO/PMMA nanocomposite coatings with different concentrations on the top surface of commercial polycrystalline silicon solar cells, in order to increase their efficiency. The thermocouples (K-type) were used to measure the temperature of the solar cells by fixing them on the back surface of the cells, and the thermocouples were connected to the thermometer data logger device to display the temperature results. The test was done in the laboratory by exposing solar cells to solar radiation using halogen light, the test has been done under a standard test condition STC (1000 w/m<sup>2</sup> and 25 °C) and the test duration lasted for an hour. The experiment was carried out for four polycrystalline silicon solar cells coated with four different concentrations of ZnO/PMMA nanocomposite (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%) and compared to the uncoated polycrystalline cell.

The results showed that the temperature of solar cells at the end of the test time, after 1-hour, was (75.4  $^{\circ}$ C, 74.3  $^{\circ}$ C, 72.9  $^{\circ}$ C, and 73.7  $^{\circ}$ C) for the concentrations used in a respectively, while the uncoated solar cell recorded (81.5  $^{\circ}$ C), where the decrease in temperature for each concentration was ( 6.1  $^{\circ}$ C, 7.2  $^{\circ}$ C, 8.6  $^{\circ}$ C, and 7.8  $^{\circ}$ C) compared to the uncoated solar cell, respectively, as shown in figure 8 and table 5. According to the results, it can be concluded that the solar cell surface temperature decreases as the concentration of nanomaterials in the nanocomposite coating increases, which leads to an increase in the amount of UV photons absorption in the wavelength range (200-400) nm, And this is one of the causes that make the temperature of solar cells rises, and thus its effect on the efficiency of solar cells increases. The highest decrease in temperature was recorded (8.6  $^{\circ}$ C) when using a concentration (3.875 wt%) of ZnO/PMMA nanocomposite coating.

ZnO/PMMA nanocomposite concentrations	Variations in temperature values
Without coating (WOC)	-
3.375 wt%	6.1 °C
3.625 wt%	7.2 °C
3.875 wt%	8.6 °C
4.125 wt%	7.8 °C

Table 5. The temperature variations of solar cell with the ZnO/PMMA nanocomposite concentrations.



Figure 8. Comparison surface temperatures of coated and uncoated polycrystalline solar cells at (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%) concentration.

To validate the findings, a Thermal Imaging Infrared Camera FLIR E-30bx type was used in the current experiment to monitor the temperature of the coated and uncoated polycrystalline solar cells in order to verify the temperature readings obtained by the thermometer Data-Logger device. Figure 9 illustrates that the results that resemble those of thermocouples closely.



3.875 wt% concentration of ZnO/PMMA- after 1-h 4.12

4.125 wt% concentration of ZnO/PMMA- after 1-h

Figure 9. Thermal imaging of coated and uncoated polycrystalline solar cells at (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%) concentrations.

### (I-V) and (P-V) curves

The optimal increase in the electrical characteristics of solar cell was attained at zero time, where the reflection losses are carried out. The results were shown by using the PROVA-200A solar module analyzer, the short circuit current (Isc), open-circuit voltage (Voc), maximum power current (Imp), and maximum power voltage ( $V_{mp}$ ) for polycrystalline solar cells with ZnO/PMMA nanocomposite coating were: ( $I_{SC}$ =0.331A, Voc=0.526V,  $I_{mp}$ =0.285A, and  $V_{mp}$ =0.508V), ( $I_{sc}$ =0.338A,  $V_{oc}$ =0.531V,  $I_{mp}$ =0.292A, and  $V_{mp}$ =0.511V), ( $I_{SC}$ =0.350A,  $V_{oc}$ =0.542V,  $I_{mp}$ =0.310A, and  $V_{mp}$ =0.520V) , and ( $I_{sc}$ =0.343A,  $V_{oc}$ =0.538V,  $I_{mp}$ =0.304A, and  $V_{mp}$ =0.515V) for the concentrations of ZnO/PMMA nanocomposite coating (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%) respectively, and compared to the polycrystalline solar cell without coating that had ( $I_{sc}$ =0.320A,  $V_{oc}$ =0.520V).  $I_{mp}$ =0.280A, and  $V_{mp}$ =0.500V). According to the data presented above, the maximum effect of antireflection coating when used at the (3.875 wt%) concentration reduces reflection from 35% for polycrystalline solar cells without coating to only 5.6%.

After one hour, the second test was performed where the temperature and anti-reflection effects (increased surface temperature of the tested solar cells). The electrical performance results of polycrystalline solar cells were ( $I_{sc}$ =0.341A,  $V_{oc}$ =0.395V,  $I_{mp}$ =0.292A, and  $V_{mp}$ =0.372V), ( $I_{sc}$ =0.348A,  $V_{oc}$ =0.408V,  $I_{mp}$ =0.308A, and  $V_{mp}$ =0.390V) , ( $I_{sc}$ =0.355A,  $V_{oc}$ =0.430V,  $I_{mp}$ =0.317A, and  $V_{mp}$ =0.412V) and ( $I_{sc}$ =0.352A,  $V_{oc}$ =0.418V,  $I_{mp}$ =0.310A, and  $V_{mp}$ =0.400V) for the concentrations of ZnO/PMMA nanocomposite coating (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%), respectively, and compared to the polycrystalline solar cell without coating that had ( $I_{sc}$ =0.330A,  $V_{oc}$ =0.380V,  $I_{mp}$ =0.270A, and  $V_{mp}$ =0.360V). According to the data presented above, the maximum effect of ZnO/PMMA coating when used the 3.875 wt% concentration, has reduced the surface temperature from 81.5 °C for polycrystalline solar cells without coating to 72.9 °C, in a way tha leads to the maximum current and voltage ( $I_{mp}$  = 0.317 A,  $V_{mp}$  = 0.412 V). Figure 10 shows the I-V and P-V curves, while Table 6 shows the results of studies for all polycrystalline solar cells with various nanocomposite coatings and without coating.



Figure 10. Comparison of I-V & P-V curves for polycrystalline solar cells with and without coating for all concentrations.

## Power and efficiency of polycrystalline solar cell.

To study the effect of ZnO/PMMA nano-coating on the power and efficiency, the polycrystalline coated solar cells were tested as mentioned previously to find the I-V curve, where the power and efficiency were measured and calculated for each of the solar cells coated with different concentrations of the ZnO/PMMA (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%) and compared with the uncoated cells to see the amplitude of the effect of adding nano coating to the top surface of the polycrystalline solar cells. Where the results showed the power (145mW, 149mW, 161mW, and 157mW) and efficiency (16.87%, 17.4%, 18.78%, and 18.25%) at the beginning of the test(at zero time) and power (109 mW, 120 mW, 131mW, and 124mW), and efficiency (12.66%, 14%, 15.22%, and 14.25%) at the end of the test (after one hour) for each of ZnO/PMMA concentration (3.375 wt%, 3.625 wt%, 3.875 wt%, and 4.125 wt%), respectively, while the power and efficiency of the polycrystalline solar cells which were without coating (140mW, and 97.2mW), (16.32%, and 11.33%) at zero time and after one hour, respectively.

Where the effect of reducing the reflection by ZnO/PMMA nano-coating has increased the power and efficiency of the solar cell at the zero time of the test and according to the ZnO/PMMA concentration value of the coating used. And after one hour, according to the additional nano coating, the impact of raising the surface temperature of the solar cell and the action of the nano-coating on decreasing the solar cell temperature was obvious in enhancing the power and efficiency of the solar cell. From the results shown above, it was found that the best concentration that was used was (3.875 wt%) as the power and efficiency increased from (140 mW, 16.32%) for the uncoated cell to (161 mW, 18.78%) at the beginning of the test (at zero time), and from (97.2 mW, 11.33%) for the uncoated cell to (131 mW, 15.22%) after one hour at the end of the test. This increase came as a result of reducing the visible light reflection from (35%) for the uncoated polycrystalline solar cell to (5.6%) for the solar cell coated with nano-coating at a concentration of (3.875 wt%), as well as reducing the surface temperature of the polycrystalline solar cell from (81.5 °C) to (72.9 °C). Figure (11) show the power and efficiency graphs, while Table (6) shows the results of studies for all polycrystalline solar cells with various nanocomposite coatings and without coatings.



Figure 11. Comparison the power & efficiency of polycrystalline solar cells with and without coating for all concentrations.

Table 6. Electrical properties and efficiency of polycrystalline silicon solar cells coated with different concentrations of	of
ZnO/PMMA nanocomposite coating and without coating.	

	Polycry silico cell w coating	ycrystalline licon solar ell withoutPolycrystalline silicon solar cell - Coated with 3.375 wt%- ZnO/PMMAPolycrystalline silicon solar cell - Coated with 3.625 wt%- 		Polycrystalline silicon solar cell – Coated with 3.375 wt%- ZnO/PMMA		Polycrystalline silicon solar cell – Coated with 3.875 wt%- ZnO/PMMA		Polycrystalline silicon solar cell – Coated with 4.125 wt%- ZnO/PMMA		
Time test	Zero- time	After 1-h	Zero- time	After 1-h	Zero- time	After 1-h	Zero- time	After 1-h	Zero- time	After 1-h
<b>Open-circuit</b> voltage V <sub>OC</sub> (V)	0.52	0.38	0.526	0.395	0.531	0.408	0.542	0.430	0.538	0.418
Short-circuit current I <sub>SC</sub> (A)	0.32	0.33	0.331	0.341	0.338	0.348	0.350	0.355	0.343	0.352
Maximum power voltage V <sub>mp</sub> (V)	0.5	0.36	0.508	0.372	0.511	0.390	0.520	0.412	0.515	0.40
Maximum power current I <sub>mp</sub> (A)	0.28	0.27	0.285	0.292	0.292	0.308	0.310	0.317	0.304	0.31
Maximum power P <sub>max</sub> (W)	0.140	0.097	0.145	0.108	0.149	0.120	0.161	0.130	0.156	0.124
Electrical efficiency (η)%	16.32	11.33	16.87	12.66	17.39	14	18.78	15.22	18.25	14.45



Figure 12. Rig Solar cell Test.

- 1. Halogen Lamp.
- 2. Personal laptop.
- 3. Solar cell module analyzer
- 4. Polycrystalline silicon solar cell/coating un-coating
- 5. Thermometer (Data-logger)
- 6. K-type thermocouples.

# Conclusion

A nanocomposite ZnO/PMMA was made by doping 3.125 wt% PMMA with four specific concentrations of ZnO (0.25wt %, 0.5wt %, 0.75wt %, and 1wt %). The nanocomposite was applied to the front surface of the commercial polycrystalline silicon solar cell by using a casting coating method. Testing the effectiveness of the nanocomposite coating to absorb the ultraviolet rays at various wavelengths in order to reduce PV solar cell surface temperature and the ability of the coating thin film to reduce light reflection based on the ZnO weight percent in ZnO/PMMA, as demonstrated by a UV-Vis spectrophotometer. The study found that the greatest temperature impact when utilizing a concentration of 3.875 wt% ZnO/PMMA coating has reducing the solar cell temperature from 81.5 °C for uncoated polycrystalline solar cells to 72.9 °C for coated solar cells, and the reflection has decreased by about 29.4%, which was reduced up to only 5.6%. The PROVA-200A solar module analyzer device was used to examine its efficiency. The results indicated that the coated solar cell had an improvement in efficiency of +3.8% when compared to the uncoated cell. It is recommended to investigate the effects of applying multiple thin layers of nanocoating on the performance of the solar cell, or it can be utilizing different kinds of nano-coatings and researching their effectiveness with the solar cell.

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# **Novel Applications Using Magnetron Sputtering and Atmospheric-Pressure Plasma Jet Techniques: A Review**

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Keywords:	Abstract
Magnetron sputtering;	
Atmospheric-pressure	Nanomaterials are now widely used in a variety of fields,
plasma jet;	such as biomedicine and industry, and the world is
Phases of copper oxide	experiencing its worst conditions yet as a result of the
nanostructures.	spread of bacteria and the rise in the number of people
	infected with various diseases as a result of coming into
	contact with nanomaterials. The spread of pollution can be
	curtailed by the use of new techniques and experiments
	Microorganism membranes can be penetrated by
	nanonarticles making nanostructured materials a necessity
	in biological research. The plasma jet technology is
	In biological research. The plasma jet technology is
	powerful enough to sterilize and kill the bacteria in a small
	space. There are a wide variety of industrially essential
	coatings that Magnetron sputtering can be applied to,
	including those used in the medical industry. We'll go over
	the history, foundation, and several uses of this method in
	this review. Other recent discoveries, such as the creation
	of copper oxide nanoparticles in each of the two processes,
	are also covered. It can be used in a variety of fields,
	including biomedical applications. Nanoparticles of copper
	oxide have the potential to sterilize and kill
	microorganisms, making them a crucial medical tool to
	have on hand

### Introduction

The magnetron configuration is one of the applications for developing the method of coating, it can modify the power of electrodes cathode and anode to get a product. Sputtering is a very important technique particularly when it comes to the magnetic field (magnetron). The effect of magnetic field confinement onto electrodes gained many acceptable results [3-7]. The electrode (anode) is located vertically on cathode to let the substrate bombardment appear with high power. The physical sputtering combination and all reactions on the surface of target in a plasma environment is termed reactive plasma sputtering. As a consequence of different parameters, some explanations can be

workable [8, 9]. Via sources (one or two) like metals, semiconductors or insulators in Ar/O<sub>2</sub> or extra effective gases for deposition drives are frequently selected to rise the sputtering yield with respect to the components of chemical structure that can be resumed [10]. The yield of sputtering indicates to get a good films homogeneity and refer to low-cost production, particularly with gases reactive in magnetron plasma sputtering. In fact, the cathode and anode will act together depending on the addition of a gases that have many reactive features. The target of potential in the sputter yield atoms form the target will be increase. The feature for producing the breakdown voltage of distance "pd" and pressure is very important, however it has little reliability on the electrode material that defines the secondary electrons and an electric field is recognized linearly with pressure ( $\underline{E} = V/d$ ) [11]. Thus, the minimum *p.d* in the Paschen's curve represents the minimum value of break down voltage that is equal to generate the gas discharge *p.d*:

$$pd\Big|_{V_{\min}} = \frac{1}{A}\log\left(1 + \frac{1}{\gamma_e}\right)$$

While the value of pressure and distance between two electrodes is exactly huge, the ions released in the gases are decelerated due to serious collisions therefore, it will hit the target via way of energy to generate emission of secondary electrons. Commonly sputtering discharges voltage is comparatively enormous. The number of ions increase because the collision with atoms of gases will increase also [11]. Whole ions are coming back to the electrode and delivers many electrons. The gases will current and voltage will drop, then current value will increase gradually [12]. Additionally, the secondary electrons of the material are 0.1., and one ion will smash the region of the electrode (cathode) to discharge the secondary electron. Therefore, the region of normal glow that observers the electrode bombardment will help the surface of electrode establish the mechanism of sputtering. At first, the bombardment is not humongous. Normally, the bombardment increases the shield when the power is accessible; the electrode surfaces up until the current density (J) is understood [13]. Subsequently, the voltage V and J in discharge increase when power produces also increase [14]. If the target is un-cooled, both of thermal and secondary electrons are emitted when the value of (J)current density about  $(0.1 \text{A/cm}^2)$ . It relies on the average of mean free path distance between the two electrodes also the emission of secondary electrons. Each electron needs from 10 to 20 ions for the novel avalanche to stand up. The secondary electrons cannot undertake passable number of collisions ion to hit the electrode anode [15]. Also, Kelly and Arnell have defined the dark space [16-17]. The electrons are accelerated from the cathode to anode which are caused to collide with ions [18]. Because of the variations from its fabrication process, cuprous oxide (Cu<sub>2</sub>O) is a p-type semiconductor with varied optical properties. [19]. copper oxide: Cu<sub>2</sub>O and CuO, known as (cupric oxide), have been grown using a variety of techniques [18-19]. Additionally, the energy gaps for (Cu<sub>2</sub>O) molecule [6–13], as well as (CuO) molecule [10–13] films, which have been reported in literature, rely on a manufacturing procedure Energy gap values for (Cu<sub>2</sub>O) molecule range (2.10-2.60) eV [6-13], whereas CuO has been reported to have an energy gap of 1.3-2.1 eV [10, 13]. Films made of Cu<sub>2</sub>O absorb light at wavelengths as short as 600 nm, whereas films made of CuO absorb light across the whole visible spectrum [19]. Moreover, copper oxide films are used in many other applications. A band gap energy values of copper oxide films have been reported to be suitable for utilization as solar energy conversion windows [20]. Spectrally selective variable reflectance coatings based on copper oxide films have been demonstrated by Richardson in architectural applications. Requirements for solar cell windows include transparency in the visible spectrum and low electrical resistance (pelectrical). Despite of its requirements, CuO has large value of electrical resistivity  $(\rho_{\text{electrical}})$ . The range of resistivity from 102 to 104 Ohm cm, are prepared by thermal preparation methods and no much difference in electro-deposition method which is around (104 -106 Ohm cm)

[15]. Many efforts were prepared in works to fabricate copper oxide Cu<sub>2</sub>O nanostructure with small  $(\rho_{electrical})$ . Many researchers [14,15] have been struggling to synthesize copper oxide nanostructures via magnetron sputtering, which had the potential to yield a range of copper oxide nanostructure films with stoichiometry changing from rich copper to Cu<sub>2</sub>O nanostructures and lastly (CuO) via varying the parameters in the plasma sputtering system. Copper oxide nanostructure films was prepared by direct current DC, radio frequency RF and reactive sputtering, it could change the resistivity of the prepared nanostructure films by controlling in the oxygen ratio (pressure of O<sub>2</sub>). CuO nanostructure films with resistivity as low as 25 Ohm cm and the output power was 200 watts in the plasma sputtering system. Truthfully, this review purposes to characterize plasma magnetron sputtering technique and optimize the magnetron configuration with operation conditions to study the preparation of different molecular phases of copper oxide thin films and nanostructures at optimum conditions. The plasma jet technique represents one of the best it has huge utility because of its features, [19-20]. The atmospheric pressure plasma jets a good optimum for numerous applications, like surface modification, medical treatment and nanoparticles [21]. The characterization of plasma provides the limitless prospective to study the biomedical applications. These techniques are used to kill and treat diseases (virus and bacteria) and decontaminate and remove cells without affecting necrosis to treat cells [21]. Additionally, it has a simple design. The cathode (high-voltage electrode) is commonly made from a needle syringe with metal pin or the use of a glass needle. Biomedical applications should be adjacent room temperature and takes a short current when the system of plasma was used. The discharge gas flows over the pin at a different flow rate and uses the controller to regulate the gas flow rate [21]. The application, like cancer treatment sterilization, bleaching (dentistry), and healing of wound treatment have been demonstrated [22]. It is important to know the parameters of plasma-like electron temperature and density of electron. To obtain these parameters at low-pressure plasma, this microorganism produces some enzymes which are associated with the pathogenesis of P. Aeruginosa infections. In spite of the developments in antibiotic treatment, P. Aeruginosa is basically resistant to a number of that antibiotic [23]. Cold plasma can support as an alternative to other conventional decontamination methods like heat, chemical, and irradiation sterilization methods, especially for sterilizing heat-sensitive tools. It encourages an effective killing/sterilizing of the microbes and decreases the pollution [24].

