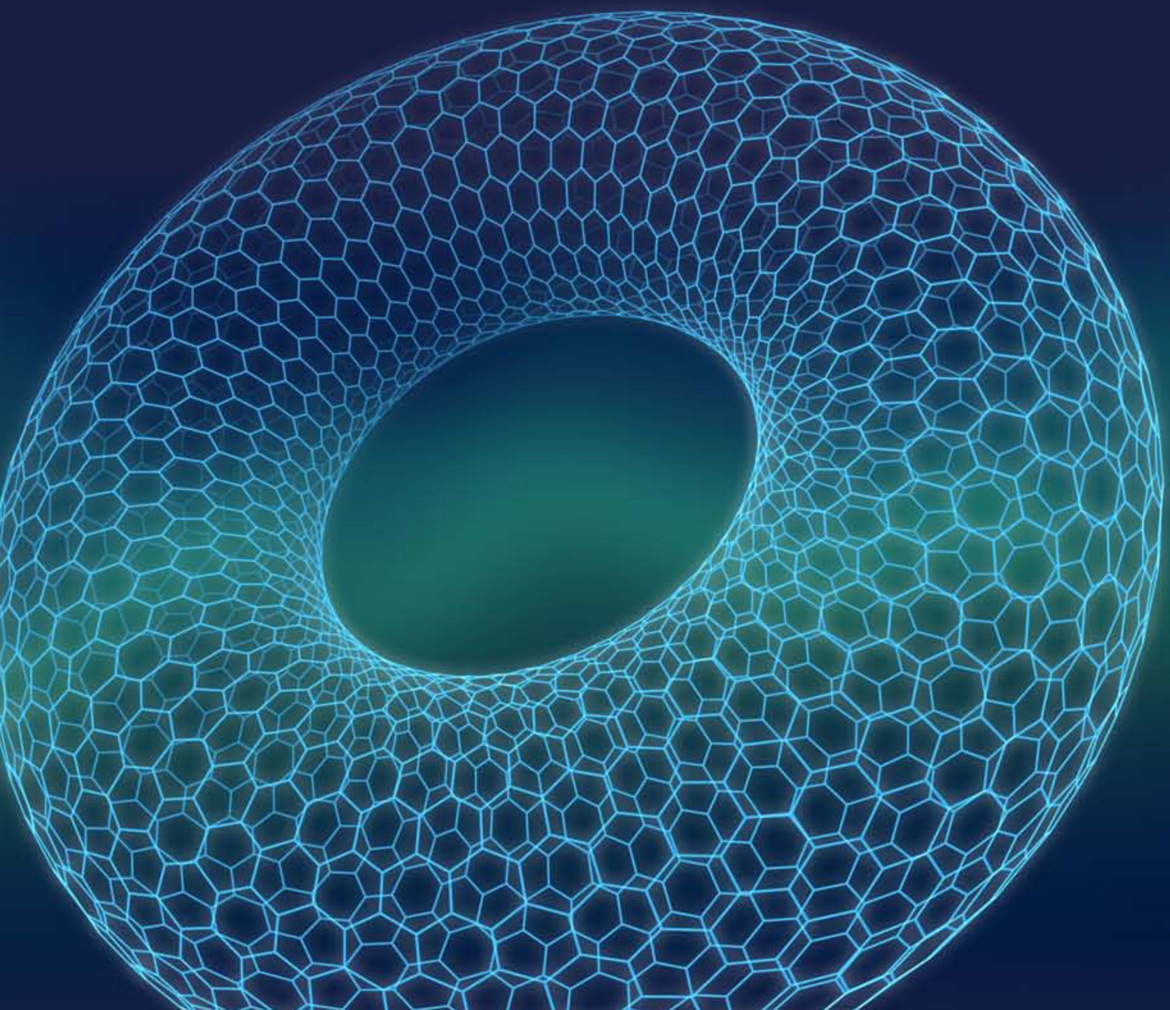
RECENT ADVANCEMENTS IN MULTIDIMENSIONAL APPLICATIONS OF NANOTECHNOLOGY



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Recent Advancements in Multidimensional Applications of Nanotechnology

(Volume 1)

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PREFACE

In this rapidly evolving field, nanotechnology has emerged as a powerful tool with endless possibilities. This book aims to provide a comprehensive overview of the latest advancements and applications of nanotechnology across various dimensions. It covers a wide range of topics, from electron microscopy to biogenic synthesis methods, from energy applications to agro-nanotechnology, and from nanotherapeutic strategies to nanosensors for virus detection.

Chapter 1 explores the remarkable capabilities of the electron microscope for qualitative and quantitative analysis of nano-materials. It sets the stage for subsequent chapters that delve into specific applications of nanotechnology. Advancements in perovskite nanomaterials for advanced energy applications are discussed in Chapter 2, emphasizing their significance in the quest for sustainable energy solutions. Chapter 3 explores the current developments in the use of copper oxide nanoparticles in the oil and gas industries, highlighting their potential for enhancing efficiency and performance. In Chapter 4, the application of nano-coatings to combat hot corrosion of metallic substrates is examined, presenting an innovative approach to protect materials subjected to extreme conditions. Agro-nanotechnology, discussed in Chapter 5, presents a promising pathway towards sustainable agriculture, where nanotechnology is harnessed to enhance crop production and mitigate environmental challenges. The impact of economic natural dyes on the performance and efficiency of TiO_2 nano-structure solar cells is explored in Chapter 6, uncovering new possibilities for greener and more efficient solar energy generation. Chapter 7 investigates the effect of annealing conditions on chemical bath-deposited CdTe thin films, offering insights into optimizing thin-film deposition processes. Chapter 8 highlights the biomedical necessities and green future of metallic nanoparticles, revealing their potential in various healthcare applications. Chapter 9 focuses on the production of silver nanoparticles with enhanced cytotoxicity and biological activity from Kalanchoe Gastonis-Bonnieri leaf extract, opening avenues for novel therapeutic approaches. Chapter 10 provides an overview of recent biogenic synthesis methods of metal nanoparticles and their applications, showcasing the potential of nature-inspired approaches in nanotechnology. Chapter 11 takes a step further by benchmarking different CNN architectures on a COVID-19 dataset, highlighting the role of nanotechnology in addressing public health challenges. Finally, Chapter 12 explores the application of novel nanotherapeutic strategies in treatment through herbal medicines, presenting an exciting fusion of traditional and modern medicine.

Readers of this book will gain a comprehensive understanding of the recent advancements in nanotechnology and its multidimensional applications. From the fundamentals of electron microscopy to cutting-edge developments in nanotherapeutics and biogenic synthesis methods, this book offers a broad perspective on the field. It equips readers with the knowledge to explore new possibilities, drive innovation, and contribute to the advancement of nanotechnology across various domains.

We hope that this book serves as a valuable resource for researchers, scientists, academicians, and students interested in nanotechnology and its applications. It is our sincere belief that the knowledge shared within these pages will inspire further research, foster interdisciplinary collaborations, and contribute to the realization of a more sustainable and technologically advanced future.

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CHAPTER 1

Electron Microscope: The Tool for Qualitative and Quantitative Analysis of Nano-Materials

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Abstract: An electron microscope is a highly advanced sophisticated tool where high energy electron beam is used as the source. Since an electron beam has a shorter wavelength than visible light photons, it may expose the structure of tiny objects and has a higher resolving power than a light microscope. While most light microscopes are constrained by diffraction to around 500 nm resolution and usable magnifications below 2000, a scanning electron microscope (SEM) may attain 5 nm resolution and magnifications up to roughly 10,000,000. Electromagnetic lenses, which are similar to the glass lenses of an optical light microscope, are used in electron microscopes to create electron optical lens systems. Large molecules, biopsy samples, metals, crystals, and other biological and inorganic specimens, among others, can all have their ultra-fine structure studied using electron microscopes. Electron microscopes are frequently used in industry for failure analysis and quality control. The images are captured using specialised digital cameras and frame grabbers by modern electron microscopes to create electron micrographs. To create an appropriate sample from materials for an electron microscope, processing may be necessary. Depending on the material and the desired analysis, a different procedure is needed. Transmission electron microscopes (TEM), scanning electron microscopes (SEM), reflection electron microscopes (REM), scanning tunnelling microscopes (STM), and other types of electron microscopes are commonly employed in academic and research institutions. The initial and operating costs of electron microscopes are higher and they are also more expensive to construct and maintain. High-resolution electron microscopes need to be kept in sturdy structures (often underground) with specialised amenities like magnetic field cancelling devices.

Keywords: Cryogenic transmission electron microscopy, Electron mapping, Energy-filtered transmission electron microscopy, Electron energy loss spectroscopy, Electron microscope, Environmental electron microscope, Low-voltage electron microscope, Magnification, Nano-materials, Scanning transmission electron microscope.