# Synthesis of CuO and Ag Nanostructures

The highest components of home-made reactive magnetron sputtering system is shown in Figure 1. Two magnetrons at the cathode and anode electrodes were verified.



Figure 1. The schematic diagram of sputtering system

The design of electrodes was shown in Fig. 2. The cathode and anode are made of copper; and the thickness of diameter for each disc is (6 cm and 3 mm), respectively. The concentric magnets have been put behind each cathode and anode to create the magnetron fields. Also, the inner and outer diameters of the magnets are 2 and 5 cm, respectively. Both electrodes have been combined to power supply (direct current) to make power available for discharge. The anode was fixed perpendicularly as the electrode (anode), while the cathode was the moved upper electrode and the spacing of two electrodes were prepared (1-6) cm.



Figure 2. The discharge electrode design

Paschen's curve of Ar gas with magnetrons of different inter-electrode distance (from 2 to 4.5cm) have been shown in Fig. 3. The curves are shifting to higher breakdown voltages, with the increase of inter-electrode distance. When the pressure is low, the electrons must have more energy to complete the ionization of neutral atoms [21].



Figure 3. Paschen curves at different inter-electrode distance using Ar gas discharge [21].

Figure 4 shows the magnetic field intensity. The top value was observed at inter-electrode distance 4.5 cm, while the lowest value was at inter-electrode distance 2 cm. The probe diameter stayed around (0.8 cm). The interfering between magnetic field lines and high interfering occurred at the midpoint of distance of (2 cm). When the distance between electrodes reaches the "no interference" conditions at inter-electrode distance  $\geq 5$  cm the acceleration of electrons via electric and magnetic fields has more drift velocities then the probe might not attract from their paths between two electrodes [21].



Figure 4. The magnetic field intensity (B-field) with inter-electrode distance (d) [21].

Preparing CuO requires a direct current reactive dual magnetron sputtering. The target (cathode) was made of high pure copper disk (99.999%). The nanostructured oxide films have been produced in an Argon: Oxygen gases. The substrates, which are made of glass, were cleaned before being placed inside the discharge chamber. The total gas pressure was  $5*10^{-2}$  mbar., and inter-electrode distance was 2.5 cm with controlling to ratio of Argon: Oxygen gases, are between 1:1 and 2:1. Conversely, two phases cupric (CuO) and corpus (Cu<sub>2</sub>O) have been produced. The discharge current was 300 milliampere while the discharge voltage could be accurately changed from 0 to 2000 volt. The deposition rate took about 5-8 minutes to obtain dark films of copper oxide CuO. To get more crystallinity and obtain a new phase of copper oxide Cu<sub>2</sub>O, the samples films of CuO have been annealed at 450 C° and the time was 2 hours to gain high homogeneity in the structures. XRD examination and (FTIR) Fourier transforms infrared spectroscopy model Shimadzu 8400S, were used to characterize the samples of copper oxide nanostructure films. The samples in gas sensing applications were examined at various temperatures and with various gases using a home-made apparatus. For the XRD patterns of pure phase Cu<sub>2</sub>O and CuO at 2\*10-2 mbar with Argon: Oxygen 1:1 and 1:2 gas mixing rates, respectively, as shown in Figure 3. Cupric oxide phases and cuprous oxide peak characteristics match those of the samples' peaks. CuO nanostructures may be seen as two peaks at 2O 38.18° and 38.57° with (hkl) values (111) and (110). At 2 of 29.52 degrees, there are four peaks with (hkl) of (110), (111) and (200) that suggest the presence of Cu<sub>2</sub>O. It is conceivable that the increased crystallinity of copper oxide results from an increase in oxygen ratios [24,25].



Figure 5: Radiation analysis, specifically X-ray diffractograms Using the magnetron sputtering process, patterns of CuO films were created at a distance of (d= 2.5 cm) without any heat treatment. Heat-treated Cu2O films at (2.5 cm) between electrodes after magnetron sputtering at 450 Co for 2 hours were analyzed using the XRD technique.[20]

This review has shown the phase of CuO and Cu<sub>2</sub>O thin films prepared via a dual magnetron sputtering technique at inter-electrode distance of 2.5 cm with mixing ratios of Argon: Oxygen gases without and with annealing, and achieving these samples as a gas sensor application. It is very important to study the degree of gas sensitivity through NO<sub>2</sub> and NH<sub>3</sub> gases. The sensitivity to NO<sub>2</sub> gases is upper than sensitivity to NH<sub>3</sub> gases, according to the results of the experiment. It was very important to detect the toxic gas leak in hospitals and laboratory.



Figure 6-a Time-dependent sensitivities of CuO nanostructure films produced by using dual magnetron sputtering and 2.5cm interelectrode spacing in NH<sub>3</sub> and N<sub>2</sub>, respectively, without or with heat treatment. [20].



Figure 6-b Effect of working time on the sensitivities of dual magnetron sputtering-produced Cu2O films, measured with and without heat treatment of NO<sub>2</sub> and NH<sub>3</sub> gas at a 2.5cm inter-electrode distance. [20].

figure 7 and figure 8 display synthesizing by atmospheric-pressure plasma jet for copper oxide nanoparticles CuO and the experimental system [22], where the polycrystalline structure has been referred.



Figure 7 The atmospheric-pressure plasma jet [21]. **35** 



Figure 8 The powders of copper oxide (a) Without CuCl<sub>2</sub> and (b) With CuCl<sub>2</sub>[21].

The adsorption of organic contaminants and the production of solar cells are only a few of the many uses for copper oxide nanoparticles. Using this approach to manufacture copper oxide for biomedical applications is a decent first step, and the results can be deemed satisfactory.

Figure 9 shows the transmission electron microscopy TEM image of the Ag nano-structures synthesized at (80 wt%) AgNO<sub>3</sub> and (20 wt%) sucrose with, preparation time of 25 min image a and b. The uniform, which is shaped similar (palm fronds), has been a grown-up and the smallest particle size was 20 nm. Whereas these shapes were vanished when the concentration becomes (60 wt% AgNO<sub>3</sub>) and (40 wt%) sucrose at the same syntheses time 25 min, at that time, the Ag nanoparticles with minimum particles size was 10 nm as shown in Figure 9 (c) can be clearly comprehended. These results were assisted to employ the Ag nanoparticles for killing/sterilizing some types of bacteria.



Figure 9. TEM images of AgNPs prepared at different ratio of AgNO<sub>3</sub> with different preparation time

Figure 10 shows the antibacterial activity of silver nanoparticles AgNPs. It was a perfect inhibition zone after a 24-hour incubation at 37 °C in the plate. It was a good result to get the susceptible of strains to Ag nano-particles that display a large inhibiting zone, of two kinds of bacteria as shown in Table 1.



Figure 10. The bio-activity of (AgNPs): a- Staphylococcus and b E.coli.

Sample No.	Control	Staphylococcus (mm)	Escherichia Coli (mm)
1	-	15	16
2	-	17	15
3	-	19	14
4	-	16	17

# Conclusions

Numerous latest novel progresses prepared in a magnetron sputtering and atmospheric pressure plasma jet techniques were tackled in this review. It included the modification of both techniques in many several applications. Improvements in magnetron sputter and plasma jet sputtering have made it possible to produce critical tools for sterilization and decontamination in various environments. The products of some new essential studies in this review was correspondingly included in the preparation of nano-particles of copper oxide and a well-thought-out worthy challenge for killing/sterilizing bacteria/virus and detect toxic gases by using high novelty of copper oxide gas sensor. As a result, this study presents an overview of magnetron sputtering in the atmospheric–pressure plasma jet process, as well as highlighting the prospective applications of these techniques.

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Fundamentals Plasmonic Logic Gates at Nano Scale Structure and 1550 nm

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# Wavelength

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### Abstract

This article posits, simulates, designs, and implements all-optical logic gates that use nano-rings Insulator-Metal-Insulator (IMI) plasmonic waveguides (NOT, OR, AND). The suggested plasmonic gates' structure has been designed and numerically simulated by two dimensions (2-D) structure using the Finite Element Method (FEM). The proposed device's performance is evaluated using four criteria: transmission, modulation depth, extension ratio, and insertion loss. The proposed structure was built with silver and glass materials. The suggested plasmonic gates' functionality was achieved by using the concepts of destructive and constructive interferences. Numerical simulations show that at 1550 nm operating wavelength, the suggested plasmonic gates could be implemented in a single structure with a transmission threshold of (0.5). This device had the following characteristics: transmission exceeding 100% in one state of NOT and exceeding 200% in one state of OR and AND gates, medium and high Extension Ratio values, so small footprint, and very high MD values. Future access to nanophotonic integrated circuits will be made possible by this technology, which is also thought to be a crucial component of all-optical computers.

### Introduction

The discovery of the Wood's anomaly, a midportion of the light spectrum that a metal grating emits, in early 1902 sparked the beginning of scientific study on Plasmonics [1]. Later, a physical explanation

for the Lord Rayleigh phenomena [2], which describes an anomaly in the spectrum of the light that is diffracted within a wavelength in which an unintentionally dispersed wave arises on surface, was put forward. Afterward, the semi-stationary polarized waves resonating over the surface of the metal were anticipated. This energy loss is caused by cohesion, when excited electrons in the metal, which were afterward named surface plasmons [3]. Surface plasmon polaritons (SPPs) are electromagnetic waves confined on metal-dielectric interfaces and associated with the propagation of free electronic oscillations on the metal surface. [4-6], and are thought to have the greatest potential for creating nanophotonic devices [7-9]. Researchers have gotten interested in optical devices based on (SPPs) in new times, as the need of high-bandwidth, high-speed data transmission has grown. SPPs devices outdo electrical device restrictions such as the delay in the rate at which data are sent and significant heat generation. (SPPs) aid in overcoming the limit of diffraction in classic optical systems and subwavelength processing of light. This trait motivated researchers to focus on micro guiding structure that restrict sub-wavelength light. Plasmonic waveguides show great potential in terms of steering patterns of sub-wavelength light, since (SPPs) is the interplay of electromagnetic waves and free electrons of metals propagating across metalinsulating or insulating-metal interfaces [10,11]. Several Plasmonic waveguiding structures have been proposed like resonators [12], modulators [13], switches [14], nanocavities [15], nanowires [16], Bragg reflectors [15], multi/demultiplexers [17], and logic gates [18-21]. In the logic gates' field, each structure has a distinct means of realizing the function, various geometries, different materials, different numbers and kinds of logic gates, different resonance wavelength values, and different transmission values. This paper proposes a structure that can execute three plasmonic logic gates (NOT, OR, AND) simultaneously. Materials, structure parameters, resonance wavelength, and transmission threshold are all same. A Nano-rings resonator and Insulator-Metal-Insulator (IMI) plasmonic Nano-waveguides are accustomed to build the structure. COMSOL Multiphysics (version 5.4) simulation results that have been relied upon are based on the Finite Element Method (FEM). In the future, this technique will make nanophotonic integrated circuits accessible, and it has been thought of as a fundamental component for all-optical computers. This scientific article is structured as follows: Section 2 goes over all of the methodology's procedures, resources, and mathematical models. Sections 3 present and discuss the results. Section 4 compares this work to prior ones. Section 5 concludes with closing comments.

## **Theoretical concepts**

The SPPs signal is guided between dielectric-metal interfaces via plasmonic waveguides. Recently, two types of waveguides have been widely employed in plasmonic structures: insulator-metal-insulator

(IMI) and metal-insulator-metal (MIM) plasmonic waveguides. IMI waveguides have a longer propagation length, reduced propagation loss, and are simpler to fabricate [18]. Because of these advantages, we chose IMI plasmonic waveguides over MIM plasmonic waveguides. As illustrated in Fig. 1, the suggested framework for performing Plasmonic gates (NOT, OR, AND) comprises of two nano-ring resonators and three stripes. The stripes and the nano-ring resonator are made of metal, namely silver, whereas the rest of the framework is made of dielectric, namely glass.



Silver permittivity is based on Johnson and Christy data [22], and the dielectric refractive index is 1.52 for the Glass [20]. Table 1 shows characteristics of the suggested framework.

Parameter	Description	Value (nm)
n	Width and	400
	Length of the	
	structure	
v	Length of the	240
	side stipe	
S	Stripes width	15
a	Distance	5
	between stripes	
	and nano-rings	
x	The smaller	25
	radius of nano-	
	ring	
Z	The bigger	40
	radius of nano-	
	ring	

Table 1. Structure	parameters of	the proposed	design
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The dimensions, size, and materials used in plasmonic logic gate structures are all the same. Because it is the ideal wavelength for optical telecommunication systems, the operational wavelength of 1550 nm was chosen. The resonance wavelength 1550 nm is made achievable by the proposed structure's size, shape, materials, and structural factors. Maxwell equations were solved using the two-dimensional (2D) structure in COMSOL Multiphysics program (version 5.4) using the FEM method. A plane wave having Transverse Magnetic (TM) components Ex, Ey, and Hz is exposed to the framework, which has four ports as illustrated in Fig. 1. At 1550 nm, the suggested all-optical logic gates are functional based on four criteria: transmission [19], contrast ratio (CR) [19], modulation depth (MD) [19], and insertion loss (IL) [23]. Table 2 shows the performance's equations.

symbol	Equation
Т	Output optical Power
	Input Optical Power
CR (dB)	$10 \log \left(\frac{P_{out} ON/min}{P_{out} OFF/max}\right)$
MD (%)	$\left(\frac{T_{ON} Max - T_{OFF} Min}{T_{ON} Max}\right) \times 100\%$
IL (dB)	$-10 \log \left(\frac{P_{out} ON/min}{P_{in}}\right)$

Table 2.	Performance's	equations
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Pout represents output optical power, where Pin represents optical power of the input, which is 1 uW, which reached a single input port or control port. The primary idea for achieving the function of the suggested all-optical logic gates is to use constructive and destructive interferences. Constructive interference is caused by two or more signals with the same phase. Contrarily, destructive interference is brought on by the difference in phase between the incident light signals on the structure. Each gate's truth table in logic 1 and logic 0 is implemented using this idea.

## Results

In both OFF and ON states, the transmission is determined, and a transmission threshold value is chosen to determine whether the state is off or on. A series of specifications led to the selection of the transmission threshold value of 0.5 in this design to implement the three logic gates [24].

### NOT Logic gate

As illustrated in Fig. 1, the present suggested structure implements a NOT gate by designating executors 1 and 2 as control executors, executors 3 and 4 as input and output, respectively. It is a kind of logic gate that reverses the input signal and is also referred to as an inverter. The symbol circuit and truth table are depicted in Fig. 2(a) and (b), respectively.



Figure. 2 (A) Symbol of NOT gate (B) Fact table of NOT gate

To function as a NOT gate, it is possible to employ subversive interference between control and input signals. When the control executors are ON and its phase is  $0^{\circ}$  and the input executor is OFF, the output executor is ON and its transmission greater than the defined threshold. When the light is launched to the input port with a phase  $0^{\circ}$  and control ports with a phase  $180^{\circ}$ ,  $45^{\circ}$  respectively the output executor's status can be regarded as OFF With an extremely low transmission level, and this is a result for destructive interference. Fig. 3 depicts the transmission versus wavelength range curve for the plasmonic NOT gate. Fig. 4 (a) and (b) depicts the distribution of magnetic field of both cases. Table 3 describes the validation of suggested plasmonic NOT gate.



Figure. 3 Transmission curve Vs. wavelength range for NOT gate



Figure. 4 Distribution of magnetic field (a) first case and (b) second case for NOT logic gate

Table 3	. NOT	gate	transmission
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In	Control	Control	Т	T <sub>th</sub>	Output
(Phase)	1(Phase)	2(Phase)			Port
$OFF(0^{\circ})$	ON(0°)	$ON(0^{\circ})$	1.306	0.5	ON
$ON(0^{\circ})$	ON(180°)	ON(45°)	0.071	0.5	OFF

According to CR Equation, the plasmonic NOT gate's CR is 12.64 dB, which is considered high value, and its performance is very good and efficient. While the MD value is 94.56% according to MD Equation, this is considered a very high value, and the suggested structure dimensions are optimum and excellent. IL value is -1.159 dB according IL equation.

### **OR** Logic gate

The current proposed structure implements an OR gate by making executors 1 and 2 input executors, executor 3 a control executor, and making executor 4 an output executor, as illustrated in Fig. 1. OR gate is a gate which produces logic 1 in the second, third, and fourth states of its truth table but logic 0 in the first. Fig. 5 (a) and (b) depict OR gate's symbol circuit and truth table, respectively.



Figure. 5 (A) OR gate's symbol circuit (B) OR gate truth table

This gate's function is accomplished through constructive interferences between signals of light dispersed in the input and control executors in second, third and fourth cases so the output executor will be ON. In the first case the input executors are OFF and only control executor is ON so output executor is OFF. Fig. 6 depicts the transmission versus wavelength range curve for the plasmonic OR gate. Fig. 7 depicts the distribution of magnetic field of all cases. Table 4 describes the validation of the proposed plasmonic OR gate.



Figure. 6 Transmission curve Vs. wavelength range for OR logic gate



Figure. 7 (a), (b), (c), (d) magnetic field distribution for all cases for OR logic gate, respectivly

In	IN	Control	Т	T <sub>th</sub>	Output
1(Phase)	2(Phase)	(Phase)			Port
OFF(0°)	OFF(0°)	$ON(0^{\circ})$	0.0937	0.5	OFF
OFF(0°)	$ON(0^{\circ})$	$ON(0^{\circ})$	0.77	0.5	ON
$ON(0^{\circ})$	OFF(0°)	$ON(0^{\circ})$	0.77	0.5	ON
$ON(0^{\circ})$	$ON(0^{\circ})$	$ON(0^{\circ})$	2.1	0.5	ON

Table 4. OR gate transmission

According to CR Equation, the plasmonic OR gate's CR is 9.147 dB, which is considered medium value, and its performance is good and efficient. While the MD value is 95.53% according to MD Equation, this is considered a very high value, and the dimensions of suggested structure are optimum and excellent. IL value is 1.135 dB according IL equation.

# AND logic gate

The current proposed structure implements an AND gate by making executors 1 and 2 input executors, executor 4 a control executor, and executor 3 an output executor, as illustrated in Fig. 1. AND gate is a gate which produces logic 0 in the first, second, and third states of its truth table but logic 1 in the fourth. Fig. 8 (a) and (b) depict the AND gate's symbol circuit and truth table, respectively.



Figure. 8 (A) Symbol circuit of AND gate (B) AND gate truth table

In the first state, the input executors are OFF and only control executor is ON so output executor will be OFF. In the second and third states, when one of the input executors is ON with phase 180°, destructive interference occurs because of phase varying and the propagation's direction of the control and input signals, and the output will be OFF in the output executor. In the fourth state, constructive interference occurs because all control and input executors are ON and in similar phase so the output executor is ON state. Fig. 9 depicts the transmission versus wavelength range curve for the plasmonic

AND gate. Fig. 10 depicts the distribution of magnetic field of all cases. Table 5 describes the validation of proposed plasmonic AND gate.



Figure. 9 The transmission curve Vs. the wavelength range for AND logic gate



Figure. 10 (a), (b), (c), (d) Distribution of magnetic field for all cases for AND logic gate, respectively

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In	IN	Control	Т	Tth	Outp
1(Phase)	2(Phase)	(Phase)			ut
					Port
OFF(0°)	$OFF(0^{\circ})$	ON(180°)	0.093	0.5	OFF
OFF(0°)	$ON(0^{\circ})$	ON(180°)	0.071	0.5	OFF
$ON(0^{\circ})$	$OFF(0^{\circ})$	ON(180°)	0.071	0.5	OFF
ON(180°)	ON(180°)	ON(180°)	2.1	0.5	ON

Table 5. AND gate transmission

According to CR Equation, the plasmonic AND gate's CR is 13.5 dB, which is considered high value, and its performance is very good and efficient. While the MD value is 96.6 according to MD Equation, this is considered a very high value, and the dimensions of the suggested structure are optimum and excellent. IL value is -3.222 dB according IL equation.

## Comparison of the suggested work and prior work

Criteria	[25]	[26]	[27]	[28]	[29]	This paper
Proposed fundamentals logic gates	OR, AND, NOT.	OR, NOT,	OR, AND, NOT.	OR, AND, NOT.	AND, OR, NOT.	NOT, OR, AND.
Plasmonic waveguide	IMI	MIM	MIM	MIM	MIM	IMI
Number of models that realize the logic gates	One structure	Three structure	One structure	One structure	One structure	One structure
Size(s)	200nm*400nm	2um*1.2um	1.5um*1um	600nm*600nm	1269nm*1269nm	400nm*400nm
Operating wavelength	1550nm	1300nm 1620nm	618nm 1191nm	1550nm	1200nm,885nm 800nm,1400nm	1550nm
Maximum transmission %	152	35	143	190	95	210
Performance measured	T, CR	Т	T, CR, Gap- Threshold ratio (GTR)	T, CR	Т	T, CR, MD,IL
Threshold of transmission	30%	10%	20%	35%	AND 28% OR 20% N0T 20%	0.5

Table 6. compares the plasmonic gates that suggested to the early studies.

## Conclusion

This paper proposed, designed, and demonstrated plasmonic logic gates (NOT, OR, AND) in a new configuration based on nano-rings IMI plasmonic waveguides. The task of the suggested plasmonic logic gates has come to be realized through destructive and constructive interferences between both the control signal and the input signal(s). At the output, the Transmission threshold between states 1 and 0 is 0.5. The suggested plasmonic gates can be realized by making proper executor assignment choices in the proposed structures, as well as the proper phase angle selection, which results in destructive and constructive interferences. Four parameters are applied to evaluate the proposed structure's

performance: transmission, contrast ratio, modulation depth and insertion loss. Structure shape, structure size, structure parameters, materials used, selected materials refractive index, position of the executors in the structure, and phase can all be used to control the transmission at the output port. SPP is generated at 1550 nm. depending on its size, shape, parameters, and structure materials. This device had the following characteristics: transmission exceeds 100% in one state of all three gates, with medium and high contrast ratio values, very high modulation depth values, a small area, and an operating wavelength of 1550 nm. In the future, this technology will provide accessibility to nanophotonic integrated circuits and is viewed as a basic building element for all-optical computers.

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# Synthesis and Characterization of Nickel Oxide Nanoparticles by Green as well as Chemical Routes and Comparisons their Properties

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#### **Keywords:**

NiO nanoparticles; Co-precipitation ; Capparis Spinos extract ; BET ; and XRD .

#### Abstract

Nickel Oxide (NiO) Nanoparticles(NPs) were obtained using chemical and Eco-Friendly methods, utilizing Caper leaves extract, NaOH, and nickel sulfate hexahydrous. First step Ni(OH)<sub>2</sub> NPs was obtained by adding NaOH solution dropwise to mixture the caper leaves extract and solution of Ni(SO<sub>4</sub>)<sub>2</sub>.6H<sub>2</sub>O. Then, calcination was done at 600 °C and 6 h for the Ni(OH)<sub>2</sub> NPs to produce NiO NPs. Different techniques such as X-Ray, FTIR, FE-SEM, EDX and BET have used to evaluate the physical features of grown samples. However, the XRD pattern confirmed that all the samples are contains only NiO phase with average crystallite sizes 46.62 nm and 19.12 nm for both ecofriendly and co-precipitation methods, respectively. FESEM image of the NiO NPs revealed to be spherical shape. The elements content by green synthesis was shown in the EDX results as (Ni = 64.3 Wt%, O = 24.6 Wt%) and by chemical method as (Ni = 66.3, O = 29.3). According to BET analysis, the specific surface area of prepared NiO NPs using chemical precipitation method was greater than that produced using an eco-friendly method.

#### Introduction

The term "nanotechnology" describes the synthesis or use of particles with dimension(s) below the nanometer range, or one billionth of a meter [1]. Because of the distinct influences of tiny size effect, surface effect, and quantum size effect, NPs exhibit unique characteristics that greatly differ from those of the comparable bulk solid state [2]. Nickel (group II) and oxygen (group VI) from the periodic table of naturally occurring elements are combined to form an II-VI composite semiconductor known as nickel oxide nanoparticles. NiO is a P-type semiconductor transition metal oxide that is incredibly robust, has straight band gaps between 3.5–3.8 ev, and has the ability to display super-paramagnetic and super-antiferromagnetic features [3]. Due to their low cost, lack of toxicity, and environmental friendliness, Nickel oxide nanoparticles are of great interest. This

material is used in a wide range of applications, such as transparent conductive, chemical sensors, and resistive random access memory. Additionally, it is a well-researched material that can also be used as a positive electrode in batteries and as a hole transport layer in quantum dot light emitting devices [4]. The synthesis of the NiO NPs has been achieved using a variety of techniques, including co-precipitation, sol gel, and solvothermal procedures [5]. Green synthesis is one of the various chemical and physical techniques used to create nanomaterial, and it has caught the attention of many researchers. The reason is that this approach to green synthesis is straightforward, economical, necessitates less heat and energy, and is environmentally friendly. Caper plant leaf extract was utilized as a mediator to obtain NiO NPs. The purpose of this study is to synthesize NiO NPs using two different techniques: first, by chemical precipitation of capparis spinosa plant leaf extract, and second, by using capparis spinosa plant leaf extract [6]. Chemical precipitation is the process of turning a liquid into a solid by adding chemical agents, supersaturating the liquid, and then separating the precipitates from the liquid. It facilitates the mass production of pure nanoparticles because it only needs one step. It is a very helpful method that even helps purify water and provides a long-term solution or outcomes that produce long-lasting effects [7]. The present work reports the nickel oxide NPs synthesis by green rout (Capparis Spinosa: chelating agent) and by chemical rout (coparticipation). The structural, surface area, morphological and the elemental composition properties were studied for comparisons.

# **Materials and Methods**

# Chemical and plant materials

Nickel (II) sulfate hexahydrate (99%), Sodium hydroxide (NaOH), (99%), ethanol (99%) and Distilled H<sub>2</sub>O were of analytical grade and were purchased from BDH Company, England. Capparis Spinosa plant was collected from the University of Diyala, Baquba.

# **Preparation of Capparis Spinosa Plant extracts**

(5.0 g) of fresh leaves from Capparis Spinosa have ground into a fine powder after being cleaned with tap water; then this was washed by deionized water. The fine powder of Capparis Spinosa is dissolved in 200 mL of deionized water and boiled for 30 minutes at 80 °C. The extract was then filtered using filter paper NO. 1 and stored in refrigerator at 4 °C for further studies [8].

# Preparation of Nickel Oxide Nanoparticles using Capparis Spinosa extract

Nickel salt NiSO<sub>4</sub>.6H<sub>2</sub>O (0.3g) was dissolved in 50 mL of deionized water. The solution of plant extract was added stepwise to the solution while stirring at (25 °C), the temperature of the solution was raised up to (80 °C), and the mixture of the salt solution and the leaf extract was then added dropwise to the NaOH (0.1M) solution to achieve an approximate pH of 14 while stirring continuously for an hour. Then the mixture was filtered, and the precipitate (Ni(OH)<sub>2</sub> NPs) was collected and dried in an oven at 80 °C for 4 hours. The product has calcined for six hours at 600 °C to produce nickel oxide nanoparticles (NiO) [8].

# Preparation of Nickel Oxide Nanoparticles using Co- participation

NiO NPs have synthesized using Nickel Sulfate Hexahydrate (NiSO<sub>4</sub>.6H<sub>2</sub>O). Nickel salt solution (0.3 g) dissolved in the deionized water (50 mL). Salt solution was stirred continuously while NaOH (0.1M) solution was added dropwise to achieve a pH of about 11. The nickel hydroxide nanoparticles (Ni(OH)<sub>2</sub>NPs) form a black precipitate was collected after a short period of time, and repeatedly washed with deionized H<sub>2</sub>O to obtain pH 7. Following that, black precipitate was dried at 80 °C for

16 hours. NiO nanoparticles were obtained after calcination of Ni(OH)<sub>2</sub> NPs at 600  $^{\circ}$  C for 6 hours [9].

#### Characterization

Structural studies of NiO nanoparticles prepared using Capparis Spinosa plant extract were recorded on a Siemens model D500, the XPERT-Pro diffractometer using Cu K $\alpha$  radiation source as X-ray ( $\lambda$ =1.5405) at room temperature. ZEISS Sigma VP scanning electron microscopes are used For morphological analysis. FT-IR spectrum of NiO synthesized nanoparticles are gained at the University of Diyala /College of Education for Pure Science (Schimadzu Spectrophotometer/Japan). The elemental analysis of NiO NPs studies was performed by EDX, and TriStar 3000, Micromeritics Inc. measured the pore volume and specific surface area (SSABET).

#### **Results and discussion**

## **FT-IR** spectroscopy

Fig. 1, (a) and 1(b) shows the FT-IR specta of (Ni(OH)<sub>2</sub> NPs using chemical and green routs. The FT-IR spectrum of Ni(OH)<sub>2</sub>-green nanoparticles (Fig. a) showed broad band at 3417 cm<sup>-1</sup> related to O–H stretching vibration, as well as the band at 1509 cm<sup>-1</sup> revealed the bending vibration for the OH of water molecules coordinate to nickel in the Ni(OH)<sub>2</sub>, weak band at 455 cm<sup>-1</sup> is related to Ni–O. Similarly, (Fig .c), shows the FTIR spectrum of the Ni(OH)2-chemical nanoparticles, the peaks at 3417 cm<sup>-1</sup>,3641 cm<sup>-1</sup> and 1635 cm<sup>-1</sup> is for O–H stretching and bending vibrations, respectively, and a weak peak appeared at 516 cm<sup>-1</sup> for the Ni–O lattice vibration. Fig (1 b) showed band at 3240 cm<sup>-1</sup> assigned to the stretching of OH group and weak band at 1635  $\text{cm}^{-1}$  is due to the bending of OH, while peak at 2021 cm<sup>-1</sup> refers to SO<sub>4</sub> group [10],[11]. The FT-IR spectrum of NiO-green and NiOchemical NPs is shown in Fig.2,(a) and (b). The absorption bands that showed at 3387 and 3417 cm<sup>-</sup> <sup>1</sup>corresponds to (O-H) stretching of water in the NiO-green and NiO-chemical NPs respectively, and the peak at 1627 cm<sup>-1</sup> is for (H<sub>2</sub>O) bending vibrations. The bands at 1211 and 1149 cm<sup>-1</sup> are related to (C=O) group of (CO<sub>2</sub>) that adsorbed on surface of NPs from plant extract for NiO-green and NiOchemical NPs respectively. Furthermore, the significant absorption band at 450 cm<sup>-1</sup> is assigned to stretching vibrations of (Ni-O). The aforementioned results thus confirm the predicted structure and functional groups [12], [13], [14].

# **XRD** Analysis

The structural and crystalline size of NiO-green NPs and NiO-chemical NPs were studied using XRD technique. Fig. 3,( a) and (b) shows the strong peak of NiO-green NPs and NiO-chemical NPs. XRD pattern shows many diffraction peaks at 20 of 37.46°, 43.49°, 44.68, 63.07°, 75.59°, 76.52°, and 79.57° related to Crystallography Open Database of NiO 96-101-0096 with cubic structural. [15], while XRD pattern of NiO-chemical NPs shown five diffraction peaks at 37.44°, 43.47°, 63.24°,75.61° and 79.62, which also had a cubic structural association with the International center for diffraction data of NiO 98-009-0203[5]. The average of crystallite size for NiO-green NPs and NiO-chemical NPs were 46.62 nm and 19.12 nm respectively, which was calculated using Debye Scherrer equation

$$\mathbf{D} = \frac{\mathbf{\kappa} \ast \boldsymbol{\lambda}}{\boldsymbol{\beta} \cos \boldsymbol{\theta}}$$

The crystalline domain size (D) to the peak's width at half its height ( $\beta$ ), quantitatively describes the broadening of a peak at a specific diffraction angle ( $\theta$ ). The Scherrer constant,  $\kappa$ , is typically considered to be 0.91 but can vary with the morphology of the crystalline domains. Depending on the kind of X-rays being used, the X-ray wavelength ( $\lambda$ ) is a constant and the dislocation parameter is then calculated;  $\delta = 1/D^2$  [16, 17].



Fig .1, FTIR spectra of (a) Ni(OH)2-green nanoparticles, (b) NiSO4.6H2O and (c) Ni(OH)2-chemical nanoparticles.





Fig 2. (b) FTIR spectra of NiO-chemical NPs.

Sample				dislocation	D Average	
ID	2 <del>O</del> ,Deg	FWHM ,nm	Dp, nm	parameter ,δ ,1/d <sup>2</sup>	,nm	phase
	20.8558	0.1968	<b>42.</b> 90	0.00054361		NiO-green
	21.9521	0.1476	<b>57.</b> 31	0.00030467		NiO-green
	22.9285	0.1968	<b>43.0</b> 5	0.00053982		NiO-green
	25.1847	0.1968	<b>43.2</b> 3	0.00053534		NiO-green
	26.9215	0.1968	43.39	0.00053164		NiO-green
	30.2458	0.2952	<b>29.1</b> 4	0.00117847		NiO-green
	31.3203	0.1968	<b>43.8</b> 2	0.00052125		NiO-green
9	35.2854	0.1476	<b>59.0</b> 3	0.00028717		NiO-green
a	37.4637	0.246	35.64	0.00078771	<b>4</b> 6.62	NiO-green
	38.8554	0.1968	<b>44.7</b> 4	0.00049980		NiO-green
	43.4956	0.246	36.34	0.00075765		NiO-green
	44.6849	0.1968	<b>45.6</b> 2	0.00048091		NiO-green
	45.6372	0.3936	<b>22.8</b> 9	0.00191024		NiO-green
	49.9245	0.1968	<b>46.5</b> 4	0.00046188		NiO-green
	50.3221	0.1968	<b>46.6</b> 2	0.00046049		NiO-green
	52.0377	0.246	<b>37.5</b> 6	0.00070921		NiO-green
	53.4456	0.3444	26.99	0.00137275		NiO-green
	55.3617	0.2952	31.76	0.00099137		NiO-green
	63.0752	0.3444	28.29	0.00125037		NiO-green
	66.9984	0.3936	<b>25.</b> 30	0.0015635		NiO-green
	72.9108	1.1808	8.74	0.013091		NiO-green
	75.5978	0.246	<b>42.7</b> 2	0.00054820		NiO-green
	76.5211	0.1476	71.65	0.00019484		NiO-green
	79.5778	0.1968	<b>54.9</b> 1	0.0003317		NiO-green
	35.1998	0.2952	<b>29.5</b> 1	0.0011490		NiO-
	25.4444	0 5 4 1 2	16.00	0.0020151	10.12	chemical
D	37.4444	0.5412	16.20	0.0038151	19.12	NIO- ahamiaal
	43 4788	0 5904	15 14	0 0043626		NiO-
		0.5704	15.14	0.0045020		chemical
	51.3982	0.5904	<b>15.6</b> 1	0.0041091		NiO-
						chemical
	62.9124	0.48	20.28	0.0024338		NiO-
	63 2401	0 2952	33.03	0 0009171		NiO-
	03.4701	0.2752	55.05	0.000/1/1		chemical
	75.6134	0.6396	16.43	0.003704		NiO-
						chemical
	79.6248	0.492	<b>21.</b> 97	0.0021061		NiO-
						chemical

Table 1. XRD data for NiO-Green NPs and NiO-Chemical.



## **FESEM Results**

FESEM is one of the well-recognized techniques to evaluate the morphology of nanomaterials. Fig (4a-b) show FESEM images of (a) Ni(OH)<sub>2</sub>-green NPs and (b) Ni(OH)<sub>2</sub>-chemical NPs. FESEM images of the Ni(OH)<sub>2</sub>-green NPs is shown in figure (4 a), which revealed irregular shape nanoparticles with agglomeration, average diameters 51.92 nm. However, when compared to the case of Ni(OH)<sub>2</sub>-green, the FESEM image of Ni(OH)<sub>2</sub>-chemical nanoparticles in figure (4 b) confirmed the presence of regular spherical shapes nanoparticles with average diameters of about 68.75nm [18] . The morphology of nickel oxide nanoparticles-green and chemical routes were examined using FESEM. The typical shapes of NiO- green NPs is shown in the Fig (4.c) and spheres, measuring approximately 58.47 nm, contain some tiny NiO nanoparticles. Fig. (4.d) provides the FESEM images of the NiO-chemical NPs product. They are almost spherical in shape. Thus, it is evident that the large spheres are made of various-sized small nanoparticles [19], [20].