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INTRODUCTION

Electron microscopy for nanotechnology is the use of electron microscopes to observe, analyse and manipulate materials at the nanoscale [1 - 5]. This field plays a crucial role in the development of modern nanotechnology and materials science, as it enables scientists and engineers to observe and study the structure, composition, and properties of nanoscale materials and devices [6, 7]. There are several types of electron microscopes used for nanotechnology, including Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Scanning Transmission Electron Microscopy (STEM), and Cryogenic Transmission Electron Microscopy (Cryo-TEM) [8, 9]. TEM works by passing a beam of electrons through a thin sample, producing an image of the internal structure of the material. SEM, on the other hand, uses electrons to scan the surface of a sample and produce a high-resolution image. STEM uses a beam of electrons to probe the sample and obtain chemical and structural information. Cryo-TEM operates at cryogenic temperatures, allowing for the study of delicate biological samples. Electron microscopy for nanotechnology has numerous applications, including the study of materials for electronic and energy applications, the development of new drug delivery systems, the investigation of cellular and molecular structures, and the characterization of nanoscale devices and materials [7 - 10]. The electron microscope, which uses electrons instead of light to magnify images, was first developed in the 1930s and revolutionized the field of microscopy [11, 12]. In the early days of electron microscopy, the technology was primarily used for imaging biological samples, but as the field developed, researchers began to apply the technology to the study of materials at the nanoscale. The development of electron microscopy was closely tied to advancements in the field of physics [13 - 16]. In the late 19th and early 20th centuries, scientists were exploring the properties of electrons and the way they interacted with matter. This research laid the foundation for the development of the electron microscope, which would use electrons to image samples and reveal their structure at an incredibly high level of detail [17]. In the 1930s, two German scientists, Max Knoll and Ernst Ruska, independently developed early versions of the electron microscope. These first-generation electron microscopes were large, complex devices that required a high level of expertise to operate, but they were capable of producing images of biological samples with a much higher level of detail than was possible with light microscopes [18 - 20]. In the decades that followed, advances in technology allowed for the development of smaller, more accessible electron microscopes. These microscopes made it possible for researchers to study a wider range of samples, including inorganic materials and materials at the nanoscale. In the 1960s and 1970s, the field of electron microscopy underwent a major expansion as researchers began to develop new techniques for imaging materials at the nanoscale [21]. This was a critical development, as it allowed scientists to study materials in much greater detail than was previously possible. With the ability to see materials at the nanoscale, scientists were able to discover new properties and behaviours that could not be observed at the macroscale. One of the key applications of electron microscopy in nanotechnology is imaging materials at the atomic scale. This allows researchers to study the structure and composition of materials at the smallest possible level, which can provide important insights into their properties and behaviour [22, 23]. In recent years, electron microscopy has also been used to study materials in various states, including liquids, gases, and even plasmas. Electron microscopy has also been critical in the development of other important technologies, such as nanolithography and nanofabrication. Nanolithography involves the patterning of materials at the nanoscale, and electron microscopy is used to verify the accuracy and precision of these patterns. Nanofabrication involves the creation of nanoscale structures and devices, and electron microscopy is used to study and refine these structures during the fabrication process [24, 25]. Today, electron microscopy is an essential tool in the field of nanotechnology and materials science, allowing researchers to study materials at the smallest possible scale and uncover new properties and behaviours. The field of electron microscopy continues to evolve and advance, with new techniques and innovations being developed all the time.

TYPES OF ELECTRON MICROSCOPY

Electron microscopes are a key tool in nanotechnology, allowing scientists and engineers to visualize, analyse and manipulate materials at the nanoscale. There are several types of electron microscopes, each with its advantages and limitations. Here are the most common types:

1. Transmission Electron Microscope (TEM): This type of microscope uses a beam of electrons to form an image of a thin sample. The electrons pass through the sample and are scattered, forming an image of the internal structure. TEMs are used for high-resolution imaging and analysis of a variety of materials, including metals, ceramics, and biological samples [26].

2. Scanning Electron Microscope (SEM): This type of microscope uses a beam of electrons to scan the surface of a sample, producing a topographical image. SEMs are used for surface imaging and analysis, and can also be used to obtain information about the chemical composition of a sample [27]. The schematic representation of the Field Emission Scanning Electron Microscope (FE-SEM) is illustrated in Fig. (**1**).

CHAPTER 2

Amelioration of Perovskite Nanomaterials for Advance Energy Applications

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Abstract: The demand of energy highlight the need to explore new energy resources with less emissions without depleting the environment. With this perspective, novel perovskite lead-free materials are taking over the conventional energy systems of fossil fuels that produce carbon in the environment. It has been years of struggle that scientists are working on materials for more energy with less waste materials. The challenge was readily accepted by perovskite nanomaterials that can generate energy, store it, and use it when required. The development of these nanomaterials with their promising properties such as dielectric coefficient, superconductivity, and sustainability at high temperatures, withstand high mechanical properties and can be coated, pasted, or in the form of thin and thick films. This can be done by the solid-state reaction (SSR) mixing the metallic oxides in a fixed ratio in ball milling by wet or dry method. The composites prepared were calcined, pressed, and sintered at high temperatures. Following the characterization to check the properties make them superior for high-energy advanced applications. The perovskite nanomaterials' composites can be utilized perfectly for hydrogen generation and production, photocatalysis reactions, photovoltaic solar cells, solid oxide fuel cells, electrolysis, supercapacitors, sensors, actuators, structural health monitoring applications and metal-air batteries. This chapter covers the application-based synthesis, characterizations, and properties of the perovskite nanomaterials for high-energy applications.

Keywords: Actuators, Batteries, Dielectric, Superconductivity, Sensors.

INTRODUCTION

Energy demands are increasing day by day as the world population increases. For this, the non-renewable energy is not sufficient. In this regard, scientists and researchers are working on renewable energy sources. Improvement of new materials and their co-relation for the betterment of human beings is always an

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important area of research in the modern era of science and technology. It is always a desire to develop materials using advanced and latest technology at lower expense. Everyday life demands materials with producing energy. Therefore, study and development of energy materials is important. The materials performing multiple tasks are under highest consideration at present all over the world. Smart energy materials are those materials, which change their properties (*i.e.*, physical, and electrical) on the application of external source *i.e.*, electrical or mechanical. Piezoelectric, magneto strictive, electro strictive and shape memory materials are some types of smart materials [1].Among all the smart materials, piezoelectric materials are most common and widely used all over the world because of their good sensing and response by applying external source [2 - 4]. Many applications of these materials are found written in Table **1**.

Table 1. Piezo-electric devices & their uses [5]

Devices	Uses
Piezoelectric Sensors	Micro Phones, Force Sensors, Strain Sensors, Pressure Sensors, Micro Balances, Acceleration and Acoustic emission sensors
Piezoelectric Actuators	Loudspeakers, Piezoelectric motors, Acousto-optic modulator, Atomic force microscopes, Scanning, tunnelling microscopes, Inkjet Printers, Diesel engines, CT, MRI Scanners
Piezoelectric Transducers	Non Destructive Testing, Mega Sonic Cleaning, Vibration Monitoring, Doppler Probes, Industrial and Process control, Automotive engine management Systems, Medical imaging.

Among all the perovskites lead based ceramics, the solid solution $PbZrO_3$-$PbTiO_3$, *i.e.*, Lead Zirconium Titanate (PZT), is the most considerable material because of its piezoelectric and dielectric properties. Having matchless electromechanical coupling coefficients (Kp), PZT based piezo ceramics are the main materials for actuators, motors, and sensors of the present era. A few examples of piezo ceramics are included.

- $Pb(Nb_{2/3} Mg_{1/3})O_3$-$PbTiO_3$ (PT- PMN)
- $Pb(Nb_{2/3} Zn_{1/3})O_3$-$PbTiO_3$ (PT- PZN) [6].

However, the major concern is that the PZT-based piezoelectric ceramics contains toxic lead oxide (PbO), which has very adverse effect on environment and human health because of its adverse effect on intellectual and neurological development. Therefore, extensive study is being done to find out the materials free of lead but having properties comparable to PZT [7, 8]. Some of the lead-free classes of materials includes.

• Perovskites (ABO_3)

• Aurivillus Oxide type layered structure,

• Tungsten Bronze families

The first class, being extensively used due to good energy generation by piezoelectric effect and dielectric properties as compared to the last two [9 - 11].

Piezoelectric ceramics are one of the excellent sources to convert energy from mechanical to many other forms of energy. The piezoelectric effect can be utilized by number of compositions from bismuth-based ceramics, barium-based ceramics, and by mixing the compositions of these two of the solid solutions [12 - 17]. Among the perovskite class, $BaTiO_3$ (BT), KNN and NBT are considered the best replacement of PZT. Moreover, BT family is considered as a best replacement of PZT because of its high piezoelectric properties [11, 18, 19]. However, the lower Curie temperature (Tc ~ 120˚C) limits its applications, because polarization disappears as it reaches and crosses its curie temperature T_c [18, 20, 21]. Asymmetric crystal structure creates polarization in crystalline materials. As T_c reaches, crystal becomes symmetric and polarization disappears [22, 23].

Another important class of materials used in multi-effect nanogenerator is inorganic ferroelectrics. The main prominent features which make them highly competitive and attractive materials for multi-effect nanogenerators are improved opto-electricity, piezoelectricity, die-electricity, pyroelectricity and multifunctional nature. Generally, they possessed better and higher dielectric constant, piezoelectric constant, and anomalous photovoltaic features. Multiple materials have been developed to use as hybrid nanogenerators like Barium Titanate (BTO), Lead Zirconate Titanate (PZT) and Bismuth Ferrites [24, 25].

Multiferroic materials are those materials that have both ferroelectric and ferromagnetic behavior at the same time, also have magnetoelectric coupling (ME) between ferroelectric and ferromagnetic materials. These materials are being extensively used in electronic devices such as tunable filters, phase shifters and generators. As single-phase multiferroics does not have both properties (ferromagnetic & ferroelectric) at the same time so this behavior limits their applications. So, to overcome this problem, multiferroic composites are suggested because they overcome those problems that are faced using single phase multiferroics [26 - 28]. Few composite multiferroics have been successfully reported in the recent past. Perovskite oxides are usually suggested to prepare ferroelectric type material *e.g.*, barium titanate ($BaTiO_3$/BT). BT based multiferroic composite systems are not amply reported in the literature. Owing to its modified piezoelectric properties, barium calcium zirconium titanate

CHAPTER 3

Copper Oxide Nanoparticles in Oil and Gas Industries: Current Developments

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Abstract: This chapter presents an in-depth analysis of Copper oxide nanoparticles (CuONPs) and their emerging role in the oil and gas industry. Over the past five years, nanomaterial technology, especially CuONPs, has attracted significant attention due to its diverse applications in fields like petroleum. In the context of the oil and gas industry, CuONPs have been revolutionary, particularly in enhancing oil recovery (EOR) and as innovative drilling fluids. Their application leads to more efficient extraction and reduced viscosity of trapped oil. The synthesis of CuONPs has evolved, with biological methods standing out for their cost-effectiveness, safety, and environmental friendliness. These green synthesis methods have redefined industry standards by offering a sustainable alternative to traditional physical and chemical approaches. The chapter aims to provide a comprehensive overview of the practical applications of CuONPs in the oil and gas sector, emphasizing their production through green routes. It also addresses the challenges and prospects of CuONPs, setting a foundation for further research and technological advancements in this field.