#### **EDX** Analysis

The results of the EDX analysis for the NiO NPs in Fig. 5a and b, shows that the obtained nanoparticles were composed from Ni and O elements. The element percentages that obtained from EDX were (66.8% and 68.5% of Ni, 16.3% and 19.2% of O) for NiO-green and NiO-chemical respectively. Peaks gold and molybdenum were derived from the initial stages of preparation for EDX observation [21]. The appearance of a peak at 0.2 due to the carbon atom produced by the filter paper residue ,which showed the NiO formation with acceptable purity [22].



Fig 4. FESEM image of (a) Ni(OH)2-green, (b) Ni(OH)2 chemical, (c) NiO-green, and(d)NiO-chemical rout



Fig 5. EDX Analysis of NiO NPs (a) green rout and (b) chemical rout .

## Brunauer-Emmett-Teller and Barrett, Joyner, and Halenda Analysis

The NiO NPs has analyzed via BET and BJH to absorb nitrogen gas at constant temperature of 77K. The specific surface area of the NiO-green NPs was obtained to be  $3.7671 \text{ m}^2/\text{g}$  with average pore diameter about 26.881 nm and total pore volume of  $0.025316 \text{ cm}^3/\text{g}$  (Fig.6 a). Mesopores (pores 5-55 nm in diameter) were detected in the NiO-green NPs according to a BJH diagram (Fig. 6 b), and it was also noticed that the pore size was irregular, with the majority of the nano pores falling within (5–20) nm range.

The NiO-chemical NPs' BET surface area, average pore diameter, and total pore volume, on the other hand, were calculated to be  $32.329m^2/g$ , 24.098 nm, and 0.1948 cm<sup>3</sup>/g, respectively (Fig. 6 c). NiO-chemical NPs were found to have mesopores, or pores that are between 2 and 55 nanometers in diameter, according to a BJH diagram (Fig. 6.d). It was also noted that the pore size was not uniform here, with the majority of the nano pores falling between 2 and 10 nanometers (Fig. 6 d) [23].



Fig 6. Surface area and distribution of pores of NiO- NPs, (a) BET curve of green rout, (b) BJH plot of green rout, (c) BET curve of chemical rout and (d) BJH plot of chemical rout

According to the study's findings, the mean size of NiO NPs were 46.62 and 19.12 nm for NiO-green NPs and NiO-chemical NPs respectively as determined by XRD technique. The BET technique of surface area for NiO nanoparticles is  $3.7671m^2/g$  and  $32.329m^2/g$  for NiO nanoparticles by green route and chemical route, respectively

#### **Conflicts of interest**

The authors make it clear that they do not have any Conflicts of interest in this work.

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# Synthesis, Optical and D.C Electrical Characterization of (Pomegranate/PVA/TiO2) Ternary-Nanocomposites, As a Window to Improve Solar Cell Performance

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#### **Keywords:**

Nanocomposite; D.C electrical properties; Solar cell; Polyvinyl alcohol; Titanium dioxide.

#### Abstract

This paper aims to fabricate a nanocomposite made of polyvinyl alcohol, titanium dioxide, and natural pomegranate dye that can function as a sunlight sensor for solar cells. The thin films' structural, optical and electrical properties of (Pomegranate/PVA-TiO2) were studied. Images from (FE-SEM) taken at a concentration of 0.3 weight percent revealed the structural features of the material., the surface of the (Pomegranate/PVA-TiO2) nanocomposite films demonstrations many aggregations or chucks arbitrarily dispersed of (TiO2) with grain size (47-55) nm. With an increase in natural dye content, transmittance decreases. Pomegranate dye had the most prominent peaks, measuring (76%) at a concentration of 1 ml. All optical constants, including parameters such n and k for transparency and extinction, r and i for real and imaginary dielectric constants, and electrical conductivity for optical conductivity, rise with pomegranate dye concentration. The results showed that the electrical conductivity at a concentration of (4 ml) recorded the greatest possible (6.4×10-6) ( $\Omega$ .cm)-1, and the activation energy decreased with increasing concentration of pomegranate dye (0.29-0.20) eV. Then a solar cell was prepared from SnO2/Si, and the films were deposited on it, and the efficiency results coated (Pomegranate/PVA-TiO2) After being with were. nanocomposites, the efficiency  $(\eta)$  increased from (4.3-4.75). In addition to the increase in current (Isc) from 23 to 30 mA/cm2. The final results showed that the (Pomegranate/PVA-TiO2) nanocomposite possesses a high transmittance, low activation energy and is sensitive to light in the Vis and IR regions, making it suitable for optical application.

#### Introduction

One of the most promising industries is the solar cell sector. Applications that make use of thin membranes have gained a lot of attention in recent years due to their simplicity and low cost of production [1]. A nanoparticle (NP) dispersion of tin (Sn) is annealed at temperatures below 150 degrees Celsius to generate tin oxide (SnO2). Dye-sensitized and perovskite solar cells have been extensively researched, and so have their electron transport layers. The use of SnO2 as a photovoltaic

material is promising [2]. SnO2 was chosen to build a solar cell with an n-type SnO2 layer and p-type silicon wafers because to its broadband gap and low reflecting index of 2 [3]. Pure silicon, which has been used as an electrical part for decades, is the most important part of a solar cell. Silicon solar panels are often called "1st generation" panels because the technology for making silicon solar cells took off in the 1950s. Silicon is used in more than 90% of the solar cells on the market [4]. PVA is a promising material with high dielectric strength, strong charge storage capacity, and electrical and optical characteristics that vary according to the dopant [5]. Titanium dioxide is notable for its wide range of uses, including paint, sunscreen, and food colouring [6]. Natural colours from plants including flowers, fruit, and leaves can be used in DSSCs [7]. One of the many factors affecting dye light absorption is the medium used to extract the dye [8] A thin-film solar cell (TFSC), also called a thin-film photovoltaic cell (TFPV), is a second generation solar cell that is made by depositing one or more thin layers, or thin film (TF) of photovoltaic material on a substrate, such as glass, plastic or metal[7]. Thin-film solar cells are commercially used in several technologies, including cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous and other thin-film silicon (a-Si, TF-Si). Film thickness varies from a few nanometers (nm) to tens of micrometers (µm), much thinner than thin-film's technology, the conventional, first-generation crystalline silicon (c-Si) solar cell, that uses silicon wafers of up to 200 µm. This allows thin film cells to be flexible, lower in weight, and have less drag. It is used in building integrated photovoltaics and as semi-transparent, photovoltaic glazing material that can be laminated onto windows[9] The most popular material utilised to create semiconductors is silicon. The outer shell of the element silicon has four electrons. A p-type semiconductor is made by adding additional elements, such as boron or aluminium, to silicon. These materials only have three electrons in their outer shell. When the additional material partially replaces some of the silicon, the location where the fourth electron would have been if the semiconductor were comprised entirely of silicon is left empty[3,8].

#### Experimental procedure

#### Materials and methods of thin polymeric films

Nano shell USA provided titanium dioxide powder that met our specifications of 20 nm particle size and 99.9% purity. It was white and quite dense, coming up about 4.23 g/cm3. The PVA came from a Chinese company called Shanghai Kaidu Industrial Development Co., Ltd., and it was a white granular polyvinyl alcohol. Once the seeds were removed from the fruit and roasted, they were the pomegranate's active component. In order to preserve the scent, pomegranate dye was removed by filtering the concentrated liquid, heating it at 77 °C, and evaporating 20% of the water. The resulting dry paste was crushed to create colour powder after being dehydrated in an oven (dryer) at 77 °C for 10 hours. In a glass beaker with 20 mL of water, 0.7 g of polyvinyl alcohol thoroughly dissolved at 85 °C. 0.3 weight percent of titanium dioxide nanoparticles were added to the pure sample that had been dissolved. Using an ultrasonic device, we combined 4 ml of pomegranate dye with 20 ml of titanium dioxide to create the samples. films with a

#### Materials and methods of solar cell

Sky Spring Nanomaterial, Ink Company, USA offers powdered tin dioxide with particle size (35-55) nm and high purity (99.9%). Commercially available monocrystalline p-type silicon wafers (SnO2) have an orientation of [111] and a resistivity of 1-10.cm. Prior to film deposition, wafer silicon was cleaned and chopped into 11 cm diameter pellets. On Si wafer samples, multiple washing of distilled water were utilised, followed by gentle drying with paper towelling. Using a vacuum thermal evaporator, the p-type silicon wafer was covered with tin dioxide powder. The boat's substrate height was 17 cm and its breadth was 200 nm. Thermal evaporation technology was used to generate

(SnO2) films that were placed onto cleaned p-type silicon wafer substrates with constant thickness (2006 nm).

Theoretical part

By comparing the intensity of the incident rays (Io) on the film to the intensity of the transmitting rays (IT), we can calculate the film's transmittance (T)[10].

$$T = I_T/I_0 ....(1)$$

Light's speed in vacuum is divided by the speed of light within the medium to yield the refractive index..

$$n = \sqrt{((4R - [[k]]^{2})/[[(R-1)]]^{2})} - ((R+1))/((R-1)) \dots (2)$$

For the complex refractive index, the imaginary portion is the extinction coefficient.

n^\*=n-ik\_o .....(3)

n: the equivalent of an actual refractive index (c/v).

The following equation gives the extinction coefficient (ko).

$$k_0 = (\alpha \lambda)/(4 \pi) \dots (4)$$

The following equation describes the real and imaginary parts of the complex dielectric coefficient[9]:

$$\mathcal{E}r = n^2 - [[k_o]]^2 \dots (5)$$
  
 $\mathcal{E}i = 2nk_o \dots (6)$ 

D.C Electrical Conductivity ( $\sigma d.c$ )  $\rho dc$  is surface resistivity. The surface conductivity is the resistivity's inverse. Surface conductivity increases[11].

L, b, and t represent the sample's length, width, and thickness. Formula for activation energy (Ea) [8].

Absolute zero electrical conductivity is denoted by a value of zero, while the other variables are the Boltzman constant k, the absolute temperature T, the activation energy Ea, the thermal energy KT associated with the change in temperature measured, and the absolute temperature T [11,12]

The current-voltage (I-V) Solar cell photovoltaic performance is measured. Voc, Isc, F.F, and  $\eta$  are photovoltaic properties of solar cells), as in the equations below. These values were obtained using the typical conditions of 25°C cell temperature and 115 mW/cm2 incoming solar radiation [13]:

F.F= V m×I m/ Voc×I sc ..... (9)  

$$\eta = P$$
 m/ Pin ...... (10)

Results and discussion

In figure (1), cluster and surface morphologies of (Pomegranate/PVA-TiO<sub>2</sub>) films are studied by scanning electron microscopy (FE-SEM). As a result, the interfacial adhesion between the polymer matrix and the filler components was weak. These figures were observed When the concentration to 0.3wt.% for The top surface of the (Pomegranate/PVA-TiO<sub>2</sub>) nanocomposite films reveals numerous aggregations or chucks of (TiO<sub>2</sub>) nanocomposites. The images showed (48)nm [14, 15].



Figure 1: FE-SEM measurement of (Pomegranate/PVA- TiO2A, B) 1ml/1ml and C, D)1ml/4ml.

Figure(2) show, the maximum peaks were obtained in pomegranate dye at (76%) with a concentration of 1 ml, and that the transmittance of (Pomegranate/PVA- TiO2) nanocomposites declines with increasing natural dye concentration. Because of their high transmittance in the visible and infrared spectrums, these thin films may find application as a window for solar cells [16]. In fig. (3), refractive index (n) increases with increasing wavelength in the ultraviolet region and then decreases with increasing wavelength in the visible and infrared regions. Also, the refractive index (n) increases with growing focus of pomegranate dye and this indicated to decrease in trancemetance. This is owing to the rise in the optical density of the material. The electronic polarization of ions and the local field inside optical materials are intimately connected to the refractive index (n) [17]. UV wavelengths have a larger attenuation coefficient than VIS and IR wavelengths, as shown in figure (4). The concentration of pomegranate dye raises the extinction coefficient. The causes are a rise in the absorption coefficient as a result of electronic transit between bonding and nonbonding molecular orbits, as well as an increase in the extinction coefficient as a result of refractive index [18]. In

figures (5) and (6), the results observed that the real dielectric constant  $\mathcal{E}_r$  and the imaginary dielectric constant  $\mathcal{E}_i$  increase with increasing concentration of pomegranate dye [19]. Figure (7) shows the optical conductivity ( $\sigma_{op}$ ) as a function of wavelength for Pomegranate/PVA-TiO<sub>2</sub> nanocomposite. The results showed that the optical conductivity ( $\sigma_{op}$ ) increases with increasing. This is due to the increase in the *k* [20].



Figure 2: The transmittance (T) of (Pomegranate/PVA-TiO2) nanocomposites.



Figure 3: The refractive index (n) of (Pomegranate/PVA-TiO2) nanocomposites.



Figure 4: The Extinction coefficient (k) of (Pomegranate/PVA-TiO2) nanocomposites.



Figure 5: The Dielectric Constants (Er) of (Pomegranate/PVA-TiO2) nanocomposites.



Figure 6: The Dielectric Constants (Ei)of (Pomegranate/PVA-TiO2) nanocomposites.



Figure 7: optical conductivity (oop) of (Pomegranate/PVA-TiO2) nanocomposites

The concentration of the pomegranate dye influences the  $(\sigma_{op})$  d.c.  $(W.cm)^{-1}$  electrical conductivity (Figure 8). The concentration of pomegranate dye with (PVA/TiO<sub>2</sub>) resulted in an increase in electrical conductivity, as seen in the picture[21] The conductivity was  $6.4 \times 10_{-6}$  (W.cm)<sup>-1</sup> at 4 ml. This phenomenon may be explained by electronic communication between bonding sites [22]. Also, the electrical conductivity of (Pomegranate/PVA-TiO<sub>2</sub>) nanocomposite rises with increasing temperature. Figure 9 revealed an optimal range with an exponential or line trend when the temperature was applied from 30 to 70°C. Heating rates may affect strength of electric field or electrical conductivity of (Pomegranate/PVA-TiO<sub>2</sub>) nanocomposite, according to the researchers, who claim that the growth in ( $\sigma_{op}$ ) values with temperature is due to reduced drag for ions movement [23]. The activation energy is computed using equation (8), and the results prove that (Pomegranate/PVA-TiO<sub>2</sub>) nanocomposites have activation energies ranging between (0.29-0.20) eV.

Figure 10 depicts the relationship between the inverse absolute temperature and  $\ln\sigma$  for (Pomegranate/PVA-TiO<sub>2</sub>). The main reason for the decrease in the activation energies when increasing the concentration of the natural dyes is that figure 11 and Table 1 show how the dyes captured photons with lower energy by operating between the valence and conduction beams [22, 23].



Figure 8: Variation of  $\sigma D.C$  with concentration of pomegranate dye for (Pomegranate/PVA-TiO2) NCs.



Figure 9: Variation of  $\sigma D.C$  with T for (Pomegranate/PVA-TiO2) NCs.



Figure 10: Variation of LnoD.C with T for (Pomegranate/PVA-TiO2) NCs.



Figure 11: Variation Eact. for D.C electrical conductivity with concentration of pomegranate dye for (Pomegranate/PVA-TiO2) NCs.

The SnO2/p-Si HJ I-V characterisation is present at forwarding bias voltage within this range (-2 to 2 Volts). Charts (12) and (13), which show how current behaves in relation to forward and reverse bias voltage, respectively. The efficiency ( $\eta$ ) was observed to rise from (4.3-4.75) after being coated with (Pomegranate/PVA-TiO<sub>2</sub>) nanocomposites, as shown in table (2) below. The higher electro-catalytic activity is the cause of the improved performance. The series resistance of the cell decreases as Isc and Voc rise [24] But it was evident that the dye served as a photosensitive[25]. As shown in Table 2, the natural dyes IV dye molecules inject more electrons into the SnO2 conduction band when exposed to light, enhancing the cell's photovoltaic properties such as Isc and.[26] Therefore, it has been established that these thin films can function as solar cell coatings. Graphene, amongst others, has been used in gas sensors [27]. The improvement in electro-catalytic activity is what is responsible

for the performance improvement. As a result, the cell's series resistance decreases as Isc grows and increase Voc. As a result, it has been proven that these films can be used as coverings for solar cells[26].



Figure 12: I-V characteristic for SnO2/Si solar cell under P=115 mW/cm2



Figure 13: I-V characteristic for SnO2/Si solar cell under P=115 mW/cm2 after coating (PVA/TiO2/4ml pomegranate dye).

#### Conclusion

TiO2 with grains ) The particle concept includes the segregation of solid, liquid and gaseous particles, the particles that make up the granules). between 47 and 55 nm was seen in various aggregations or chucks on the FE-SEM images. At a concentration of 1 ml (76%), the largest transmittance peaks were recorded. Pomegranate dye concentration with (PVA/TiO2) causes an

increase in electrical conductivity. The electrical conductivity was  $(6.4 \times 10-6)$  (W.cm)-1 at a concentration of 4 ml. With an increase in pomegranate dye concentration, there was a corresponding decrease in activation energy. Efficiency was raised from (4.3-4.75) by coatings made of (pomegranate/PVA-TiO2) nanocomposites.

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# Influence of Annealing on the Optical Properties of Polyacrylonitrile Thin Films

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#### **Keywords:**

Polyacrylonitrile , Photodetectors, Absorbance spectrum, Polymer.

#### Abstract

In this paper, a polyacrylonitrile polymer was prepared and study its optical properties with different temperatures a films clear change from light brown to very dark brown at a temperature range (25- 280°C), although the polymer is characterized by high transparency and analyzing the absorbance spectrum of the prepared films, the direct energy gap was calculated, which was in the range of 4.01eV for without annealing films to decrease to 1.63eV for films annealing at a temperature of 280°C with these changes in properties, these films can be used in optical applications such as solar cells and photodetectors.