Keywords: Copper oxide, Green synthesis, Gas, Metal oxide, Nanomaterial, Oil recovery, Oil.

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INTRODUCTION

In the forthcoming decades, the oil and gas sector is anticipated to face increasingly complex technical challenges [1]. As the availability of easily extractable resources rapidly depletes, the challenge of locating oil and gas reserves is escalating at a swift pace. Over the long term, it is predicted that the costs associated with exploration will persist in their upward trajectory. Concurrently, there is a consistent annual rise in worldwide energy consumption. Moreover, the exploration of new oil reserves presents significant challenges, with an estimated 30-60% of oil remaining inaccessible in presently exploited reservoirs. Consequently, both researchers and oil companies are actively seeking innovative and efficient methods to recover this residual oil from mature reservoirs. In this context, nanotechnology has emerged as a particularly promising and highly regarded technology, offering novel solutions to enhance oil recovery in these settings [2]. To address this pressing demand, the industry is in urgent need of technological advancements. To date, only limited progress has been made in addressing these issues through the application of traditional macro and micro materials [3, 4]. To mitigate these challenges, Enhanced Oil Recovery (EOR) methods have significantly advanced the efficiency of oil extraction from reservoirs, particularly after the application of primary and secondary recovery techniques. These methods utilize principles such as snap-off mechanisms and capillary pressure to extract a substantial portion, approximately two-thirds, of the original oil in place. The incremental increase in oil recovery, even by a mere 1%, through EOR techniques can yield an approximate addition of 70 billion barrels from conventional oil reserves. EOR encompasses a variety of technological processes aimed at augmenting the recovery factor from existing reservoirs. These include, but are not limited to, the injection of various fluids, and more recently, the use of microbial injections. These interventions are designed to augment the reservoir's natural energy and facilitate the effective displacement of oil towards the production wells. The interaction between the injected fluids and the reservoir's rock and oil composition creates conducive conditions for oil extraction, thereby enhancing overall production efficiency [5, 6].

Nanotechnology represents a significant breakthrough in industrial applications, particularly within the oil and gas sector, where it has instigated numerous innovative developments. The unique characteristics of nanomaterials, notably their high-volume concentration and large surface area, contribute to their distinctive properties. These nanoscale dimensions impart special magnetic, mechanical, thermal, and chemical attributes to the materials. Furthermore, nanomaterials are noteworthy for their versatility in chemical treatment, allowing for the alteration of their properties to meet specific technical requirements. This adaptability and the array of properties they exhibit have made nanotechnology a crucial element in advancing various aspects of the oil and gas industry [7, 8, 9, 10]. Green nano-biotechnology broadly refers to the process of creating nanoparticles (NPs) or nanomaterials through biological pathways, utilizing microorganisms, plants, viruses, and their derivatives like proteins and lipids, coupled with various biotechnological techniques. (NPs) synthesized via green methodologies are typically more advantageous than those produced through physical and chemical means. Key benefits of green synthesis include the elimination of costly chemicals, reduced energy consumption, and the production of environmentally friendly products and byproducts. The twelve principles of green chemistry have become a globally acknowledged framework for scientists, researchers, chemists, and chemical technologists, guiding the development of less hazardous chemical products and byproducts. These principles serve as a cornerstone for sustainable and responsible chemical research and development [11, 12].

The principal objective of this book chapter is to provide an exhaustive examination of both the triumphs and obstacles encountered in the realm of nanotechnology application. Specifically, it delves into the categorization of nanomaterials utilized within the oil and gas sector, highlighting the prominence of green synthesis methodologies, particularly those involving plant extracts and microorganism mediated synthesis, which are deemed superior to traditional chemical and physical approaches. Furthermore, this chapter offers an in-depth exploration of CuONPs, emphasizing their recent advancements and applications in the oil and gas industry. This analysis not only enhances understanding of nanotechnology's role in these sectors but also underscores the integration of green chemistry principles in the development and utilization of various nanomaterials. Fig. (**1**) provides the representation of NPs having a high-level surface-to-volume ratio (modified after

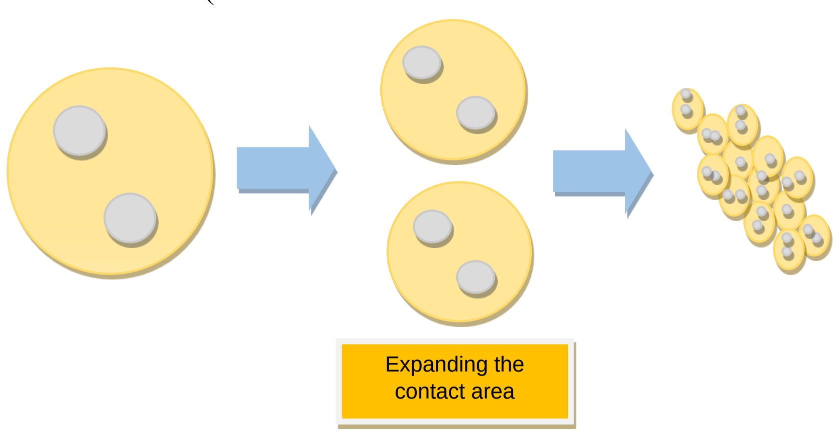

Fig. (1). Illustration of NPs having a high-level surface-to-volume ratio (modified after [13]).

CHAPTER 4

Combating Hot Corrosion of Metallic Substrate by Nano-Coating

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Abstract: Corrosion of metallic materials poses a serious threat to the efficiency of the manufacturing and construction industries. To overcome this, various surface modification techniques are employed. But, surface protection by nano-coating is gaining great potential owing to its numerous benefits. These include surface hardness, high-resistance against hot corrosion, high wear resistance, and adhesive strength. Additionally, nano-coatings can be deposited in thinner and smoother thicknesses, allowing for increased efficiency, more flexible equipment design, smaller carbon footprints, and lower operating and maintenance costs. Hence, the aim of this chapter is to provide an overview of the corrosion performance of ceramic, metallic, and nanocomposite coatings on the surface of the metallic substrate. In addition, the role of nanocoating to combat corrosion of metallic substrate is explored. Finally, the diverse applications of nano-coating in different fields including aircraft, automobile, marine, defense, electronic, and medical industries are discussed.

Keywords: Coating materials, Coating deposition techniques, Corrosion, Nano-coating, Surface protection.

INTRODUCTION

The battle against hot corrosion of metallic substrates has been a long and ongoing one, with engineers and scientists constantly seeking new and improved solutions [1]. The emergence of nano-coatings in recent decades has offered a revolutionary approach, paving the way for dramatic advancements in combating this destructive phenomenon [2]. The historical development of nano-coating is mentioned below:

Early Efforts (Pre-1980s): Traditional methods relied on thick, sacrificial coatings like chromium or aluminum, which offered limited protection at high temperatures and suffered from diffusion limitations. The research focused on

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understanding the complex mechanisms of hot corrosion, involving oxidation, sulfidation, and molten salt attack. Further, the development of new alloy compositions with improved inherent high-temperature corrosion resistance, albeit limited in their effectiveness [3 - 5].

Rise of Thin Film Technologies (1980s-2000s): The introduction of physical vapor deposition (PVD) and chemical vapor deposition (CVD) techniques enabled the creation of thin film coatings. However ceramic and metallic coatings like alumina, yttria-stabilized zirconia (YSZ), and MCrAlY (where M represents transition metals) offered superior high-temperature oxidation resistance. Further, multi-layered coatings were developed with tailored compositions and microstructures for enhanced protection against specific corrosion mechanisms [6 - 8].

Nano-Coating Revolution (2000s-Present): Advances in nanotechnology paved the way for the development of ultra-thin nano-coatings with unique properties, although nano-structured coatings offered improved adhesion, reduced crack formation, and enhanced diffusion barrier properties. Moreover, the research shifted towards exploring various material compositions, including nano-composite coatings, self-healing coatings, and bio-inspired designs [9, 10].

One of the main issues that the nation's economy faces is corrosion, which results from a metal's contact with its environment [11]. In terms of economic elements, corrosion damages include maintenance and repair expenses, material losses, equipment damage, decreased productivity, and equipment damage. Corrosion damages also have additional negative societal repercussions, such as resource depletion, personal injury, pollution from contaminated hazardous items, and safety implications (cause of fire, explosions, release of poisonous chemicals) [12]. According to the "National Association of Corrosion Engineers (NACE)" research, the cost of corrosion worldwide is projected to be $255 billion USD or 3.4% of the world's gross domestic product (GDP) [13]. Corrosion is predicted to cost the U.S. economy $552 billion per year in direct and indirect expenditures, or 6% of GDP [14]. The expense of maintaining appliances, highway bridges, cars, aeroplanes, and industrial facilities such as petrochemical, desalination, pharmaceutical, and energy production and distribution systems are only a few examples of the direct consequences of corrosion. Indirect corrosion costs might include taxes, overhead corrosion expenses, and productivity losses from delays, failures, or outages, among other things. These costs are just as significant as direct corrosion costs. As illustrated in Fig. (**1**) [14, 15], the corrosion costs for the economic sector for five distinct locations were gathered.

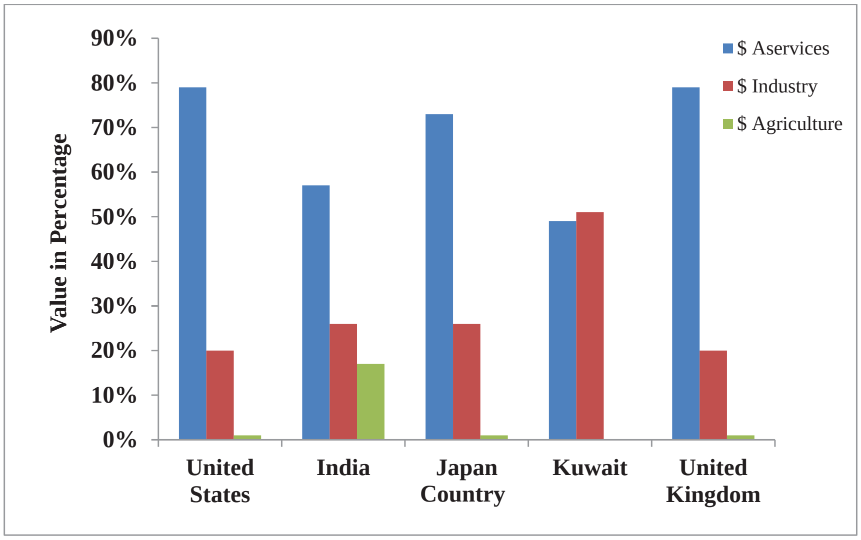

Fig. (1). According to the Worldwide actions of anticipation, application, and economics of corrosion technology research, a NACE international publication, the cost of corrosion varies amongst economic sectors in five different nations.