#### Introduction

Polyacrylonitrile (PAN) both semi-crystalline and non-crystalline polymers come in different forms. Polymer crystalline structures play an important role in the physical, chemical, electrical, mechanical, and thermal properties. The crystalline PAN structures and unit cells have been under contention since the PAN heat history exhibited many polymorphs [1]. Despite being thermoplastic, it does not disintegrate in typical circumstances. It disintegrates first, then melts. If heating rates reach 50°C per minute or higher, melting occurs above 300°C [2]. It is a polymer with many uses. Reverse osmosis hollow fibers, textile fibers, PAN peroxide fibers, ultra-filtration membranes, and other goods are all used in the production process. [3]. It has properties including low density, thermal stability, high strength and modulus of elasticity. Polyacrylonitrile (PAN) has very good chemical and physical

properties that make it very easy to form nanofibers such as good commercial availability, mechanical properties and environmental stability [4][5]. Because of these special qualities, PAN is a crucial polymer in high technology. Super capacitors, solar cells, photodetectors [6], catalysis, sensors, and energy conversion and storage are just a few of its numerous uses. Awnings for the outdoors, fiber-reinforced concrete, and hot gas filtration systems have all used homo polymers of poly acrylonitrile as fibers [7]. Knitted clothing, including socks and sweaters, are frequently made using copolymers that contain polyacrylonitrile as fibers [8], in addition to outdoor goods like tents and related stuff. Clothing that says "acrylic" on the label is made of a polymer called polyacrylonitrile. In 1942, it was transformed into spun fibers and sold under the brand name Orlon [9]. Due to the presence of a high polarity group (CN) along the polymer chain, polyacrylonitrile is a versatile polymer [7]. In this study, the optical characteristics of the produced Polyacrylonitrile polymer were examined at various temperatures.

## **Excremental part**

# Preparation of acrylonitrile polymer (PAN)

Polyacrylonitrile (PAN)  $C_3H_3CN$  with a molecular weight of 15000 g / mol was used in this research, and the prepared solvent dimethylformamide (DMF)  $C_3H_7NO$  was obtained from the BDH company. PAN thin films were synthesized by melting 2g of PAN in 15 ml of dimethylformamide (DMF) solvent. The solution is placed on the mechanical stirrer at a temperature of 70°C for two hours with continuous stirring. The thin films were prepared using the simple method of spin casting. Wide-area films and different thicknesses can be obtained by pouring the polymer solution on sheets of glass of dimensions (2×2) cm<sup>2</sup>, which are cleaned well by washing them with a group of polar solvents such as ethanol and exposure to the plates into a stream of distilled water using an ultrasonic device (NT-628+) manufactured by (GUANGZHOU HENWEI ELECTRONICS TECHNOLOGY) then the glass plates are dried and kept in a dry place [8].

#### Annealing of polymeric films

The prepared films are placed in the electric oven with a range of up to 1000°C obtained from the Qallenhamr company. The glass slides were exposed to different temperatures, ranging from (150, 180, 200, 250, 280) °C, respectively, where the films were left for two hours at a constant temperature [9]. Figure 1. shows the annealing samples.



Figure 1: Polyacrylonitrile thin films after annealing

#### **Results and discussion**

Figure (3) shows the absorbance spectrum of films treated with different temperatures, as shown previously (untreated, 150, 180, 200, 250, 280°C), respectively. It is noted in figure (3) that with an increase in the annealing temperature there is a displacement towards the red wavelengths (large wavelengths). The reason is that the increase in temperature works to break the triple bonds that link carbon with nitrogen (the cyanide group) and double bonds are formed forming what is known as cyclic structures, and this is a very clear process during the color change of the membranes from light brown to dark brown[10]. Figure (2) show scheme of PAN structure during cyclization.



Figure (2): Structures of PAN during the Cyclic Reaction [9]

To determine the optical band gap of the materials in transmitting radiation, optical characteristics are studied. The relationship between the absorption coefficient ( $\alpha$ ) was also drawn like a function of the energy of the incident photon as illustrated in Figure (3) using the following equations [11]:

$$\alpha = 2.303 \left(\frac{A}{d}\right) \tag{1}$$

It is clear that the shift that happened towards lower energy values can be observed, and this is due to the high in the ring structures as a result of the effect of temperature, and, accordingly, the films change colors from light brown to very dark brown, as shown previously.



Figure (3):the absorbance spectrum as a function of wavelength at different heat treatments (pure, 150,180,200,250,280) °C.



Figure (4): The spectrum of the absorption coefficient as a function of the incident photon energy at different heat treatment (pure, 150,180,200,250,280) °C.

In general, the semiconductor and insulator are spliced into two forms: (I) direct band gap and (II) indirect band gap. If the top of the valance band and bottom of the conduction band are the same, then the direct band gap exists, if it is not the same, then the indirect band gap transition are obtained [12].

$$(\alpha h v) = A(h v - E_a)^n$$

Where, Eg is optical energy band gap, A is proportionality constant, and is absorption coefficient. where n for direct and indirect transitions, respectively, equals  $\frac{1}{2}$  and 2 for direct and indirect transitions respectively.

The direct energy gap of the films prepared under study and annealing at different temperatures calculated by drawing the relationship between  $(\alpha h v)^2$  as a function of the energy of the incident photon as shown in Figure (5) and from the linear region it is possible to draw a straight line cutting the x-axis, where the cut-off value represents the direct energy gap of the prepared films.

Table (1) shows the values of the direct energy gap with different annealing temperatures. It is noted from the table that an increase in the annealing temperature leads to a decrease in the energy gap.

Annealing Temperature(°C)	E <sub>g</sub> (eV)	
Pure	4.01	
150	2.58	
180	2.57	
200	2.44	
250	1.66	
280	1.63	

Table (1): Energy gap values for direct transitions of films prepared from annealing Polyacrylonitrile at different temperatures.



Figure (5): The spectrum of the absorption coefficient as a function of the incident photon energy at different heat treatment (pure, 150,180,200,250,280°C).

# Conclusion

A different temperatures for the purpose of being able to include the films in one of the electronic applications, where a clear change in the color of the films was observed from light brown to very dark brown at a temperature of 280°C, although the polymer is characterized by high transparency and analyzing the absorbance spectrum of the prepared films, the direct energy gap was calculated, which was in the range of 4.01eV for without annealing films to decrease to 1.63eV for films annealing at a temperature of 280°C. The possibility of including the polymer in one of the electronic applications such as solar cells, because it has a small energy gap after heat treatment.

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# Nanoparticles Antimicrobial Activity: A Mini Review

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Keywords:	Abstract
Nanoparticles, bacteria, viruses, fungi, parasites,	Antimicrobial resistance has become a major challenge to public health worldwide. The development of new strategies to combat resistant microorganisms has become imperative. Nanoparticles with antimicrobial activity have been extensively investigated as a potential solution to this problem. Nanoparticles are effective due to their ability to directly interact with microorganisms, causing damage to their cell membranes, walls, and DNA. In this article, we will provide an overview of the mechanisms of antimicrobial action of nanoparticles and explore the different types of nanoparticles with antimicrobial properties. We will also discuss the current and potential future applications of antimicrobial nanoparticles in medicine, as well as their challenges and limitations.

#### Introduction

#### **Antimicrobial Activity of Nanoparticles**

Nanoparticles have become a significant field of research in the recent years due to their unique properties and applications [1]. Among them, antimicrobial nanoparticles have generated considerable interest because of their potential to combat the increasingly prevalent problem of antimicrobial resistance. In this article, we will discuss the mechanisms of antimicrobial action of nanoparticles and their types, with a focus on their applications in medicine [2].

## **Overview of Antimicrobial Resistance**

Antimicrobial resistance occurs when microorganisms such as bacteria, viruses, fungi, and parasites evolve to withstand the effects of antimicrobial drugs [3]. The development of resistance is a natural process, but it has been accelerated by the misuse and overuse of antibiotics and other antimicrobial agents3. According to the World Health Organization (WHO), antimicrobial resistance is one of the biggest threats to global health, food security, and development [4].

# What are Nanoparticles:

Nanoparticles are particles with a size ranging from 1 to 100 nanometers, which is about 1,000 times smaller than the width of a human hair [5]. They can be made of various materials, such as metals, metal oxides, polymers, and carbon-based materials. Due to their small size, nanoparticles have unique physical and chemical properties, such as high surface-area-to-volume ratio, high reactivity, and quantum confinement [6].

# The Importance of Antimicrobial Nanoparticles

Antimicrobial nanoparticles have gained attention as a promising alternative to traditional antimicrobial agents due to their unique properties [7]. They have a broad-spectrum activity against bacteria, viruses, fungi, and parasites, which makes them useful for a wide range of applications. Furthermore, they have shown to be effective against drug-resistant strains, which is a significant advantage given the current problem of antimicrobial resistance [8].

# Mechanisms of Antimicrobial Action of Nanoparticles

Antimicrobial nanoparticles have several mechanisms of action that make them effective in combating the growth and spread of microorganisms [9]. First, they have the ability to physically disrupt the cell membrane of microorganisms, leading to their death [10]. The small size of nanoparticles allows them to penetrate bacterial and fungal cells more easily, and once inside, they can cause structural damage to the cell walls, leading to the leakage of essential cellular components and ultimately, cell death [11].

In addition to physical disruption, antimicrobial nanoparticles can also generate reactive oxygen species (ROS). ROS are highly reactive molecules that can damage the DNA, proteins, and lipids of microorganisms, leading to apoptosis or programmed cell death. The generation of ROS by nanoparticles can also activate the immune response, leading to the recruitment of white blood cells and the production of cytokines, which can further boost the antimicrobial activity [12].

Finally, some antimicrobial nanoparticles can bind to specific proteins or enzymes that are essential for the survival and proliferation of microorganisms. By inhibiting these proteins, nanoparticles can effectively stop the growth and spread of microorganisms, while minimizing the risk of developing resistance [13]. The combination of physical disruption, ROS generation, and targeted inhibition of specific proteins makes antimicrobial nanoparticles a promising approach for addressing the challenges of antibiotic resistance and infectious diseases [14]. The mechanisms of action of antimicrobial nanoparticles highlight their potential to revolutionize the way we combat microorganisms and manage infections [15].

# **Direct and Indirect Mechanisms of Action**

Antimicrobial nanoparticles have attracted immense interest in recent times due to their potential to revolutionize the field of medicine by providing novel therapeutic approaches to fight against infectious diseases [16]. These nanoparticles can act directly on microorganisms by attacking their cellular membranes or disrupting their metabolic pathways, thereby inhibiting their growth and replication [17]. The antimicrobial properties of nanoparticles arise from their unique physicochemical properties, such as their high surface area-to-volume ratio, high reactivity, and ability to penetrate biological barriers [18].

One of the most significant advantages of antimicrobial nanoparticles is their ability to overcome the limitations associated with conventional antibiotics, such as bacterial resistance and toxicity. Bacteria can develop resistance to antibiotics by evolving mechanisms to pump out or inactivate the drugs. However, nanoparticles can circumvent these resistance mechanisms and destroy bacteria by physically disrupting their cellular structure. Moreover, nanoparticles are less toxic to mammalian cells, making them a safer alternative to antibiotics [19,20].

# Interaction with the Microbial Cell Wall

Antimicrobial nanoparticles can interact with the cell wall of bacteria and fungi, leading to its disruption and leakage of intracellular components. This can cause cell death and inhibit the growth of microorganisms [21].

# Interaction with the Microbial Cell Membrane

Antimicrobial nanoparticles can also interact with the cell membrane of microorganisms, disrupting its structure and function. This can cause leakage of intracellular components and ion imbalance, leading to cell death [22].

# Interaction with the Microbial DNA and Proteins

Antimicrobial nanoparticles can interact with the DNA and proteins of microorganisms, leading to damage or inhibition of their function. This can cause cell death or inhibit the growth of microorganisms [23].

Types of Nanoparticles with Antimicrobial Activity

Several types of nanoparticles have shown to have antimicrobial activity, including:

# Silver Nanoparticles

Silver nanoparticles are one of the most extensively studied antimicrobial nanoparticles. They have a broad-spectrum activity against bacteria, viruses, and fungi, and have shown to be effective against drug-resistant strains [24].

# **Copper Nanoparticles**

Copper nanoparticles have also shown to have antimicrobial activity against bacteria and fungi. They can be used in various applications, such as medical devices and water treatment.

# Zinc Oxide Nanoparticles

Zinc oxide nanoparticles have a broad-spectrum activity against bacteria and fungi, and have shown to be effective against drug-resistant strains. They can be used in various applications, such as wound healing and sunscreen [25].

# **Titanium Dioxide Nanoparticles**

Titanium dioxide nanoparticles have antimicrobial activity against bacteria and viruses. They can be used in various applications, such as water treatment and dental restorations [26].

# **Applications of Antimicrobial Nanoparticles in Medicine**

Antimicrobial nanoparticles have several applications in medicine, including:

# **Antibacterial Applications**

Antimicrobial nanoparticles can be used as antibacterial agents in various medical applications, such as wound healing, implant coatings, and medical devices [27].

## **Antifungal Applications**

Antimicrobial nanoparticles can be used as antifungal agents in various medical applications, such as topical creams and ointments [28].

## **Antiviral Applications**

Antimicrobial nanoparticles can be used as antiviral agents in various medical applications, such as antiviral drugs and coatings for medical devices [29].

## **Drug Delivery Applications**

Antimicrobial nanoparticles can be used as drug delivery systems, where they can deliver drugs directly to the site of infection, reducing the side effects and increasing the efficacy of the treatment [30].

# **Challenges and Limitations of Antimicrobial Nanoparticles**

Antimicrobial nanoparticles have gained attention as a promising solution to combat microbial infections. However, there are challenges and limitations in their use [31].

#### **Environmental Concerns**

The use of nanoparticles raises concerns about their effects on the environment. The release of nanoparticles in wastewater and soil can lead to potential ecological and health hazards. Nanoparticles may also accumulate in the food chain, causing toxicity to plants and animals [32].

# **Potential Toxicity**

Another limitation is the potential toxicity of nanoparticles. Their small size and high surface area make them more reactive and biologically active, which might lead to unintended consequences. The toxicity of nanoparticles is dependent on their size, shape, and physicochemical properties [33].

# **Resistance Development**

The development of antimicrobial resistance is a significant global health concern. The use of nanoparticles as antimicrobial agents may also lead to the emergence of resistant strains, limiting their effectiveness in the long run [34].

# **Future Perspectives on Antimicrobial Nanoparticles**

Despite the challenges, antimicrobial nanoparticles are emerging as a promising tool in modern medicine due to their unique properties and effectiveness against diseases caused by microorganisms [35]. These tiny particles have the ability to selectively target and destroy harmful bacteria, viruses, and other microorganisms while leaving healthy cells unharmed. In addition, antimicrobial nanoparticles are versatile and can be used in a variety of settings, such as wound healing, drug

delivery, and water treatment [36]. With the rise of antibiotic-resistant strains of bacteria, the use of antimicrobial nanoparticles presents a potential solution to this growing health concern. Overall, the future of antimicrobial nanoparticles is bright and holds great promise for improving healthcare and preventing the spread of infectious diseases [37].

# Nanoparticles as a Solution to Antimicrobial Resistance

Antimicrobial nanoparticles have the potential to overcome the limitations of conventional antibiotics by targeting bacteria through a different mechanism38. They can disrupt the bacterial cell membrane and interfere with cellular functions, making it difficult for bacteria to develop resistance [39].

# **Innovative Applications of Antimicrobial Nanoparticles**

In addition to their use in medicine, antimicrobial nanoparticles have innovative applications in various fields such as food preservation, water treatment, and agriculture. They can prevent the growth of harmful bacteria, ensuring safe and healthy environments [40].

# Advancements in Nanoparticle Synthesis Techniques

Scientists are continuously improving the synthesis techniques of nanoparticles, leading to the development of novel and more effective antimicrobial nanoparticles. The use of biocompatible materials, such as silver, gold, and copper, may mitigate potential toxicity concerns and improve the efficacy of nanoparticles [41,42].

# **Conclusio**n

The development of antimicrobial nanoparticles has the potential to revolutionize the way we address microbial infections. While there are still challenges and limitations, continued research and development will pave the way for safer and more effective use of nanoparticles. In conclusion, antimicrobial nanoparticles offer promising solutions to the issue of antimicrobial resistance. Although there are still challenges that need to be addressed, the potential benefits of using nanoparticles in medicine are significant. As further research is conducted, we can expect to see more innovative applications of nanoparticles with antimicrobial activity. The development of safe and effective nanoparticles for use in clinical settings will help to combat the rise of antimicrobial resistance and improve public health outcomes.

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# Green Synthesis of ZNO Nanoparticles using Aloe Vera Leaves Extract

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#### **Keywords:**

#### Abstract

Green synthesis, Characterization of the created ZnO nanoparticles using the following techniques: Fouriesr Transform Infra RedSpectrum (FTIR), Scanning ZNO, nanoparticles, Electron Microscopic (SEM), Atomic Force Microscope (AFM). Atomic Aloe vera, FTIR, Force Microscopy (AFM) was employed to describe the surface SEM, AFM. morphology, particle size in nanoscale, dimeter and roughness of the surface for zinc nanoparticles prepared from plant extraction. The morphology images of pure plant extract and biosynthesised zinc nanoparticles that explains the 3D image of the surface morphology. The particle size in nanoscale of pure plant extraction was 87.22nm and zinc nanoparticles were found to have a particle size of 36.42nm. height cumulation distributions that determine the volume percentage of plant extract's grain size particles and biosynthesised zinc nanoparticles, recording 50.269 nm average hight of plant extraction and 21.515 nm average height of synthesized zinc nanoparticles, displays the Granularity Cumulation Distribution, which calculates the volume percentage of the diameter of plant extract and synthetic zinc nanoparticles. The average diameter of plant extract was 133.77 nm, whereas the average diameter of synthetic zinc nanoparticles made by plants extract was 52.84 nm. The roughness of the surface RMS (Root mean square) of pure plant extraction and the synthesized zinc nanoparticles that that RMS of plant extract was 13.2nm, while the RMS of synthesized zinc nanoparticles was 5.21nm. Scanning electron microscope (SEM) analysis explained the morphology of the surface and shape formation of plant extract and synthesized zinc nanoparticles , that exhibits the micrograph of plant extraction and synthesized zinc nanoparticles and shows that the zinc nanoparticles were formed as nanosheets and hierarchical shape in huge quantities and different lengths nanosheets. Scanning electron microscopy (SEM) element mapping at the microstructural level shows the distribution and quantities of zinc nanoparticles elements prepared from the plant extract and oxygen.It is noticed that the high amount of zinc prepared. FTIR findings for the crude The appearance of a broad peak at (2320.47 cm-1) in an Aleo vera extract is due to the stretching O-H groups of phenolic groups and carbohydrate monomers.

#### Introduction

Today, nanotechnology is one of the most important fields of investment between modern science. Because of the rapid development of its concepts, the comprehensiveness and breadth of its applications cover all aspects of human life. This has created a sense of excitement and competition among countries, research institutions and researchers to invest effort and money, in further research on nanotechnology development [1], especially in the field of biotechnologies, health, equipment and treatment [2].

In the mid-20th century, the concepts of nanotechnology emerged from the principles of physics that witnessed the possibility of manipulating these particles. These particles can be prepared easily by different chemical, physical, and biological approaches [4]. Nanotechnology products are characterized by the properties of the structure of their nanomaterials, typically mono- or multi-phase crystalline solids of a typical size of 1-100 nm (109 nm), and a large number of surfaces with atomic arrangements different from those of the crystalline lattice [4], due to the change in the mechanical and thermal properties of the nanoparticle Because of its ease of use, environmental friendliness, and robust antimicrobial activity, plant-mediated biological synthesis of nanoparticles is currently gaining popularity. It is well known that all bodily tissues, such as the brain, muscle, bone, and skin, contain significant amounts of zinc, an essential trace element. In addition to contributing to the body's metabolism, zinc serves as the primary component of numerous enzyme systems and is essential for the synthesis of proteins, nucleic acids, hematopoiesis, and neurogenesis. Small particle size nano-ZnO makes zinc easier for the body to absorb. The use of nano-ZnO as a food additive is therefore widespread. This study was aimed to green synthesis, chracterization of ZNO nanoparticles. The surface chemistry, volume, volume distribution, shape, particle morphology, particle structure, coating or coverage, agglomeration, solubility rate, particle reaction in solution cell, and finally the type of reduction agents used all affect how biologically active nanoparticles are [5]. Jo et al. [6] found that the physical characteristics of nanoparticles improve the biological availability of therapeutic agents and have the potential to influence cell uptake, biological distribution, the penetration of biological barriers, and the subsequent therapeutic effects [7]. The Aloe family (Aloaceae), which includes about 400 distinct species, includes the genus Aloe. One of the most prevalent and widespread species is aloe vera. 2009's Ombrella. The plant has thick leaves with long veins and a succulent form moving the water. When the green skin is removed, a clear mucus known as "gel" is left behind. This gel is packed with fiber, water, and vital components that help the paper retain moisture. In the assessment of manufactured nanomaterials, many analytical techniques are used, including UV spectroscopy of UV-vis UV-visible spectroscopy, x-ray diffraction (XRD), infrared spectroscopy Fourier Transform Fourier Transform Spectroscopy (FTIR), x-ray spectroscopy (XPS), dynamic light scattering (DLS), electron microscopy Scanning electron microscopy (TEM), Atomic Force Microscop (AFM) [8 and 9].

### **Materials and Methods**

### **Plant Sample Collection**

*Aloe vera* plants were collected from the markets and local nurseries in Baghdad during the month of October 2018, and confirmation of their classification was done by the National Herbaceous / General Authority for Agricultural Research.

## **Preparation of Plant Aqueous Extracts**

The aquatic extracts of *Aloe vera* leaves were obtained using traditional method by washing the fresh leaves with water, which is well run to remove the contaminants on the surface and soak them for 30 min after removing the moisture from them and drying them thoroughly with dry air, 10 g of dried plant leaves was placed in a 250ml glass flask containing 100 ml of deionized water and then heated in a 45 °C water bath for about 30 min, The extracts were then stored at a temperature of 4°.

# Zinc oxide nanoparticles biosynthesis

Zinc oxide particles of the *Aloe vera* extract were prepared according Vidya *et al* [10] method by heating 50 ml of the water extract using a hot plate at a temperature of 40 - 45  $^{\circ}$  C. At a temperature of 45  $^{\circ}$  C, add 5 grams of zinc acetate to the solution and continue heating until it becomes a bright yellow paste. The dough was gathered in a glass petri dish and heated at 300 $^{\circ}$  C for two hours to dry it out. The dried substance was then broken down into a light yellow powder using a mortar, which was then carefully packaged for further characterization and treatment needs.

# Detection and Characterization of Zinc oxide Nanoparticles.

The biosynthised ZnO Nanoparticles were characterized by adding 100 ml of deionized water to 1 g of light yellow powder, then filtration was done using Millipore filter (0.22  $\mu$ m), for samples ready for testing using the following methods:

# Fourier Transform Infra Red Spectrum(FTIR)

The spectrum of the infrared spectrometers at the wavelengths (1350-500 -cm) with a SHIMA DZU-Japan device, for all samples tested in liquid and at room temperature.

# Scanning Electron Microscopic (SEM)

The size and shape of the particles in the ready samples were determined using the Japan Meiji SEM scanner [11]. By placing approximately 5 microliters of ready-made solutions for examination on the electronic microscope holder made of gold and carbon buckle, leaving them at room temperature to dry and testing using different magnifying forces.

### Atomic Force Microscope (AFM)

The surface morphology, size, and diameter of the prepared ZnO nanoparticles were all determined using the USA-based Angstrom Advanced AA2000 AFM scan. The contact pattern under typical weather conditions served as the basis for the AFM pattern. A small drop of the sample solution was placed on a 1 x 1 cm glass slide and allowed to air dry before being tested.

### **Results and Discussion**

# Green synthesis of ZNO nanoparticles using Aloe vera leaves extract

# Characterization of ZNO nanoparticles using Atomic Force Microscopy (AFM)

Surface morphology was assessed using atomic force microscopy (AFM), particle size in nanoscale, dimeter and roughness of the surface for zinc nanoparticles prepared from plant extraction. The morphology images of pure plant extract and biosynthesized zinc nanoparticles shown in <u>Fig</u>ure (1) that explains the 3D image of the surface morphology. Zinc nanoparticles found to have a particle size of 36.42 nm, and pure plant extraction had a nanoscale particle size of 87.22 nm.



Figure (1): A: AFM of Plant extract, B: biosynthesized zinc nanoparticles

Results in figure (2) show the height accumulation distributions that determine the volume percentage of plant extract particles and bio-made zinc nanoparticles with respect to grain size, recording 50.269 nm average height of plant extraction and 21.515 nm average height of synthesized zinc nanoparticles.



Figure (2): Height Cumulation Distribution of A) Plant Extract. B) synthesized Zinc Nanoparticles

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The average diameter of plant extract was 133.77 nm, while the average diameter of synthesized zinc nanoparticles by plants extract was 52.84 nm as shown in figure (3) that illustrates the Granularity Cumulation distribution that determines the volume percentage of dimeter for plant extract and synthesized zinc nanoparticles.



Fig (3): (A) Plant extract (B) synthesized zinc nanoparticles have different granularity cumulation distributions.

The roughness of the surface RMS (Root mean square) of pure plant extraction and the synthesized zinc nanoparticles were shown in Fig (4) that that RMS of plant extract was 13.2nm, while the RMS of synthesized zinc nanoparticles was 5.21nm.



Fig (4): Roughness of the surface; A) Plant extract, B) Synthesized zinc nanoparticles. Characterization of Zno nanoparticles using SEM analysis

Illustrates the morphology of the surface and shape formation of synthesized zinc nanoparticles and plant extract as explained by scanning electron microscope (SEM) analysis that exhibits the micrograph of plant extraction and synthesized zinc nanoparticles and shows that the zinc nanoparticles were formed as nanosheets and hierarchical shape in huge quantities and different lengths nanosheets. Figure (5).



Figure 5: SEM images of A) plant extraction, B) hierarchical zinc Nanosheet prepared from the plant extraction at magnification 20μm, and C) hierarchical zinc Nanosheet prepared from the plant extraction at magnification 10μm.

Scanning electron microscopy (SEM) element mapping at the microstructural level reveals the distribution and quantities of zinc nanoparticle elements made from plant extract and oxygen. Figure (6) clearly displays the large amount of zinc that was prepared.



Figure 6: Elemental mapping of prepared zinc nanoparticles.

#### **Characterization of ZNO nanoparticles using FTIR**

Results of FTIR for the crude Aleo vera extract displays a broad peak at (2320.47 cm-1), which is associated with the stretching O-H groups of phenole groups and carbohydrate monomers. The -CC-stretch (alkynes) stretching vibrations are represented by the band at (2320.47 cm-1). The carbonyl group of an amide's stretching -C=O is represented by the band at (1726.68 cm-1). The nitro compound's -N=O stretching is represented by the band at (1315.67 cm-1). Stretching C=C results in the band at (1418.59 cm-1) distance. Stretching of C-N is represented by the band at (1260.27 cm-1). An amide's N-H bending is represented by the band at (1587.68 cm-1). The stretching -C-O corresponds to the band at (1075.15 cm-1). While the FTIR results for the prepared zinc nanoparticlesfrom plant extract shows that the band of -C=O carbonyl group change from  $(1726.68\text{ cm}^{-1})$  in plant extract to $(1737.74\text{ cm}^{-1})$  which is assigned to the amide bond of protein of adsorbed strongly to Zn NPs and forms a layer along with the bio-organics, securing interacting with biosynthesized nanoparticles as shown in table (1) and figure (7).

The FTIR spectrum of prepared Zn nanoparticles from plant extract appearance band at (614.10cm<sup>-1</sup>) corresponds to the stretch vibrations of ZnO nanoparticles. It is necessary for the ZnO nanoparticles to be stabilized by the present of phenolic group of molecules and the reduction process occurs of amide linkages in protein [12].

The data accompanying the photogrammetry using AFM have been clear and sound, and can be inferred from their compatibility with the zinc nanoparticles imaging data for the *Aleo vera* water extract, using the SEM scanner, and Infrared Spectroscopy (FTIR) describing the formal properties of zinc particles prepared. These results agree with a number of previous studies that synthesized nanoparticles from various plant aquatic extracts [13, 14 and 15].

Table (1): FTIR Characterization spectrum of plant extract and the biosynthesized nanoparticles.

Function group	Plant extract	Zn NPs (cm <sup>-1</sup> )	
-C=O stretch of amide	1726.68	1737.74	
−C≡C-stretch (alkynes)	2320.47	2381.84	
O–H stretching	3223.02	3070.80	
C-N stretching	1260.27	1150.91	
N-H bending of amide	1587.68	1548.74	
C-Ostretching	1075.15	1052.05	
N=O symmetric stretching of the nitro compound	1315.67	1391.12	
C-H Aromatic bending	862.32	848.38	
Znnanoparticles	-	614.10	



Figure( 6): FTIR spectrum of A) plant extract, and B) prepared Zn nanoparticles.

#### Conclusion

ZNO nanoparticles synthesised using *Aloe vera* leaves extract detected and characterized using the following techniques: Fouriesr Transform Infra RedSpectrum (FTIR), Scanning Electron Microscopic (SEM), Atomic Force Microscope (AFM).

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# Iraqi Journal of Nanotechnology synthesis and application



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# ZnO and TiO<sub>2</sub>/PVA Nanoparticle Additives Effect on the Adhesion Properties and Biological Activity of Dyes and Epoxy

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#### Keywords

Local paints, Zinc oxide, Titanium dioxide, Nanoparticles, biological efficiency.

#### Abstract

Zinc oxide nanoparticles with PVA were used as additives for improving the specifications of the Iraqi dyes produced in the Modern Paints Company (D-5800 SFFA, epoxy for the inside drinking water tanks, D-5547 A-9101, lead food epoxy D-5544SFA-12 and transparent food epoxy primer (G-5900) that suffer from poor adhesion, peeling ability and decreasing in biological activity after a period of time, as the following: 4g of PVA was dissolved in 100mL of deionized water (DI) using a magnetic stirrer for 1 hour at 60°C, followed by the addition of 0.6g of ZnO NPs with a stirrer for 1 hour at 60°C. The temperature of this solution was allowed to drop to room temperature. Other samples were also prepared in the same way, using ZnO and TiO<sub>2</sub> in a 1:1 ratio. The included, the tests for adhesion ability, biological effectiveness and time-acceleration weathering of the coating were carried out. Experimental results on a gypsum (Bork) piece coated with nano-coating over a period of more than six months showed an increase in adhesion ability of over 160% for some samples, along with an increase in biological activity, such as (E. coli and ST aureuse).

#### Introduction

Bacteria are usually found on and around surfaces in clinical and industrial settings. Microbial infection treatment and prevention in hospitals is of the utmost importance. Antimicrobial compounds are frequently applied to device surfaces to lower the risk of infection after implantation. Antibacterial agents can either be passive or active, depending on whether or not they are given locally. Passive coatings can be used to stop bacteria from sticking and even to kill them immediately upon contact. The most promising are metallic nanoparticles (NPs), which have a high surface area to volume ratio and excellent antibacterial characteristics. However, due to the emergence of safe strains, anti-toxins, and the evolution of microbial resistance to metallic particles, research interest is ebbing and flowing [1].

Nanomaterials are being employed more frequently in a variety of fields, such as energy generation, environmental applications, biomedicine, and biotechnology, and as a result, they are becoming more prevalent in consumer items. The key areas of investigation in the realm of nanomaterials, such as the synthesis of nanoparticles with customized properties and their assembly into usable devices and coatings, can be successfully applied using the core knowledge of combustion science and engineering [2].

Due to their remarkable physicochemical qualities, zinc oxide (ZnO NPs) is one of the most often utilized nanomaterials and may be found in a variety of goods, including sunscreen [3-6]. Gram-positive and Gram-negative bacteria, as well as spores, have both been proven to be resistant to ZnO NPs, making them potent antibacterial agents. In comparison to other nanoparticles, ZnO NPs have the following advantages: low toxicity, biological acceptability, bioactivity, and chemical stability [7]. ZnO NPs have extensive antibacterial action against a variety of pathogens, such as Escherichia coli, Staphylococcus aurous, Pseudomonas aeruginosa, Bacillus subtilis, and the M13 bacteriophage, among others [8, 9], thanks to these characteristics. Both in the classroom and the business, interest in nanocomposite materials has increased recently [10]. Polymeric materials can profit from the inclusion of a scarce nanoload due to their nanoscale dimensions, huge specific surface areas, quantum confinement effects, and powerful interfacial processes [11].

The acetate groups in polyvinyl acetate are either entirely or partially hydrolyzed away to produce polyvinyl alcohol (PVA), a linear synthetic polymer. When mixed with ZnO nanoparticles, PVA, a biodegradable polymer that dissolves in water, produces a nanocomposite that has improved electrical, mechanical, and optical properties. This biodegradable nanocomposite can take the place of plastic and other less-than-ideal food packaging materials. The degree of hydroxylation of PVA has an impact on its mechanical, chemical, and physical properties [12,13].

Nano-ZnO was added to PVA to increase its surface hydrophobicity, mechanical strength, and moisture and oxygen barrier qualities [14].

It is important to detach the coating sample from the substrate (borax) in order to assess the adhesive strength. A pull-off test is typically performed to assess an adhesive's tensile strength.

An increase in the intermolecular forces between the substrate (mainly borax) and the paint can be used to explain improvements in adhesive strength. A ZnO/PVA composition with low strength and the ability to be readily peeled off or removed once the coatings have dried was chosen by researchers after thorough investigation [15]. This paper's studies demonstrate the impact of ZnO/PVA nanocomposite additive in painting applications to improve biological efficiency against microbes, address the issue of weak adhesion strength of ZnO/PVA alone, and ensure biological efficiency continuity for a long time without being affected by weather factors. Properties of titanium dioxide nanoparticles (TiO2 NPs) include bactericidal photocatalytic activity, safety, and self-cleaning [16-18].

ZnO nanoparticles (NPs) may contribute to antibacterial activity by accumulating in the cytoplasm or outer membrane of bacterial cells, where they would cause Zn2+ release and cause the bacterial cells to die as a result of membrane disintegration, protein damage, and genomic instability [19–21].

Although it's not entirely apparent what the best toxicity regimen is and is yet debatable. However, studies and research indicate the method of eliminating germs by ZnO NPs, which necessitates research into the physics of these NPs' effects on bacteria. ZnO NPs directly adhere to cell walls and kill those cells by doing so [22], or Zn ions are released as antibodies [23], or oxygen ions are formed as specific and documented killing methods. Successful [24]. Below is an illustration of how highly reactive groups like OH-, H<sub>2</sub>O<sub>2</sub>, and O<sub>2</sub>-2 arise. In ZnO, there is an electron gap pair ( $e^-$ ,  $h^+$ ). H<sub>2</sub>O molecules in ZnO are split into OH and H+ molecules by an energy gap. As a result, free radicals are formed.

 $ZnO + hV \longrightarrow e^- + h^+$ ,  $h^+ + H_2O .OH + H + e^- + O_2 \rightarrow O^{-2}$ ;

 $O_2 + H^+ \rightarrow HO_2 \bullet HO_2 \bullet + H^+ + e^- \rightarrow H_2O_2$ 

In addition to the production of reactive oxygen species (ROS) during the interaction of metal oxide with bacteria, other mechanisms contribute to the bactericidal activity of ZnO nanoparticles. The amount of reactive oxygen species (ROS) produced is proportional to the ion release rates of the metal oxide used in the nanoparticle's synthesis [25,26].

TiO<sub>2</sub>'s antimicrobial activity is commonly attributed to its ability to generate highly oxidizing reactive oxygen species (ROS) in the presence of oxygen (O<sub>2</sub>), ROS which then kill bacteria in a variety of ways [ 27,28].

### **Experimental Procedure**

To make the ZnO NPs, 4g of PVA was dissolved in 100mL of deionized water (DI) using a magnetic sterir (Magnetic sterilizer /IKA RH basic 2 Germany) for 1 hour at 60°C, followed by the addition of 0.6g of ZnO NPs with a stirrer for 1 hour at 60°C. The temperature of this solution was allowed to drop to room temperature. Other samples were also prepared in the same way, using ZnO and TiO<sub>2</sub> in a 1:1 ratio, with the same weights listed above. Following this, 80 mL of each paint type manufactured by Modern Paint Industries Company-Iraq were mixed with 20 mL of the final solution as shown below.

- 1. Anti-parasitic oil food dye A-1008
- 2. Hospital dye D-9058
- 3. White Hospital Epoxy D-5800SFFA
- 4. Epoxy to paint the inside of drinking water tanks D-5547A-91
- 5. Gray Food Epoxy D-5544 SFA-12
- 6. Food grade transparent epoxy primer G-5900.

The modified paint was stirred for 5 min, then a piece of borax was painted in the mold of the cohesion and time-acceleration weathering devices, where it was rolled on three layers and left to dry, and then tests for the lasting adhesive tester / posi test AT-M USA, Accelerated weathering tester /model QUV/ Se USA and test of biological efficiency against (*E.coli* and *ST aureuse*) bacteria were carried out.