Installing a layer of coating is one of the simplest ways to stop metals from corroding [11]. Corrosion experts have used a variety of coatings, most of which are based on electrochemical principles, to prevent corrosion. Fortunately, the metal and metallurgy sectors frequently use four different coating kinds based on cost and efficacy. Utilizing barrier coatings like plastic, powder, and paint is one of the most affordable and efficient ways to avoid corrosion. Therefore, nanocomposite coatings applied by electrochemical deposition provide superior metal surface corrosion and abrasion resistance [16]. Instead of replacing the components, these coatings might be utilised to restore them, which would save maintenance costs and disruption [11, 17].

The word "nano" is derived from the Greek word for "dwarf." It relates to a dimension scale between 10^{-9} and 10^{-8} metres. An interdisciplinary field of study known as nanotechnology and nanoscience uses the principles of physics, biology, chemistry, and engineering to investigate and manage matter at the molecular and atomic scales. Nano-materials and nano-particles frequently have high surface region-to-volume ratios when compared to bulk materials, which has a variety of intriguing impacts on the subsequent behaviour of these materials [18 - 24]. Different strategies are used to prevent corrosion, and selecting the best one requires balancing method cost, technique performance, and corrosion impacts. Thus, the corrosion can be avoided by: (a) Choosing materials that are either relatively inert in the -galvanic series or capable of forming a passivating oxide layer in a specific atmosphere; (b) Altering the atm parameters, such as by

CHAPTER 5

Agro-Nanotechnology: A Way Towards Sustainable Agriculture

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Abstract: Addressing the global population's dietary needs is crucial amid crop damage issues like insect infestations and adverse weather affecting one-third of conventionally farmed crops. Nanotechnology, recognized for its efficacy and environmental benefits, has gained attention in the past decade. While it has transformed medicine, its applications in agriculture are underexplored. Current research investigates the use of nanomaterials in agriculture for targeted delivery of genes, insecticides, fertilizers, and growth regulators. Nanotechnology shows promise in mitigating abiotic stress in plants by mimicking antioxidative enzymes. This chapter assesses nanoparticles' roles in plant research, highlighting their effectiveness as growth regulators, nanopesticides, nanofertilizers, antimicrobial agents, and targeted transporters. Understanding plant-nanomaterial interactions opens new avenues for enhancing agricultural practices, improving disease resistance, and crop productivity, and optimizing fertilizer use.

Keywords: Agriculture, Nanofertilizer, Nanopesticide, Production, Sustainable.

INTRODUCTION

Agriculture, the cornerstone of a thriving economy, plays a pivotal role in providing sustenance for an ever-growing global population. However, the agricultural sector faces challenges such as climate uncertainties, soil contamination from fertilizers and pesticides, and an escalating demand for food [1]. The imperative to boost food production by over 50% to meet the needs of the burgeoning population underscores the urgency of finding innovative solutions [2]. Industrialization, while contributing to economic growth, poses a significant threat to natural resources vital for sustenance, including forests and seas. Preserving ecological diversity is paramount for maintaining the delicate balance

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between food production and the environment, enhancing agriculture's resilience to environmental stresses that could lead to crop failure. In response to these challenges, the adoption of nanomaterials (NMs) represents a progressive step in revolutionizing current farming techniques [3]. Nanomaterials, with their remarkable reactivity owing to a large surface area to volume ratio and distinctive physicochemical characteristics, can be easily tailored to meet the increasing demands in agriculture. Nanoparticles (NPs) are already making strides in various consumer products, drawing keen attention from the food and agricultural industries. These NMs exhibit unique surface chemical, electrical, and optical properties, enhancing sensitivity, detection limits, and response times [4, 5].

Fertilizers, vital for increasing crop output, often disrupt soil fertility by upsetting mineral balances and can contribute to environmental pollution. Nanoparticles offer a solution by reducing production costs, minimizing the need for plant protection agents, and mitigating nutrient losses to enhance yields. Innovative applications, such as intelligent agrochemical delivery systems utilizing NMs as carriers for active chemicals, are continually evolving [5]. Moreover, agricultural waste materials, like soy hulls and grain straws, can be transformed into advanced bio-nanocomposites with enhanced mechanical and physical qualities for industrial applications. This chapter emphasizes the superior potential of nanomaterials in enhancing agriculture and food systems [6]. Despite these advancements, challenges remain, requiring improvements in procedure design, risk assessment of nanopesticides and nanofertilizers, and regulatory frameworks for the commercialization of nano-agroproducts, to fully realize the benefits of nanotechnology in agriculture.

APPLICATIONS

Agriculture is the mainstay of the developing economy, providing people with food and a better standard of living. A wide range of problems are currently affecting agriculture, including unforeseen climate change, soil contamination from harmful environmental contaminants like pesticides and fertilizers, and dramatically rising the demand for food due to an expanding world population [7]. On the other side, industrialization has an alarmingly quick detrimental effect on the ecological diversity, woods, and seas which promote the population's way of life. In order to meet the requirements of the population's unrelenting growth, it is urgent to increase agricultural output by more than 50%. It encourages the necessity of increased agricultural output and enhanced food security as a result. Environmental biodiversity strengthens agriculture's resistance to environmental pressures that could result in crop failure, which is essential for maintaining the delicate equilibrium between food production and the environment [8]. New techniques and strategies are constantly emerging to solve these significant issues.

Given this, one action that has been taken is the creation of products based on nanomaterials (NM) that will revolutionize the way that agriculture is now done. They also offer the advantage of being easily adjusted to satisfy growing demand.

Additionally, regulation of the excessive cost of production of these fertilizers and herbicides is also necessary. The use of NMs in agriculture seeks to decrease nutrient losses to boost yields, decrease the quantities of plant protection products, and reduce production costs to optimize output [9].

The creation of products based on nanotechnology is ongoing, including sophisticated nanopackaging products, nanopesticides, agrochemical delivery products, *etc.* Fig. (**1**). It is possible to create novel bio-nanocomposites from agricultural wastes like soy hulls and wheat straw that have improved mechanical and physical properties that can be employed in industrial applications. It is also necessary to test the level of toxicity of NM-based products before releasing them onto the market Table **1**.

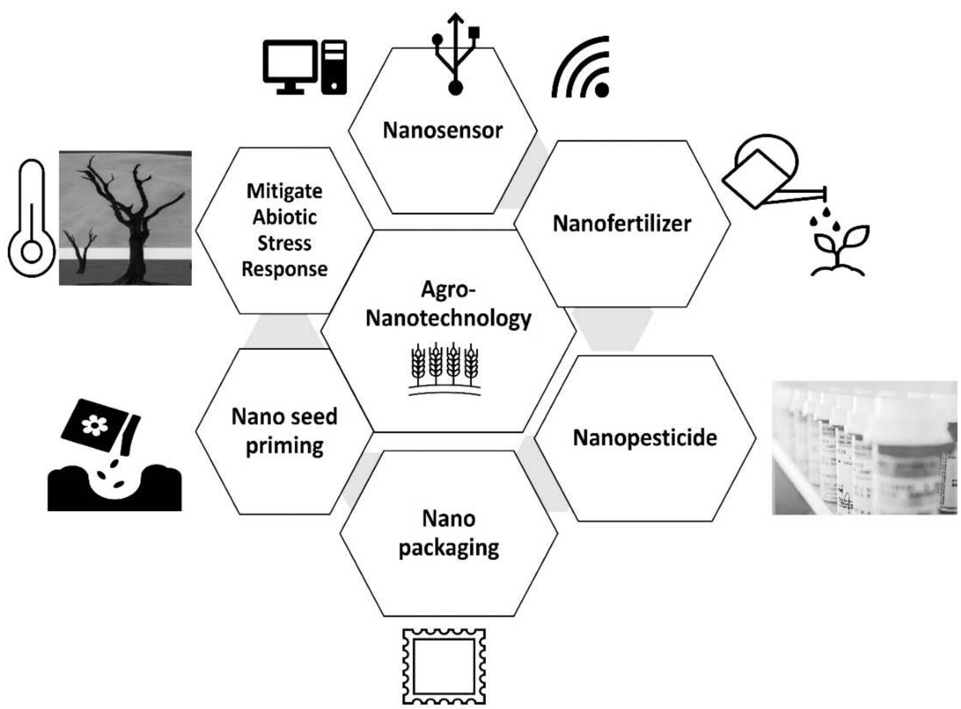

Fig. (1). Application of Nanotechnology in Agriculture.

CHAPTER 6

The Effect of Economic Natural Dyes on the Performance and Efficiency of TiO_2 Nano-Structure Solar Cells

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Abstract: The aim of this research can be divided into two stages. The first stage is to synthesize and find a simple and less expensive method to produce titanium dioxide nanostructures with optimum properties that can be used in the construction of low-cost, nanoparticle-based solar cells as a replacement for custom silicon solar cells. The second stage is to determine the effect of natural dyes on the performance and efficiency of TiO_2 nano-structure dye synthesized solar cells (TiO_2 DSSC) *via* spin coating. In order to improve and enhance the performance and efficiency of dye solar cells, thin film TiO_2 nanostructure was synthesized using the sol-gel process, which is simple and inexpensive. Afterward, different natural dies were introduced in the fabrication process over the TiO_2 layer also *via* spin coating. The function of the dye is to confine a sufficient amount of light, for optimum performance and power conversion efficiency. In the last fabrication step, graphite contacts were evaporated on the top dye layer. The I-V characteristics of the different dyes were studied and the structural properties of the TiO_2 nanostructures were investigated through an X-Ray Diffraction (XRD) pattern. The TiO_2 nanoparticles' morphology and particle size were determined by a scanning electron microscope (SEM), while the optical band gap energy was found by employing UV-VIS-NIR diffuse absorption spectroscopy. Three types of natural dye were used which were Roselle, curcumin, and black tea and their conversion efficiencies were 8.46, 6.94, and 6.33 respectively, which is considered acceptable compared to the results obtained by other researchers.

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Keywords: Band gap, Curcumin, Diffraction, Diffuse reflectance spectroscopy, Dye-Sensitized Solar Cells, Electrical properties, Fill factor, FTO, Hibiscus, Morphology, Nanostructures, Natural dyes.

INTRODUCTION

Photovoltaic (PV) is the process of converting direct sunlight into electrical energy. Solar cells have been proven to be very efficient PV devices in the process of converting solar energy into electric energy without emitting any toxic waste to the environment or producing noise. It is a clean energy source and can produce electrical energy from direct sunlight *via* the photovoltaic effect, which is the phenomenon of producing electrical energy from visible light. Solar cells have come a long way from the first-generation silicon-wafer solar cells to all types of modern high-efficiency solar cells. The implementation of dyes is one of many methods employed to enhance PV conversion efficiency (PCE) [1].

Recently, silicon solar cells were found to be the most effective and efficient solar energy source, with a PCE of about 25%. Although they are produced from a very cheap raw material, which is sand, the drawback is the high production cost and complicated fabrication process due to the requirement of innovative clean room technology, which makes it a relatively expensive energy source. The nanotechnology revolution led to great developments in solar cell technology. Dye-Sensitized Solar Cells (DSSCs) technology is considered one of the effective trends in solar cell technology. DSSCs are produced by a low-cost and simple process [2]. Due to their relatively low fabrication costs, metal oxide nanoparticles like TiO_2 have been found to be excellent replacements for silicon. TiO_2 nanoparticles are highly important in solar cell fabrication due to their n-type semiconductor properties, such as high energy conversion efficiency, physical and chemical stability, non-toxic and easy synthesis [3, 4]. Recently, TiO_2 has proved to be very efficient in photovoltaic cells, and in dye-sensitized solar cells (DSSCs). However, the rapid rate of its electron-hole recombination results in quite low efficiency when these solar cells are fabricated without dyes [5 - 8].

TiO_2 nanoparticles can enhance light scattering, and they also can increase electron transport. Their charge carrier recombination is quite low, but their surface area is quite large, which boosts the adsorption of large amounts of dye molecules, and these characteristics result in adequate electron injection into the conduction band of the TiO_2 layer [9, 10].

DSSCs in general and TiO_2-based DSSCs are considered to be essential solar energy sources for next-generation, due to their low production cost, low environmental impact, and relatively high power conversion efficiency [11].

DYE-SENSITIZED SOLAR CELLS (DSSCS)

DSSCs are considered third-generation solar cells. The determination of the efficiency of DSSCs is complicated, because of the effect of different parameters and layers included. Two main key layers that need more investigation and enhancement are the semiconductor photo-nodes layer and the dye layer. Both of these layers are effective in absorbing ultraviolet and visible light sensitizers [12].

In the DSSCs type of solar cells, the light absorption and separation of the electrical charges happen in the different processes involving four basic steps: light absorption, electron injection, transportation of carrier, and collection of current. Dye molecules perform the light absorption process, and the Nanocrystal inorganic semiconductor that has a wide band gap [13, 14] enables the separation of the electrical charge. An electric charge can be produced by the electron transfer procedure; when the DSSC is exposed to visible sunlight, the highest occupied molecular orbital (HOMO) electrons stimulate the lowest unoccupied molecular orbital (LUMO), and as a consequence, the electrons are infused into the conduction band. Then the electrons advance to the external circuit *via* the anode and cathode [15, 16]. DSSCs are inexpensive, thin-film solar cells. Their efficiency is relatively high in comparison to other types of solar cells, but the traditional silicon-based solar cells are an exception. In the construction of DSSCs, two layers of conductive transparent materials are used to enhance the substrate to be current collectors, and they can convert photons from sunlight into electrical energy [11, 17].

The advantages of DSSCs over regular silicon PV are the relatively uncomplicated production process, low production costs, and the ability to sensitize an extensive array of band gaps [5, 6, 9]. In order to achieve optimum conversion efficiencies, it is important for the DSSCs to collect the photo-generated charge carriers before recombination, and hence convert them into electric current. Furthermore, DSSCs can operate at very low luminous powers and subsequently produce high PCEs [18].

Researchers have been experimenting with natural dyes because they are environment-friendly, nontoxic, and much cheaper to fabricate, but they found their efficiency quite low. W. Ghana *et al* [6], managed to extract natural dyes from pomegranate and berry fruits pigments and they employed them in the fabrication process of the natural dye-sensitized solar cells (NDSSC), and the maximum PCE they achieved was 2%. Cari *et al* [19] prepared a green dye in a broccoli mixture, but the maximum PCE they managed to obtain was 0.072%. Ahmed M. Ammar *et al*. [20], obtained PCEs of 0.17%, 0.0647%, and 0.060% successively from natural dyes made out of spinach, onions, and red cabbage

CHAPTER 7

Investigation of the Effect of Annealing Conditions on Chemical Bath Deposited CdTe Thin- film from Non-Aqueous Bath

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Abstract: This research investigates the consistency of chemical bath deposition (CBD) for CdTe thin films. Films were deposited using tellurium dioxide and cadmium acetate in a non-aqueous medium at 160°C. The impact of subsequent annealing on the optical, structural, and surface properties of these films was examined. XRD, FTIR, UV-Vis, SEM, and photoluminescence techniques were used to characterize the films. EDS analysis revealed a Cd:Te ratio of 1.27 before annealing, which improved to 1.06 (closer to the ideal 1:1 ratio) after annealing. The average crystallite size of annealed CdTe film was around 25nm. Photoluminescence peaks were observed at 566 nm and 615 nm.

Keywords: Electrodeposition, FTIR spectroscopy, Schockley-Queisser, Spray pyrolysis.

INTRODUCTION

For a long time, the semiconductor CdTe, which belongs to the II-VI family, has been researched. CdTe has primarily been investigated as a polycrystalline thin film over the past ten years. The only thin film technology currently included in the top 10 global producers is CdTe thin film technology, which was initially developed in the early 1970s [1], this is because CdTe is extremely durable and chemically stable. Additionally, it can be deposited using a wide range of techniques, making it perfect for large-scale production. According to the Schockley-Queisser limit, CdTe can achieve efficiencies of around 32% with an

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open circuit voltage of more than 1 V and a short circuit current density of more than 30 mA/cm^2 by having an ideal band gap close to 1.5 eV [2]. CdTe, a material for solar cells [1] and high-energy radiation sensors [3], and highly sensitive as well as selective fluorescent sensors [4] offers ideal electrical and optical characteristics. CdTe has the potential to be used as an absorber material in thin-film solar cells and light-emitting diodes [5], enabling the production of highly efficient solar cells using inexpensive methods [6]. With a CdTe absorption value of 10^4 cm^{-1}, 90% of the light may pass through thin sheets that are only 1 μm thick [1]. Another benefit is the potential for producing p- and n-type conductivity in the films, allowing for homojunction production. The material, however, has certain drawbacks when used in solar cells; for instance, it is highly resistant and does not enable superior carrier collection. Additionally, the semiconductor-metal junction is impacted by CdTe's high work function of 5.7 eV [1]. Finding a metal with a work function bigger than the CdTe is important to improve this connection. The CdTe homojunction's high surface recombination speed also prevents the production of homojunction-based devices. As a result, CdS/CdTe heterojunctions have been often used in the processing of CdTe solar cell systems. The n-type CdTe had to be changed since the CdTe homojunction failed. So that CdTe can absorb the most light, the material must be transparent for this application. The ideal solution is cadmium sulfide. Without phonon assistance, CdTe exhibits a band to band type transition and significant optical absorption. Cadmium telluride thin films have been developed using a variety of fabrication techniques, including close spaced vapor transport (CSVT) [4, 5], laser ablation [7 - 10], spray pyrolysis [11, 12], electrodeposition [13, 14], pulsed laser deposition [15, 16], chemical vapour deposition [17, 18], physical vapour deposition [14], hot wall epitaxy [19], thermal evaporation [20], and RF sputtering [21]. Depending on the type of use the film is intended for, each of these approaches has benefits and drawbacks. Re-sputtering and similar defects in the substrate surface and film growths are caused by the enormous kinetic energy of a small number of plume species during pulsed laser deposition. In physical vapour deposition, the rate of coating deposition is often quite slow. This process generates a lot of heat as well, necessitating the use of suitable cooling systems. Expensive power supplies and additional impedance-matching equipment are needed for RF sputtering. The expensive and technically complex equipment needed for the successive ionic adsorption and reaction process makes it uneconomical. For this process, high working pressure is also necessary. Due to the low vacuum, thermal evaporation has a decreased throughput, which results in inadequate step coverage. The operation of several CdTe film deposition methods is covered in the next section.

Deposition Techniques for CdTe Film

Close Spaced Vapor Transport (CSVT)

The CSVT is a physical method that involves sublimating the substance to move the gas and deposit it on the substrate. Films of a 500 nm thickness can be produced using this method [8]. Two blocks, either made of metal or graphite, constitute the deposition system. Each block has a temperature control since these blocks must be heated by a halogen light or electrical resistance. The block above is referred to as substrate, and the block below is known as the source. A graphite boat is set between the blocks. It is then filled with the CdTe. In this instance, several people employed CdTe pellets or powder before placing the substrate on the graphite boat. Everything is contained in a vacuum chamber. In the instance of CdTe, when the source temperature is higher and the block temperature is lower, the mechanics of development involve establishing a temperature gradient between the two. The CdTe is carried to the substrate, which has a lower temperature, during the sublimation process, causing the material to be deposited on the substrate. The thin-film deposition requires a high vacuum of around 10^{-6} Torr. The benefit of this technology is that a film thickness of 500 nm is feasible due to the controlled development rate; nevertheless, the drawback of this approach is the time costs associated with the vacuum that the process necessitates.