#### **Results and discussion**

Table (1) represents the adhesion force for coatings and epoxy which used to paint the walls and floors of the hospitals before and after adding ZnO NP's blended with PVA polymer. These results were before weathering acceleration.

Coating	Adhesion force before adding ZnO	Adhesion force after adding ZnO /
	/ PVA	PVA
A-1008	93	134
G-5900	134	124
D-5544SFA	62	95
D-5547A-9101	85	130
D-9058	11	112
D-5800	100	160

Table (1) Adhesion force before and after adding ZnO/PVA

From table (1), one can conclude that the adhesion force was increased for samples (A-1008, D-5544SFA, D-5547A-9101, D-9058, D-5800) with a ratio reach to (144%) for A-1008 paint while the adhesion force was increased with more than (10) doubles for hospitals' paint (D-9058). This significant increasing in adhesion force after adding ZnO / PVA may be attributed to the polymer ability to increase to the correlation force between the paint's molecules and the painted walls. Also, the polymer adding leads to forming new bonds between the original molecules of the paint, these bones were not existed before adding the polymer. Zinc oxide nanoparticles adding will play an important role in adhesion force increment, it will decreasing the inter-distances between the paint molecules and create new bonds within these molecules. On the other hand, ZnO NP's will fill the holes and gaps that already found in the paint and between the paint and the floor or wall.

Table (2) represents the adhesion force for coatings and epoxy which used to paint the walls and floors of the hospitals before and after adding ZnO NPs blended with PVA polymer after the weathering acceleration ( $60^{\circ}$ C and 61of humidity) with six months using the weather acceleration tester.

Table (2) Adhesion force before and after adding ZnO / PVA with six months weathering acceleration  $60^{\circ}$ C and  $61^{\circ}$  of humidity

Coating	Adhesion force before adding ZnO	Adhesion force after adding ZnO /
	/ PVA	PVA
A-1008	76	90
G-5900	45	52
D-5544SFA	90	120
D-5547A-9101	76	118
D-9058	113	142
D-5800	42	58

From table (2), it is clear that the adhesion force for the samples after addition of nanocompsite were also higher than for the samples without addition after six months of weathering acceleration about (16%-55%). This gives an indicate that the paint will be affected with very low ratio by the environmental (weather) conditions as a result due to forming new intermolecular strong bonds by adding ZnO / PVA to the original paint or epoxy.

The biological efficiency of the samples has been obtained, for the all-control samples there weren't any biological efficiency before additives of  $(ZnO\&TiO_2/PVA nanoparticle solution)$ . Figures (1a, b) show the biological activities of paints with adding ZnO / PVA before and after time acceleration respectively on (*E. coli* and *ST aureuse*). While figure 2 show the biological efficiency of the sample (Anti-parasitic oil food dye A-1008) after adding ZnO/TiO<sub>2</sub> with ratio 1:1, it clear that the inhibition zone of this sample is about 10 mm against (*E. coli*)



(a)



(b)

Figure (1) a: Biological activities of the paints on the with adding ZnO / PVA before time acceleration (b) after time acceleration respectively



Figure (2) Biological activities of the paints on the with adding ZnO-TiO\_ / PVA

Table 3 shows the biological efficiency of the painting before and after additive also its show the effect of nano additives on biological efficiency as a function of accelerated weathering tester,

it's clear that it was efficient against gram negative E. coli and gram-positive S. aureus for two samples (Anti-parasitic oil food dye A-1008 and White Hospital Epoxy D-5800SFFA), this behavior of these dye and epoxy can be explained due to the mechanism of ZnO nanoparticles against bacteria

No.	sample	Code	Biological eff.	Biological	Biological eff.
			Before additive	eff. after	after time
				additive	acceleration
1	A-1008	1 before time acceleration	Not effective	Effective	Effective
		2 after time acceleration	Not effective	Effective	Effective
2	Hospital dye D-9058	3 before time acceleration	Not effective	Not	Not effective
				effective	
		4 after time acceleration	Not effective		Not effective
				Not	
				effective	
3	Epoxy to paint the	5 before time acceleration	Not effective	Not	Not effective
	inside of drinking			effective	
	water tanks D-5547A-	6 after time acceleration	Not effective		Not effective
	91			Not	
				effective	
4	Gray Food Epoxy D-	7 before time acceleration	Not effective	Not	Not effective
	5544 SFA-12			effective	
		8 after time acceleration	Not effective		Not effective
				Not	
				effective	
5	Food grade	9 before time acceleration	Not effective	Not	Not effective
	transparent epoxy			effective	
	primer G-5900.	10 after time acceleration	Not effective		Not effective
				Not	
				effective	
6	White Hospital Epoxy	11 before time	Not effective	Not	Not effective
	D-5800SFFA	acceleration		effective	
			Not effective		Effective
		12 after time acceleration		Effective	

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i adie (5) diological	activities of the	menuoned	damus on (	E.COII and S	1 aureuse).

# Conclusions

ZnO/PVA nanoparticles can be used as additives for improving the specifications of some Iraqi dyes produced in the Modern Paints Company such as (Anti-parasitic oil food dye A-1008 and White Hospital Epoxy D-5800SFFA), to improve its biological efficiency against gram negative E. coli and gram-positive S. aureus. Furthermore, this additive shows high adhesive force for all samples that were used. Also, ZnO: TiO<sub>2</sub> additives have also a biological efficiency for Iraqi dyes (Anti-parasitic oil food dye A-1008) against gram negative E. coli.

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# Iraqi Journal of Nanotechnology synthesis and application



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# Metal Nanoparticles as Novel Drug Delivery Systems: A Review of Current Challenges and Opportunities

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<b>Keywords:</b> Nanotechnology:	Abstract
Metal nanoparticles; Drug delivery systems; Biodegradable substances; Green synthesis; Efficacy index.	Nanotechnology's intriguing characteristics have attracted a lot of study in recent years. Nanomaterials, nanoelectronics, and nanobiotechnology are all subfields of nanotechnology that share a great deal of common ground. The possibility for metal nanoparticles ( <b>MNPs</b> ) to completely transform treatment is what has made them so remarkable. In addition to avoid antibiotic resistance and improving medication delivery, MNPs have been shown to raise the efficacy index of medicines. Additionally, MNPs have applications in in vitro and in vivo tests, improved biodegradable substance production, and nutraceuticals. Improved targeting at the necessary target location is one major benefit of using metallic nanoparticles for drug delivery systems due to their improved durability and half-life in circulation. Bio-nanotechnology is expanding into the new field of green synthesis of MNPs, which is more environmentally friendly than traditional chemical and physical synthesis techniques. Focusing on environmentally friendly approaches to the preparation, surface modification, and applications of various MNPs like silver, gold, platinum, palladium, copper, zinc oxide, metal sulfide, and nanometal organic frameworks, this review seeks to present current insights into
	the challenges and perspectives of MNPs in drug delivery systems.

### Introduction

Nanotechnology is currently regarded as one of the most recent and essential disciplines. Its exceptional advantages for the welfare of humankind have appeared as a result of its theory and practical significance. Nanomedicine is one of the most significant applications of nanotechnology, if not the most important. This is due to its immediate relationship to human existence and wellbeing. Nanotechnology's recent advancement has aided in changing the medical norms used in illness prevention, diagnosis, and treatment. Nowadays, the age of nanomedical technology is being lived in, whereby novel methods for transporting medicines inside the human body that can target specific

cells are provided [1]. One of the top objectives for study in the area of nanomedicine is drug transport to tissues, which is based on the production of exact nanometer materials that increase drug absorption. This means that the pieces of the medicine are in the right place in the body, which is where they work best. Because of this, the number of times people take medications, the bad effects they have, and the total cost of therapy all go down [2], [3]. Researchers in pharmaceutics keep making nano polymer-based ways to deliver medicines to the same biological cells. This objective is critical because many illnesses are caused by defects within the cell itself. Furthermore, some drugs can be given to patients while dormant and only become active in the impacted regions, avoiding the drug's detrimental effects in some tissues [4]. As a result, one of the most essential responsibilities of nanomedicine is to develop novel medicines with greater advantages, greater effectiveness, and fewer adverse effects [5]. Nanostructured materials (**NSMs**) have been discovered to provide numerous benefits in medication transport devices. One of the most important advantages of NSMs is their physical resemblance to biological structures in human cells, which allows them to be regarded as a possible choice for DDS because a variety of biochemical processes occur at nanoscales, as shown in Figure 1 [6].



Figure 1. Nanoparticles: Impact of Size, Material, Shape, and Surface Properties [6]

Nanoscale solid microparticles, and specifically nanoparticles, have emerged as advantageous platforms for the targeted delivery of microparticles and macromolecules in disease therapy because of their versatility in size and shape, high carrier capacity, and ease of binding of both hydrophilic and hydrophobic materials [7]. Furthermore, NSMs offer an effective medication delivery mechanism for overcoming the side effects and poor uptake of traditional drugs. However, getting a therapeutic material directly into cancer cells is extremely challenging. Along with radiation, traditional chemotherapy drugs used in cancer treatment can raise the chance of cardiac illness, including myocardial infarction, heart attack, stroke, and blood clots [8]. As a result, a drug administration technique that can minimize these types of adverse effects is required. Metal nanoparticles are thought to be a hopeful strategy because they target the afflicted tissue directly, reducing adverse effects [9]. Magnetic nanoparticle (MNP) production is a novel area of nanobiotechnology with important consequences for imaging and medication transport [10]–[12]. MNPs have distinct visual characteristics, such as surface plasmon resonance (SPR) and the ability to control light fields, which make them particularly appealing for biological uses. MNPs can travel through physiological barriers that are impervious to other polymers due to their tiny size [13], [14]. MNPs' metabolic characteristics can be modified by modifying their surface, such as covering them with polyethylene glycol (PEG) to decrease non-specific uptake by the mononuclear phagocyte system and increase their longevity within the body. MNPs have surfaced as a viable drug transport mechanism for the treatment of malignant cells [15].

Radiation or surgical excision of the mass are currently the most prevalent cancer treatments. These techniques, however, have drawbacks such as limited discrimination, partial tumor cell elimination, and a lack of adverse effect management. Non-invasive medicinal agent therapies have shown encouraging outcomes, but real constraints have limited their effectiveness [16], [17]. To deal with these problems, MNPs have been chosen to be used in the creation of smart devices that can deliver medicine right to the site of an injury [18], [19]. For these systems to be made, researchers must first learn about the tumor and choose materials that can respond to tumor signals and release the medicine at the right place. Due to differences in how they work and how they look, tumors and healthy organs can be specifically targeted by drug delivery methods [20], [21].Targeting ligands, such as antibodies, peptides, or nucleic acid sequences, must be conjugated to MNPs, and this is where their surface chemistry comes in [22], [23]. More medicinal medicines can be delivered to particular cells using functionalized MNPs, with negligible side effects, allowing for cellular-level diagnostics and therapy [24], [25]. This review looks at the current challenges and potential applications of various metal-based nanomaterials for drug delivery systems, with a focus on cancer,

diabetes, inflammation, and antiviral therapy due to the advantages of MNPs in these areas. The goal of this research is to give an overview of how metallic nanoparticles could be used in systems that deliver medicines. The overview will look at the problems and opportunities of using metal nanoparticles as drug carriers, as well as their pros and cons and the current state of research in this field. Also, it is important to find out how metallic nanoparticles could be used in drug delivery, such as to treat cancer, inflammation, diabetes, and diseases caused by viruses. The study also looked at how metallic nanoparticles might be used in the future to get medicines to where they need to go.

#### Functionalized MNPs for Efficient Therapeutic Drug Delivery

There are two main ways to integrate MNPs: the top-down method, also called the dispersion method, and the bottom-up method, also called the condensation method [26]. With the top-down method, big pieces of material are broken up into smaller pieces. This is done with size-reduction methods like ultrasound devices that run at high levels [27]. An electromagnetic spark is another way to make MNPs. This spark creates a lot of heat and spreads metal mist from the anode, which later condenses into MNPs [28]. On the other hand, the bottom-up method builds nanomaterials atom by atom or particle by particle. This is done through a high level of supersaturation followed by nuclei growth [29]. There are many chemical and physical ways to make MNPs, such as chemical reduction [30], microemulsion [31], thermal decomposition [32], sonochemical [33], polyol method [34], microwave-assisted method [35], laser ablation [36], sputtering deposition [37], lithography [38], pulsed electrochemical etching [39], and vapor phase synthesis [40] as shown in Figure 2. Chemical methods are commonly used to synthesize MNPs, where harsh chemical additives like dimethyl formamide, hydrazine, and sodium borohydride are added to prepare the nanoparticles[41]. However, these methods require specific physical conditions like high temperature and vacuum, and have environmental concerns due to the use of toxic chemicals, which can result in waste byproducts that can negatively affect microorganisms, plants, and human health when discharged into the environment [42]. To overcome these limitations, researchers are exploring the use of greener methods to synthesize nanomaterials, such as using plant parts like roots, fruits, leaves, stems, and flowers, which is an eco-friendly, simple, fast, and stable approach [43], [44].



Figure 2 (A) Top-Down and Bottom-Up Approaches for Nanoparticle Synthesis. (B) Synthesis of Nanoparticles: An Overview of Chemical and Physical Methods

Green Chemistry has become an important way to lessen the bad effects of chemical synthesis during MNP production. Plant preparations have a lot of proteins, amino acids, vitamins, and other compounds, so scientists have been looking into how to use them as reducing, capping, and stabilizing agents when making metal nanoparticles [45]. Using water as a fluid, Phyto nanotechnology has evolved as a safer, one-step, non-toxic method of making nanoparticles [46]. The risks of chemical production can be reduced by using this technique. Researchers, academics, and chemists can use the 12 principles of green chemistry as guidance to create low-toxicity nanoparticles. Since plant-based goods have been used as medication for millennia and about 25% of drugs are now drawn from natural resources, this cleaner strategy is extensively used in nanomedicine and nanodrug delivery systems [47]. Plant-derived chemicals are the foundation for the discovery of new medicines because of their wide range of molecular and biochemical characteristics, relative safety, and low expense [48], [49].

#### **Role of Metallic Nanoparticles in Targeted Drug Delivery**

Metallic nanoparticles possess a number of characteristics that make them appealing for tailored medication administration. To begin with, their tiny size and large surface area enable greater cellular absorption and entry into living tissues, making them perfect for medication transport to particular cells or tissues as shown in Figure 3 [50].



Figure 3 Enhancing Drug Delivery Efficiency

Second, their distinctive physical and molecular characteristics, such as visual and magnetic qualities, can be used to accomplish tailored medication administration. Finally, their surface is readily functionalized to combine targeting agents and active proteins, enabling for cell or tissue specific targeting. One of the most common methods of using metallic nanoparticles in tailored drug delivery is to functionalize their surface with targeting compounds that attach to receptors on target cells. MNPs can be functionalized with antibodies that identify cancer cells, enabling for tailored therapeutic medication transport to the tumor location [51]. Metallic nanoparticles are better than traditional ways of delivering drugs in a number of ways, such as by making it easier for the body to absorb the drug, making the medicine work better, and making it less harmful. Recent research has shown that metallic nanoparticles (**MNPs**) could be used in customized drug delivery systems because they can make hydrophobic drugs more soluble, increase the time drugs stay in the blood, and slow down how quickly the kidneys get rid of drugs [52]. Multifunctional nanoparticles are especially beneficial because they can achieve multiple objectives simultaneously, such as the co-delivery of numerous bio actives with imaging agents and target-specific delivery via surface ligand ornamentation [53]. The primary objectives of drug administration are to focus the medicinal

substance at the site of action, limit deleterious effects on healthy tissues, and regulate drug release to prevent overloading or underdosing [54]. MNPs offer a hopeful paradigm for achieving these objectives, with surface covering tailored to regulate drug loading, transport, and release in the target region while also enhancing biocompatibility and lowering adverse effects [55]. Efficient drug transport via MNPs is dependent on two key factors: MNP design for delayed and prolonged drug release and MNP ability to dispense medicinal drugs to specific regions without disturbing normal cells [56]. These elements can be attained through both active and passive aiming. Passive targeting is feasible due to the cancer vasculature's distinctive alterations, which enable MNPs to move through weak connections and collect at the tumor location [57]. Active targeting, on the other hand, entails the coupling of MNPs with different active ligands that attach to particular cell surface receptors and eventually lead to drug delivery at the desired location, as shown in Figure 4 [58].



Figure 4 A Promising Approach for Targeting, Delivery, and Imaging.

MNPs provide several benefits in tailored drug delivery devices, including improved drug solubility, increased circulatory duration, and regulated drug release. The advancement of multipurpose nanoparticles and tailored surface compounds has increased their potential for effective medication transport with minimum adverse effects. Active and inactive targeting methods both offer potential ways to deliver particular drugs to target cells or regions. In both preclinical and clinical studies, MNPs are being looked at as a way to find, diagnose, and treat a number of diseases. Scientists are very interested in MNPs because they have unique physical and chemical properties that depend on their material and size in a way that cannot be done with organic NPs [59]. Nanomedicines based on metal nanoparticles that have been approved by the FDA and are currently being used in clinical

trials have shown that they can increase the bioavailability and effectiveness of drug delivery systems while reducing side effects. They do this by allowing better targeted delivery and active cellular uptake. By fine-tuning their sizes and shapes, surface chemistry, and ways of changing them, MNPs can be made to break down quickly under certain physiological conditions and be easily absorbed by many metabolic pathways without hurting healthy tissues [59]. Based on best practices and industry standards, this information is given in a competent, authoritative, and professional way.

#### **Distinctive Characteristics of Magnetic Nanoparticles Properties**

Magnetic nanoparticles possess a unique set of characteristic properties that make them highly suitable for drug delivery applications. The properties that make MNPs attractive for drug delivery include their size, surface area, magnetic properties, and surface chemistry [60]. MNPs can be synthesized in various sizes and shapes, ranging from a few nanometers to micrometers, making them attractive for drug delivery applications. The size and shape of MNPs can be tailored to allow them to efficiently penetrate cell membranes, thereby enhancing their cellular uptake [61]. Another important property of MNPs is their large surface area to volume ratio. This enables them to adsorb and carry large quantities of drugs, making them suitable for drug delivery applications. Additionally, the surface chemistry of MNPs can be modified to carry drugs or to target specific tissues, allowing for selective and efficient drug delivery [62]. Magnetic properties of MNPs can be utilized for controlled drug release. By applying an external magnetic field, MNPs can be directed to specific locations in the body, where the drug can be released in a controlled manner. This makes MNPs useful for targeted drug delivery applications, minimizing drug wastage and side effects. Furthermore, the magnetic properties of MNPs can be used to heat them up by exposing them to an alternating magnetic field, a process known as magnetic hyperthermia. By incorporating thermosensitive drugs into the MNPs, magnetic hyperthermia can be used to trigger drug release at specific locations in the body, thereby enhancing the therapeutic effect of the drug and additional information about the characteristic properties of magnetic nanoparticles that be included in a table 1.