Laser Ablation

Laser ablation is a physical technique. Because the material is sublimated during the deposition process, it is comparable to CSVT. The method of sublimation differs because a laser beam is used in this instance to sublimate the substance. To achieve this, the energy of the laser beam must be low enough for the material to absorb light photons and be sublimated. The laser beam's pulse and intensity are used to regulate the deposit process. This method is significant in addition because it can be applied in industry. One benefit of this method is that flexible substrate can be used because the substrate maintains a low temperature, However, laser ablation includes burning and vaporizing material, which can produce a lot of fumes. As a result, the work area needs a good exhaust system to remove the fumes.

Spray Pryolysis

Spray pyrolysis is a chemical process in which the material in the solution is crushed by the pressure of a gas (argon, air, nitrogen, *etc.*). Controlling the solution's flow and the gas's pressure is crucial for this operation. To create the

CHAPTER 8

Applications, Biomedical Necessities, and Green Future of Metallic Nanoparticles

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Abstract: Metallic nanoparticles like gold nanoparticles (AuNPs), magnetic iron oxide nanoparticles (Fe_3O_4), and cysteine-capped silver nanoparticles (Cyanopes) are changing the face of green nanotechnology. Their photonic capabilities, ultrafine size (10-100 nanometers), biocompatibility, diamagnetic strength, antibacterial activity, and photochemical qualities make them extremely useful in medical applications, radiotherapies, drug delivery, cosmetics, and solar cell coatings. This chapter provides a comprehensive outlook on the applications, biomedical necessities, and green future of metallic nanoparticles. The current discussion revolves around graphene-based nanofillers, focusing on their ability to enhance the tribological properties of aluminum and its alloys within the realm of materials research. Thin metallic tin sulfide nanoparticles and titanium oxide nanorods, on the other hand, play an important role in photochemical water splitting. Modern nanotechnology is advancing biological processes by allowing for a thorough examination of metallic nanoparticle forms as highlighted in the chapter. A notable application incorporates a nanoscale metallic lattice that facilitates the transfer of cisplatin and siRNA, showing great promise in re-sensitizing ovarian tumors. This chapter provides an exhaustive analysis of the potentials, benefits, and challenges associated with metallic nanoparticles, emphasizing their extensive applications and crucial role in the advancement of various fields.

Keywords: Biomedical, Quantum dots, Green synthesis, Nanoparticles, Nanofillers.

INTRODUCTION

The realm of metallic nanoparticles presents a captivating intersection of diverse applications, critical biomedical necessities, and the promising potential for a sustainable, green future. This introduction sets the stage for a comprehensive exploration of the multifaceted role played by metallic nanoparticles in various domains [1]. At the forefront of our discussion are the applications that underscore the versatility of metallic nanoparticles. From enhancing the tribo-

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logical properties of materials, as seen in graphene-based nanofillers optimizing aluminum and its alloys, to the crucial role played by thin metallic tin sulfide nanoparticles and titanium oxide nanorods in photochemical water splitting, the breadth of applications is vast and impactful. In the biomedical sphere, metallic nanoparticles are proving indispensable [2, 3]. Modern nanotechnology is revolutionizing biological processes, allowing for a meticulous examination of metallic nanoparticle forms. Notably, the incorporation of nanoscale metallic lattices is demonstrating great promise, particularly in the targeted delivery of therapeutic agents like cisplatin and siRNA, showing potential in the re-sensitization of ovarian tumors. Moreover, the chapter delves into the essential biomedical necessities met by metallic nanoparticles, addressing challenges and showcasing benefits across various applications. The potential for precise drug delivery, diagnostic advancements, and therapeutic breakthroughs underscores the pivotal role of metallic nanoparticles in shaping the future of healthcare [1, 2]. Understanding the behaviour of dielectric losses is crucial for optimizing the performance of power cables, ensuring they meet the demanding requirements of biomedical applications. By comprehensively studying the electric field distribution in nanocomposite insulation and reliability, it is well-suited for critical biomedical applications [2]. The utilization of advanced materials, such as gold nanoparticles, magnetic iron oxide nanoparticles, and others, not only improves the electrical properties of the insulation but also aligns with sustainable and environmentally friendly practices. Looking forward, the narrative extends to the ecological front, exploring the green aspects of metallic nanoparticles. As advancements unfold, understanding how metallic nanoparticles contribute to environmentally sustainable practices becomes imperative. This introduction sets the groundwork for an in-depth analysis of the applications, biomedical necessities, and the promising trajectory toward a green future for metallic nanoparticles.

The article on green synthesis of metallic nanoparticles by Iravani *et al.* (2011) concentrates on the eco-friendly and sustainable method of producing metallic nanoparticles. The significance of hybridizing these nanoparticles using plant extracts, microbes, and other natural resources is highlighted in this chapter. It also covers green nanospheres' potential biomedical and environmental uses [1 - 3].

NMs are particularly sought-after in biomedical applications due to their unique physical and chemical features. A hybrid substance in nanospheres typically consists of a biological monolayer on top of an inorganic core. Controlled plant-mediated synthesis is more reliable, eco-friendly, economical, and less toxic than the conventional physicochemical synthesis of nanoparticles. Due to its distinctive optical, thermodynamic, magnetic, and mechanical properties, NM research has increased during the past few decades. For prospective medicinal applications, the excellent biocompatibility of nanoparticles has been acknowledged. Nanoparticles (NPS) with a range of acceptable dimensions have reportedly been shown to enter the bloodstream and undergo endocytosis in cells (Fig. **1**).

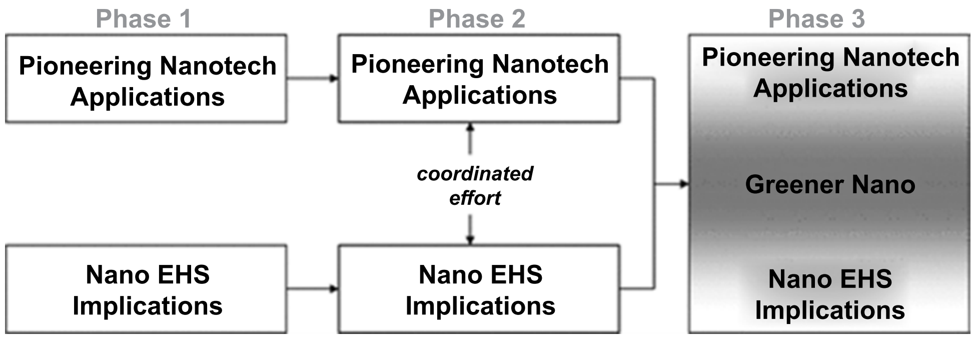

Fig. (1). Classification of green nanoscience using metallic nanoparticles [3]. (Reproduced with permission).

Nano fertilizers boost crop production efficiency and sustainability in agribusiness. Due to their nanosized characteristics, they have been found to boost productivity through targeted delivery or a gradual release of nutrients, lowering the chemical application rate. Through the use of nanosensors, plant nutrition, and plant protection, nanotechnology has applications in crop management and has the potential to be employed in precision farming. The main benefits of green nanotechnology include increased energy efficiency, decreased waste and greenhouse gas emissions, and less reliance on non-renewable raw materials. Nanoparticles offer complex antibacterial capabilities at low doses. For instance, zinc oxide nano-powders may eliminate Gram-negative and Gram-positive germs effectively. There has been an increase in research activities evaluating the technology for plant development and protection as evidence of nanoscale applications in agriculture has emerged. Nanostructured pesticide (nano pesticides) and nanostructured fertilizer (nano fertilizer) research are progressing, as shown in Fig. (**2**).

Once Michael Faraday discovered silver nanoparticles (AgNPs) (ruby-colored) in an aqueous solution in 1857 as a result of an Au salt reaction, he also discovered MNPs. These nanoparticles are useful in biomedicine due to their distinct physicochemical characteristics, such as their higher surface area-to-volume ratio. Surveys on early cancer detection are vital because the yearly prevalence of cancer is rising. Additionally, the possibility of biosensor-based cancer treatment monitoring offers promise for a customized course of treatment. This is the reason there is still a need for more practical, sensitive, and cost-effective approaches that can reveal even more details about a particular condition [4, 5].

CHAPTER 9

Silver Nanoparticles with Enhanced Cytotoxicity and Biological Activity Produced from Green Methods

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Abstract: Research in the fields of physics, chemistry, and engineering is all facing more important challenges as a result of the rapid development of nanotechnology. The green synthesis of metallic nanoparticles opened the door for improvements and protections to be made to the environment by lowering the amount of harmful chemicals used and avoiding the biological dangers that were present in biomedical applications. Simple, fast, and environmentally friendly, plant-mediated production of metal nanoparticles is rising in popularity. We show an easy and environmentally friendly way to make silver nanoparticles using biomolecules found in an aqueous extract of the leaves of the plant *Kalanchoe gastonis-bonnieri*. No other chemical-reducing or stabilizing agent is needed in this way. The reaction is carried out in an aqueous solution in a process that is benign to the environment. This chapter examines the anti-oxidant, diabetic, inflammatory, cancer, and cytotoxic properties of silver nanoparticles that were generated utilizing the aqueous extract of the leaves of the plant *Kalanchoe gastonis-bonnieri*. The results of the investigation are presented and discussed in this chapter.

Keywords: AGS cells, Alpha-amylase, Green synthesis, Silver nanoparticles, Metal nanoparticles, Medicinal plants, Phytochemicals, Protein denaturation, SKMEL cells, Zeta potential.

INTRODUCTION

The term "green chemistry" refers to the process of producing chemical products and processes that minimise the use of hazardous compounds and the manufacture of those substances, decrease waste, and lessen the demand placed on resources that are in short supply [1]. In recent years, one emerging potential new area of research has been the environmentally friendly synthesis of metallic nano-

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particles. A new way of thinking is used in the green synthesis method, which uses environmentally friendly solvents, less energy, and the removal of hazardous waste. Green synthesis has garnered a lot of attention as an alternative way to gain metal and metal oxide nanoparticles. Because conventional practices in chemical synthesis result in the production of potentially hazardous chemical species, which then adsorb onto the surfaces of nanoparticles, green synthesis is an environmentally friendly method of chemical synthesis. This is due to the fact that conventional approaches to chemical synthesis result in the creation of nanoparticles that include potentially harmful chemical species. Green synthesis does not result in the production of chemical species that are damaging to the environment [2].

Nanotechnology is the study and practice of designing, fabricating, and using nanostructured materials for a wide range of applications [3]. Richard Feynman, an American physicist who later won the Nobel Prize, is credited with having first proposed the concept of nanotechnology in 1959. At the annual conference of the American Physical Society, Richard Feynman delivered a speech with the title “There's Plenty of Space at the Bottom”. During this talk, he addressed the topic, “Why can't we write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin?” and presented a picture of the future wherein machines could be utilized to produce ever more miniature devices on the molecular level. As a result of this novel concept, which demonstrated that Feynman's ideas were accurate, Feynman is now widely recognized as the “father” of modern nanotechnology.

There has been a meteoric rise in the number of places around the globe where nanoscience and nanotechnology are being put to use, which has resulted in significant progress being made in the development of novel nanomaterials [4]. Scientific advancements and ground-breaking discoveries in this emerging sector have added to its reputation and attracted more funding for several labs in academic and business establishments [5]. Research institutes and businesses throughout the globe are now engaged in a mad dash to develop new goods and services that use nanotechnology. Many experts believe that this technology will shape the world's future as part of a new industrial revolution [6]. This boost in development is largely attributable to the unique features of these nanoscale materials. All of these recent advancements in the research and development of innovative uses for nanoparticles will have an immediate impact on business and society [7]. The majority of commercial items, which included anything from toys for children to products used for personal care, included nanoparticles made of metals and metal oxides.

The next industrial revolution will revolve around nanotechnology. Global governments have now come to terms with the fact that nanotechnology and its byproducts are here to stay; this cutting-edge technology is crucial since, unlike more antiquated methods, it does not break the bank and yields substantial financial benefits [8]. It is an amalgam of scientific knowledge and technological know-how with an eye towards practical scientific use. It all starts with atoms and molecules, the building blocks of matter. As a result, it influences pretty much every area of applied science and technology [9].

For plant genetic transformation, nanotechnology-based gene delivery technologies have recently been developed. This nano-approach demonstrates tremendous transformation performance, functionality, proper preservation of foreign nucleic acids, and the capacity to renew plant material [10]. Nanotechnologies have improved therapies for a number of illnesses, such as cancer [11], cardiovascular diseases [12], musculoskeletal disorders [13], mental and neurological diseases [14], bacterial [15], and viral infections [16], and diabetes [17]. They also hold great promise for the future of nanomedicine [18], including the development of imaging methods and diagnostic tools [19], drug [20] and gene delivery mechanisms [21], tissue-engineered constructions [22], implants [23], and pharmacological medicines [24]. Specific nanoparticle drug delivery systems can be made by attaching pharmaceuticals to radioactive antibodies that are on the same wavelength as antigens on cancer cells [25]. This method has shown promise in the past.

Because of their unique physicochemical properties, silver nanoparticles (AgNPs) are suited for a broad range of innovative profit-oriented and industrial applications. Some of these applications include antiseptic agents in the healthcare sector, beauty products, alimentary wrapping, genetic engineering, electrochemistry, and catalytic processes [26]. Even though AgNPs and NPs in general could be good for the economy, there are social concerns about their use. The most common and difficult issue to resolve prior to the general application of AgNPs synthesized by green synthesis techniques is the fine-tuning of the final properties [27].

It has been shown that a methodology that generates metal nanoparticles via the use of environmentally friendly synthesis processes is both dependable and cost-effective. Although microorganisms can also produce nanoparticles, their sluggish pace of synthesis and methodology only allows for a small range of sizes and shapes in comparison to plant-based techniques. Compared to other processes, plants create more stable nanoparticles, and scaling up is easy. There is also less worry about contamination [28].

CHAPTER 10

Recent Methods for Biogenic Synthesis of Metal Nanoparticles and their Applications

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Abstract: Nanoparticles are among the most important tools under investigation due to their application in optical, electrical, biological, sensing, and photocatalytic systems. Nanoparticles made by plants have a larger range of sizes and shapes and are far more stable. Investigators' fascination with producing metal-based nanoparticles, such as those of silver (Ag), platinum (Pt), gold (Au), zinc (Zn), copper (Cu), and cerium (Ce), has been aroused by the study of biological systems. In a manner analogous to this, microorganisms produce valuable substances like antibiotics, acids, and pigments as well as proteins and bioactive metabolites. The plant-based synthesis uses a variety of extracts, including fruit, leaves, roots, peel, bark, seeds, twigs, stems, shoots, and seedlings. The primary theme of the chapter is the synthesis of metallic nanoparticles mediated by plants. The potential applications of nanoparticles across a variety of fields have altered the research and industries that are briefly discussed in this chapter.

Keywords: Nanoparticles, Green synthesis, Photocatalytic, Thin film, Capping agent, Antibacterial, AFM, Solar cell, Silver NP.

INTRODUCTION

Nanotechnology provides methods for handling and using materials at nanoscales. Nanomaterials differ significantly in elements at larger scales in that they have a higher surface area. Additionally, there are several techniques to make nanoscale materials, but the green, eco-friendly approach is the best [1]. The application of biological processes has been viewed as an environment-friendly strategy and a

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credible technique for producing nanoparticles because of its ecological qualities [3, 4]. The synthesis of nanoparticles sustainably or biologically has several advantages, including rapid and eco-friendly production methods as well as inexpensive and biocompatible nanoparticle types. Pure nanoparticles can be made *via* physical and chemical methods, but they can be costly and even environmentally hazardous. A quick, simple, and affordable method for producing nanoparticles is known as “green synthesis.” [19]. Furthermore, since microbes and plant components act as stabilisers, there is no need to apply extra stabilising agents [2]. The foundations for sustainable (biological) chemistry enable cleaner nanoparticle synthesis. The study of metabolism and chemical tolerance mechanisms are employed in the synthesis of biological material (photosynthesis) to produce nanoparticles [5]. Due to their wide variety, plants' ability to manufacture nanoparticles of metallic material is still unrealized. In nature, there exists a wide variety of plant species and a lot of them would have been suitable for producing nanoparticles [6].

This chapter discusses general methods for producing nanoparticles utilising a range of methods and uses. The biosynthesis of nanoparticles is currently chosen because of their acceptability towards toxicity, higher bioaccumulation, relative economies, simple synthesis procedure, uncomplicated post-synthesis processing, as well as simple biomass management [8]. The creative and advantageous qualities of nanoparticles are significantly responsible for the rapid growth in industry inventions and studies in the discipline of nanotechnology. New nanomaterials, a critical component of nanotechnology advancements, allow for the creation of novel goods and services [7]. NPs are produced using extracts of plants that have several phytoconstituents, which involve phenols, flavonoids, alkaloids, terpenoids, and acids [9]. The leaf, root, stem, seed, fruit, gum, flower, and other parts of plants are only a few of the materials used to make these organic products [10]. Extracts of plants interacting with metal salts result in the formation of NPs, which give the reaction solution a specific colour [11]. Many studies have been done in the context of this topic, and a variety of plant components, including leaves, seeds, twigs, flowers, and petals have been used to make these extracts. The synthesis of nanoparticles of noble metals is the only application of this viewpoint, even though various publications have looked at using plant-based substances in nanoparticle manufacturing [12], specifically gold (Au) [14], iron (Fe) [15], silver (Ag) [13] and palladium (Pd) [16]. Gold nanoparticles are among the more commonly utilised particles because they possess a broad range of therapeutic applications for numerous disorders, including cancer, diabetes mellitus, and cardiovascular diseases [17]. Due to the absence of harmful contaminants, the nanoparticles derived from conventional pharmaceuticals are appropriate to be utilised for healthcare studies and treatments [18, 13].

The current area of interest for the study is the identification of novel ecologically safe techniques for the bioproduction of metal-based nanoparticles. Most plants contain many molecules that can scavenge free radicals, reducing sugars, terpenoids, vitamins, phenolic compounds, nitrogen compounds, as well as additional metabolites with significant antioxidant activity [19]. The goal of this chapter is to give a broad review of recent advancements in environmentally benign ways to produce metallic nanoparticles and their diverse applications across a variety of fields. Fig. (**1**) provides the advantages of biogenic synthesis methods.

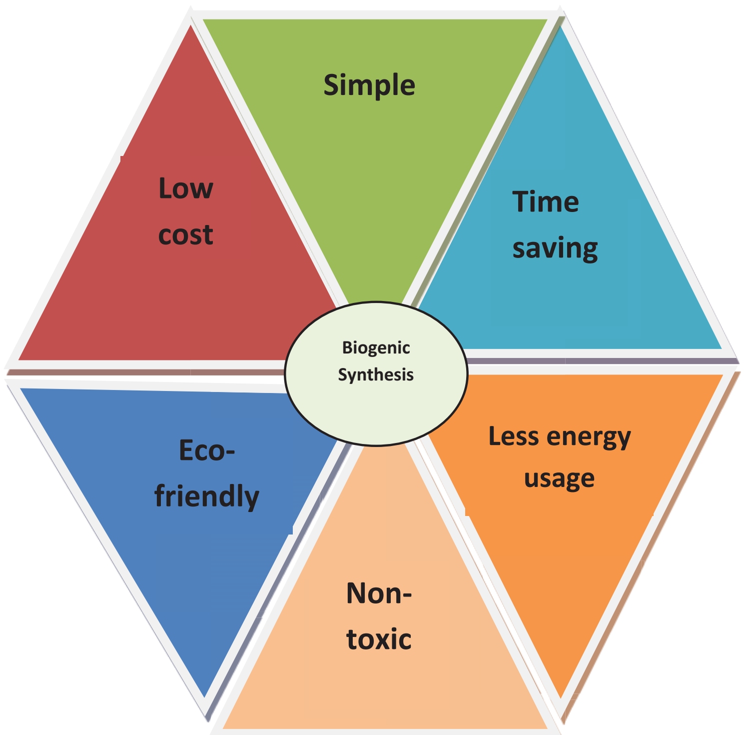

Fig. (1). Advantages of biogenic synthesis methods.