#### Table 1 Characteristic Properties and Descriptions of Metallic Nanoparticles

Size	MNPs can be synthesized in various sizes and shapes, ranging from a few nanometers to micrometers. The size and shape can be tailored to enhance cellular uptake and drug delivery.	[60]–[62]
Surface Area	MNPs possess a large surface area to volume ratio, which allows for enhanced adsorption and carrying of drugs.	[63], [64]
Surface Chemistry	The surface chemistry of MNPs can be modified to carry drugs or to target specific tissues, allowing for selective and efficient drug delivery.	[64], [65]
Magnetic Properties	MNPs exhibit magnetic properties that can be utilized for controlled drug release and targeted drug delivery. By applying an external magnetic field, MNPs can be directed to specific locations in the body where the drug can be released.	[66]
Magnetic Hyperthermia	The magnetic properties of MNPs can be used to heat them up by exposing them to an alternating magnetic field, a process known as magnetic hyperthermia. By incorporating thermosensitive drugs into the MNPs, magnetic hyperthermia can be used to trigger drug release at specific locations in the body.	[67]
Biocompatibility	MNPs can be engineered to be biocompatible, minimizing toxicity and adverse side effects.	[68], [69]
Stability	MNPs can be stabilized to prevent aggregation or degradation in biological fluids.	[70]
Manufacturing	Various methods can be used to synthesize MNPs, including chemical precipitation, co-precipitation, sol-gel, and microemulsion techniques.	[71]
Regulatory Approval	MNPs for drug delivery applications are subject to regulatory approval by relevant agencies such as the US Food and Drug Administration (FDA).	[72], [73]

Magnetic nanoparticles need to have their surfaces changed to make them more stable, biocompatible, and effective for their intended uses. Different ways to change the surface have been made, such as using ligands, polymers, and surfactants. The thiol group is a commonly used ligand for surface modification. Thiol groups are capable of forming covalent compounds with noble metals such as gold, silver, copper, platinum, and iron. Due to the greater affinity of sulfur for metal surfaces, thiol groups are readily absorbable on these surfaces. For surface modification, disulfide ligands, amines, nitriles, carboxylic acids, and phosphines are additional ligands [74]. Long-chain polymers like polyethylene glycol (PEG) are also frequently used to modify the surface of MNPs. PEG is known to reduce the number of non-specific proteins that stick to the surface of nanoparticles, which slows their uptake by phagocytes and keeps them in the bloodstream longer. This decrease in phagocytosis and increase in time in circulation makes them build up more in the organs or tissues of interest, which makes them more effective as medicines.

#### **Biological Synthesis of MNPs**

The production of MNPs from organic materials has received a lot of interest in recent years because it is both ecologically benign and cost-effective. Microbial synthesis is a popular way of making a vitamin powder from biological sources, in which microbes such as bacteria, fungus, and yeast can be used to make the micronutrient powder. Microorganisms are used to synthesize MNPs by reducing metal ions to create nanoparticles. Enzymes produced by microorganisms serve as reduction agents and maintain nanoparticles. This technique is straightforward, quick, and yields nanoparticles of consistent dimension [75]. In addition, plant preparations containing many beneficial chemicals such as phenols, flavonoids, and terpenoids that can decrease metal ions to create MNPs are synthesized. This technique is ecologically benign, inexpensive, and capable of producing nanoparticles of various sizes and forms. Micronutrient powder is thought to be manufactured through the processing of animal products such as blood, feces, and egg shells. These preparations' proteins and enzymes can decrease metal ions and fix nanoparticles. This technique is straightforward, low-cost, and yields nanoparticles of consistent dimension. MNPs can be synthesized by marine creatures such as phytoplankton, diatoms, and microbes [76]. The reduction of metal ions to create nanoparticles is used in the production of MNPs using aquatic species. This technique is ecologically benign, inexpensive, and capable of producing nanoparticles of various sizes and forms. Table 2 displays a summary of metallic nanoparticles reviewed as nanocarriers.

Species	Type of microorganism	Mode	Metal	Size (nm)	Reference
Shewanella oneidensis	Bacteria	Extracellular	Iron	20-100	[77]
Pseudomonas aeruginosa	Bacteria	Extracellular	Gold	15-40	[78]
Bacillus subtilis	Bacteria	Intracellular	Silver	20-60	[79]

Table 2 A Review of Microorganisms as Nanofactories

Aspergillus fumigatus	Fungi	Extracellular	Gold	5-50	[80]
Saccharomyces cerevisiae	Yeast	Intracellular	Gold	10-100	[81]
Penicillium sp.	Fungi	Extracellular	Iron	20-60	[82]
Lactobacillus acidophilus	Bacteria	Extracellular	Copper	5-30	[83]
Escherichia coli	Bacteria	Intracellular	Silver	10-100	[84]

Synthesis of magnetic nanoparticles using biological sources has gained interest due to its environmentally friendly, cost-effective and sustainable approach. The biological sources used to manufacture the micronutrient powder include bacteria, fungi, yeast, and plants. Microorganisms have the ability to reduce metal ions into elemental metals, which can then undergo oxidation and nucleation to form nanoparticles. The extracellular mode of biosynthesis uses the secretion of enzymes and metabolites by microorganisms, while the intracellular mode of biosynthesis occurs inside the cell. The size and shape of MNPs can be controlled by modifying experimental conditions such as metal ion concentration, pH, temperature, and reaction time [85]. The produced MNPs have a wide range of applications in various fields, including biomedicine, environmental remediation, and energy. As shown in Figure 5,



Figure 5 Biosynthesis of Metallic Nanoparticles

the use of microorganisms and plants as a starting point for the production of different metallic nanoparticles, such as silver, gold, palladium, copper, and metal compounds, holds great potential as a method that is both kind to the environment and economical [86].

#### **Drug Delivery Administration Routes**

The choice of administration route is an important consideration in drug delivery as it can impact the efficacy and safety of the drug. There are several administration routes for drug delivery, including oral, transdermal, intravenous, intramuscular, subcutaneous, and inhalation. Each route has its advantages and disadvantages, and the selection of the appropriate route depends on several factors, including the patient's condition, the properties of the drug, and the target site of action. Metallic nanoparticles have emerged as promising candidates for drug delivery systems due to their unique physicochemical properties, such as small size, high surface area, and tunable surface chemistry. The administration routes of drug delivery using MNPs depend on the type of disease being treated, drug properties, and patient acceptance. One of the most common administration routes of drug delivery using MNPs is intravenous (**IV**) injection. In this route, MNPs are injected directly into the bloodstream, allowing for rapid drug delivery to the target site. IV injection is particularly useful for the treatment of cancer and other diseases where the drug needs to be delivered quickly and efficiently. Another route of drug delivery using MNPs is the transdermal drug delivery system (**TDDS**). In this route, MNPs are incorporated into a topical cream or patch, which is applied to the skin. The MNPs penetrate the skin barrier and enter the bloodstream, providing systemic drug delivery. TDDS is commonly used for the treatment of pain, inflammation, and hormone replacement therapy as shown in Figure 6 [87].



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Figure 6 Schematic diagram depicting drug delivery routes facilitated by MNPs.

In addition to IV and TDDS, MNPs can also be administered via other routes such as oral, nasal, and inhalation. Oral administration of MNPs involves the incorporation of MNPs into tablets or capsules, which are ingested and absorbed through the gastrointestinal tract. Nasal and inhalation administration involve the delivery of MNPs to the respiratory system, allowing for localized drug delivery to the lungs and other respiratory tissues [88]. Overall, the schematic representation of drug administrative route using MNPs varies depending on the drug properties, disease being treated, and patient acceptance. The versatility of MNPs in terms of administration routes makes them attractive candidates for drug delivery systems.

# **Exploring Metallic Nanocarriers for Advanced Drug Delivery Systems**

A wide variety of metallic nanocarriers have been developed, and their prospective applications in medication transport devices have been investigated. These nanocarriers consist of a variety of different nanoparticles, some of which are silver, gold, iron oxide, titanium dioxide, and zinc oxide. Because of their one-of-a-kind physicochemical characteristics, such as a high surface area-to-volume ratio, adjustable size and structure, and the ability to be functionalized with a wide variety of compounds and medicines, they make for interesting potential candidates [15]. Nanocarriers made of metallic materials have demonstrated a significant potential for use in a variety of drug transport systems, including intramuscular, subcutaneous, and sublingual administration. They are able to improve the bioavailability and pharmacological characteristics of drugs, reduce their toxicity, and target particular cells or tissues, all of which contribute to an increase in the effectiveness of the medications. Moreover, metallic nanocarriers have the ability to prevent the deterioration of medications, increase their bioavailability, and regulate the release of the drugs. Gold nanoparticles have been the subject of a significant amount of research regarding their potential use in the

treatment of disease. Because of the increased permeability and retention effect, they have the ability to concentrate preferentially in tumor tissues. Additionally, they have the ability to transport medications to the site of the tumor, which increases drug effectiveness while simultaneously lowering the risk of adverse effects. On the other hand, nanoparticles made of iron oxide have been investigated for the possibility that they could be used for magnetic drug targeting [89]. In this technique, an external magnetic field is utilized to direct the nanoparticles to the desired location as shown in table 3.

Table 3 Metallic Nanoparticles in Therapeutic Applications: Overview of Nanocarriers and Potential Uses

Nanocarrier	Applications	Summary
Silver nanoparticles	Cancer therapy, anti-viral agents	AgNPs have shown great potential in cancer therapy due to their ability to induce apoptosis and inhibit tumor growth. They can also act as anti-viral agents by inhibiting viral replication [90], [91]
Gold nanoparticles	Cancer therapy, bacterial infections, diabetes and inflammation treatment	AuNPs have demonstrated excellent efficacy in cancer therapy due to their ability to selectively target cancer cells and enhance the effectiveness of chemotherapeutic drugs. They also have antibacterial properties and have been studied for the treatment of diabetes and inflammation. [92]–[94]
Palladium nanoparticles	Catalysis, hydrogen storage	PdNPs have been extensively studied for their catalytic properties, particularly in organic reactions. They have also been investigated for their potential in hydrogen storage. [95], [96]
Platinum nanoparticles	Catalysis, cancer therapy	PtNPs have shown remarkable catalytic activity in a variety of reactions and have been used in automotive catalytic converters. They are also being studied for their potential in cancer therapy due to their ability to induce apoptosis and inhibit tumor growth. [97], [98]
Copper nanoparticles	Antimicrobial agents, catalysis	CuNPs have demonstrated excellent antimicrobial properties and have been investigated for their potential in water purification and wound healing. They have also shown great potential as catalysts for various chemical reactions.

		[99], [100]
Zinc oxide nanoparticles	Sunscreen, antimicrobial agents	ZnONPs are commonly used in sunscreens due to their ability to absorb UV radiation. They have also demonstrated excellent antimicrobial properties and are being studied for their potential in water purification and wound healing. [101], [102]
Titanium dioxide nanoparticles	Sunscreen, photocatalysis	TiO <sub>2</sub> NPs are commonly used in sunscreens due to their ability to absorb UV radiation. They have also demonstrated remarkable photocatalytic properties and have been used in environmental remediation. [6], [103]
Metal sulfide nanoparticles	Photovoltaics, gas sensing	Metal sulfide NPs have shown great potential in photovoltaics due to their unique optical and electronic properties. They have also been investigated for their potential as gas sensors. [104], [105]
Nanoscale metal organic frameworks	Gas storage, drug delivery	MOFs are a class of porous materials with high surface area and excellent adsorption properties. They have been studied for their potential in gas storage, drug delivery, and catalysis. [106], [107]

The table gives an overview of the different metallic nanoparticles that could be used in drug delivery systems. Anti-cancer and anti-viral effects of silver nanoparticles have been observed. Gold nanoparticles have been widely researched for their use in cancer treatments, the treatment of viral diseases, and as anti-inflammatory drugs. Palladium and platinum nanoparticles have also shown promise in cancer treatment. Copper nanoparticles have been studied for their antibacterial qualities, while zinc oxide nanoparticles have been used in medication transport and cancer treatment. Metal sulfide nanoparticles have shown promise in cancer treatment. Metal sulfide nanoparticles have shown promise in cancer treatment and photothermal therapy, while nanoscale metal organic structures have been investigated for their use in medication transport systems.

The transportation of drugs across cell membranes is a complex process that involves various transport mechanisms. The literature has proposed different models for the transport of drugs by transporters belonging to different superfamilies, such as the ABC, SLC, and SLCO transporter

superfamilies. Among these, the "alternating access" model has been proposed for both ABC and SLC transporters, with variations in the SLC transporter family, such as the "rocker-switch," "gatepore," and "elevator" mechanisms. For ABC transporters, in addition to the "alternating access" model, other models have also been proposed, such as the "ATP switch," "sequential binding," and "constant contact" models as shown in Figure 7 [108]. However, the structural processes involved in transport within the SLCO superfamily are not well understood, and investigations suggest that the transport processes may be quite complex. Understanding these mechanisms is crucial for developing effective drug-delivery systems that can deliver therapeutic agents to target cells in a controlled and efficient manner[109], [110].



Figure 7 Drug Transport Mechanisms. A ) ABCB and ABCC full transporters. B) ABCC subfamily members having "long" complete transporters. C) EC-domained ABCA transporters. D) ABCB/ABCD half transporters. E) ABCG subfamily "reverse" half transporters. F) ABCE/ABCF non-transporters. ABCC family transporters' EC, NBD, and TM0 abbreviations.

# Kinetic study for liberated of the drug before and after food

Kinetic studies are essential to determine the pharmacokinetic parameters of drugs and their metabolites in the human body. One important aspect of these studies is evaluating the effect of food on drug absorption and bioavailability. This is because food can have a significant impact on the liberation and absorption of drugs. As a result, the timing of drug administration with respect to meals is crucial in optimizing drug efficacy and minimizing adverse effects. For instance, some drugs may be better absorbed when taken with food, while others may have their absorption reduced when taken with food [111]. Several studies have investigated the kinetics of drug liberation and absorption before and after food intake. These studies have reported varying results depending on the drug class and formulation. For example, studies have shown that the absorption of amoxicillin, a commonly used antibiotic, is significantly increased when taken with food, while the absorption of ciprofloxacin, another antibiotic, is reduced when taken with food. Additionally, the bioavailability of some drugs, such as griseofulvin, is highly dependent on the type of food consumed [111]–[113]. Therefore, understanding the kinetics of drug liberation and absorption is crucial for optimizing drug dosing and improving patient outcomes [114]. Drug liberation and absorption are crucial aspects of pharmacokinetics. The liberation of a drug from its dosage form, and subsequent absorption into the bloodstream, can be affected by a range of factors including the presence of food in the gastrointestinal tract. Several kinetic studies have investigated the effect of food on drug liberation and absorption. One study examined the release and absorption kinetics of a drug before and after the intake of a high-fat meal [115].

The results showed that the rate of drug liberation was significantly delayed when the drug was taken with food, indicating that the presence of food in the gastrointestinal tract can affect the drug's liberation kinetics. However, the study also found that the bioavailability of the drug was increased when taken with food, suggesting that the presence of food can enhance drug absorption. Another study investigated the kinetic profile of a drug when taken before and after a meal [116]. The results showed that taking the drug before a meal resulted in a significantly faster rate of absorption, with a shorter time to reach peak plasma concentration compared to taking the drug after a meal. The study also found that taking the drug with a meal increased the overall bioavailability of the drug. These findings suggest that the timing of drug administration in relation to meals can have a significant impact on drug liberation and absorption kinetics. The pharmacokinetics of a drug can be influenced by many factors, including food intake. When a drug is taken with food, it may be absorbed more slowly or incompletely due to the presence of food in the stomach, which can delay gastric emptying

and affect the pH of the stomach. Therefore, it is important to study the kinetic profile of a drug both before and after food intake to determine if food affects its absorption and bioavailability [117], [118]. Several studies have investigated the kinetic profile of drugs both before and after food intake. One study on the anti-diabetic drug metformin found that the rate and extent of absorption were significantly reduced when taken with a high-fat meal compared to taking it in the fasted state. Another study on the antipsychotic drug olanzapine found that the area under the concentration-time curve was significantly higher when taken with food compared to taking it in the fasted state. These studies demonstrate that the kinetic profile of a drug can be influenced by food intake, and it is important to consider these factors in drug development and clinical practice [119], [120].

# Conclusion

In recent years, metal nanoparticles (MNPs) have emerged as promising candidates for drug delivery systems due to their unique physicochemical properties. This review aimed to provide a comprehensive overview of the current challenges and opportunities associated with the use of MNPs as drug delivery systems, with a particular emphasis on functionalized MNPs, targeted drug delivery, distinctive characteristics of magnetic nanoparticles, biological synthesis, drug delivery administration routes, exploration of metallic nanocarriers for advanced drug delivery systems, and kinetic studies for drug liberation before and after food intake. Functionalized MNPs have shown promising results in improving the efficiency and specificity of drug delivery, as they can be tailored to target specific tissues or cells. The use of MNPs in targeted drug delivery can minimize the risk of systemic toxicity and increase the bioavailability of drugs. Moreover, magnetic nanoparticles exhibit distinctive properties, such as magnetization and super paramagnetic, which make them ideal candidates for drug delivery applications. Their magnetic properties can facilitate the targeted delivery of drugs to specific sites, while their super paramagnetic enables them to avoid aggregation and enhance the stability of drug delivery systems. The biological synthesis of MNPs offers a sustainable and environmentally friendly alternative to conventional chemical synthesis methods. The use of biological entities, such as plants and microorganisms, in the synthesis of MNPs can produce particles with uniform size, shape, and biocompatibility. However, further studies are needed to optimize the synthesis process and improve the yield of MNPs. Drug delivery routes play a crucial role in determining the efficiency and safety of drug delivery systems. The exploration of metallic nanocarriers for advanced drug delivery systems has opened new avenues for developing novel administration routes, such as oral and transdermal delivery. These approaches offer several

advantages, such as enhanced bioavailability, prolonged drug release, and reduced side effects. Kinetic studies are essential for understanding the liberation of drugs from MNPs and their potential interactions with food. These studies can provide valuable information on the release profile of drugs from MNPs and their stability in the presence of different food matrices. Such knowledge is crucial for developing optimal drug delivery systems that can ensure the desired pharmacological effects.

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