GREEN SYNTHESIS APPROACH FOR NANOPARTICLES

Plant-mediated Biosynthesis

Plant extract is employed for the production of nanoparticles from biomass wastes, such as leaves, peels, petals, fruits, roots, *etc.*, which is a cost-effective strategy. Furthermore, the dried part is favored; nevertheless, different plant tissues contain different amounts of water. [21] According to Mahanty *et al.*, transitioning from chemically produced nanoparticles to eco-friendly biosynthesized ones would

CHAPTER 11

Performance Benchmarking of Different Convolutional Neural Network Architectures on Covid-19 Dataset

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Abstract: The utilization of chest X-rays could offer valuable assistance in the initial screening of patients before undergoing RT-PCR testing. This potential approach holds promise within hospital environments grappling with the challenge of categorizing patients for either general ward placement or isolation within designated COVID-19 zones. This study investigates the use of chest X-rays as a preliminary screening technique for suspected COVID-19 cases in hospital settings, given the limited testing capacity and probable delays for RT-PCR testing. We assess how well several neural network architectures perform in automated COVID-19 identification in X-rays with the goal of locating a model that has the highest levels of sensitivity, low latency, and accuracy. The results reveal that InceptionV3 exhibits better robustness while MobileNet obtains the maximum accuracy. This strategy may help healthcare organisations better manage patients and allocate resources optimally, especially when radiologists are hard to come by. This will help in choosing an architecture that has better accuracy, sensitivity, and lower latency. The chosen models are pre-trained using the technique of transfer learning to save computation power and time. After the training and testing of the model, we observed that while MobileNet gave the best accuracy among all the models (VGG16, VGG19, MobileNet and InceptionV3), IncpetionV3 was still better when it comes to robustness.

Keywords: Chest X-ray, RT-PCR testing, Neural Network, Transfer learning.

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INTRODUCTION

Machine learning and computational-based methods have excited many attempts for versatile purposes including water purification [1], energy storage systems [2], antibiotic generation [3], prediction of toxicity [4], weather forecasting [5], and designing effective antigen/antibody biosensors [6]. These tools are transforming how we analyze data, solve problems, and interact with the world. This paper contributes to this exciting landscape by exploring the application of CNNs for COVID-19 detection in chest X-rays, showcasing the potential of these methods to improve healthcare through data-driven solutions.

Background: The emergence of COVID-19, a novel respiratory virus, has led to an unprecedented surge in patient caseloads, placing an immense strain on global healthcare infrastructures. Numerous countries are grappling with healthcare systems that are already stretched thin, encompassing finite resources such as diagnostic instruments, hospital capacities, personal protective gear for medical personnel, and respiratory support devices. In order to optimize the utilization of these scarce resources, it becomes imperative to discern whether individuals presenting with severe acute respiratory illness (SARI) potentially harbor COVID-19 infections.

Methodology: Within the ambit of this research, we propose the utilization of chest X-rays to detect COVID-19 infections among individuals exhibiting symptoms of SARI. Our choice of utilizing X-rays for dataset preparation stems from their inherent advantages vis-à-vis traditional diagnostic modalities. Several key advantages make chest X-rays a compelling choice:

1. Widespread availability and affordability: Compared to other diagnostic imaging tools, chest X-rays are more readily available and cost-effective in many healthcare settings.
2. Rapid analysis: Digital X-ray images allow for swift transmission and analysis, potentially accelerating diagnosis and triage decisions.
3. Enhanced safety and convenience: Portable X-ray scanners enable bedside examinations within isolation wards, minimizing staff exposure and patient movement, and reducing the risk of nosocomial infections.
4. Abundant data accessibility: Open-source repositories and readily available X-ray data facilitate research and development of robust machine learning models for automated analysis.

Leveraging these advantages, this paper investigates the performance of various Convolutional Neural Network (CNN) architectures for automatic COVID-19 detection in chest X-rays. Our aim is to identify the CNN architecture that offers the optimal balance of accuracy, sensitivity, and computational efficiency for practical clinical application. By exploring chest X-ray-based triage as a complementary tool to current diagnostic methods, we hope to contribute to optimizing resource allocation and improving patient management during the ongoing COVID-19 pandemic.

Problem Statement

Recognizing features from images is in high demand for various purposes ranging from medical diagnosis to security. The work currently done in this field includes the development of deep learning models for the classification of chest X-rays [7]. The primary goal of this project is to compare different CNN architectures on the prepared Covid-19 dataset and based on their performance find the best model that can be used to diagnose Covid19. This will help in saving precious time and resources during this period of pandemic.

Motivation

Since there has been a significant increase in COVID-19 infections worldwide, numerous different screening techniques have been created to find potential COVID-19 cases. However, there are not many open-source programs that employ chest X-ray pictures that are currently accessible [8]. Publicly accessible datasets containing chest X-rays for COVID-19 remain limited [9]. Given this context, the need arises to consolidate information dispersed across online sources and curate a bespoke dataset. This dataset is then fed into various models, enabling a comparative analysis of outcomes across distinct parameters. The objective is to discern the most appropriate architecture.

This will also help in making a baseline for a custom Neural Network architecture that predicts results specific to this problem.

Contribution

The main contribution of this work is in subjecting the same dataset to different Neural Network architectures and comparing the results to see which one is the most efficient when it comes to X-ray images. In the contemporary environment, non-radiologists often interpret radiographs. Furthermore, many radiologists may not be familiar with all the intricacies of the infection due to the virus' novelty, and they may not have the necessary competence to produce a diagnosis that is as accurate as possible. As a result, people leading this analysis can use this automated program as a guide. It is important to emphasize that our intention is not to endorse the substitution of any particular model for the established COVID-19 diagnostic tests. Instead, we propose its application as a triage

CHAPTER 12

Application of Novel Nanotherapeutic Strategies in Treatment Using Herbal Medicines

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Abstract: Herbal remedies are gaining popularity as an alternative to allopathic medicine because of how much better they are at curing modern health problems. By facilitating the efficient distribution of medicinal molecules to both targeted and non-targeted regions, nanotherapeutic approaches enhance the pharmacokinetic efficacy of herbal remedies. Active and system-based nanostructures have the potential to utterly transform herbal therapy. Nanomedicine may benefit from third-generation nanotechnology, namely system-based nanostructures, due to their self-healing properties. Research and Market predicts that the pharmaceutical market's use of nanotechnology will increase by 15.3% by 2026. The effectiveness of dual therapy treatment is enhanced by nanotechnology. The creation of cell-penetrating peptides, which allow the transport of drug molecules to the afflicted cells, is made possible by nanotechnology. The rate of medication metabolism is accelerated by nanomaterials. The use of nanotechnology to enhance histidine activity has significant implications for the treatment of cancer and acute genetic disorders. Acute illnesses such as cancer, genetic disorders, neurological disorders, behavioural disorders, cardiovascular disorders, and bone fractures can all benefit from a nanotherapeutic approach to treatment. Nanomedicines' market share is growing at an exponential rate because of their superior therapeutic efficacy. Increased access to Ayurvedic treatment will result from nanotechnology's ability to boost the efficacy of herbal remedies. Waste management is further supported by the use of nanotechnology, which enhances the ability to extract bioactive components from plant-based waste products. Due to the dynamic nature of infectious illnesses, nano vaccines work more effectively than traditional vaccinations. This chapter will describe research on the use of nanotechnology in various ayurvedic practices, which will broaden the use of herbal remedies for the treatment of long-term health problems. Additionally, it will investigate the potential of nanomaterials to enhance the efficacy of herbal remedies, which can aid in the development of novel ayurvedic treatment approaches.

Keywords: Active nanostructure, Bioactivity, Drug delivery, Genomic vaccine, Herbal medicine, Immunotherapy, Molecular pathogenesis, Nanobiotechnology.

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INTRODUCTION

Allopathic approaches to medicinal treatment based on the remediation of a target disease are becoming an outdated idea in today's scenario as the prevalence of chronic diseases is increasing due to the changing nature of the environment. The improvement of overall body function and the boosting of the immune system become the basis of modern medicinal treatment, just like in ancient times. Phytomedicines are gaining importance in the effective treatment of chronic diseases due to their potential to improve the efficiency of removing the root cause of disease by keeping the balance among the physiological, mental, and emotional health of human beings. The nervous system is one of the most important and sensitive physiological systems, as it controls other body functions. The allopathic dosage of neurological diseases increases the risk because of side effects leading to major damage to healthy neurons. On the other hand, herbal medicines focus on the repair of the overall nervous system, reducing the risk of side effects. The advancement of modern technologies like nanotechnology, biotechnology, neuroheormosis, *etc*. improves the efficiency of phytomedicines. The rapid development of the field of bioinformatics led to the emergence of neuroinformatics, which enables the detailed study of the mechanisms of the nervous system. In this way, the field of herbal medicine is developing through the application of advanced techniques. The adoption of ayurvedic medicine instead of conventional allopathic medicines promotes the healthy growth of the human population under the current challenges of global warming and climate change. The increasing use of phytomedicines also facilitates the egalitarian economic development of society by expanding the scope of the primary sector. The improvement of tribal populations is also another component of the promotion of Ayurveda. The emergence of neurophytomedicine plays a significant role in the achievement of sustainable development in the health sector. It also promotes economic growth and the development of the economy.

Therapeutic compounds are commonly carried by nanoparticles because of their enhanced chemical activity and their capacity to penetrate tissue barriers. This is due to the fact that medicinal compounds may be delivered more efficiently via nanoparticles. Nanoparticles are built with precise instructions to carry various substances into the human body and influence specific cells. These substances include proteins, plasmids, antibodies, oligonucleotides, fluorophores, ligands, polymers, radioisotopes, tissue-engineered products, and more. Another possible target for nanoparticles is a specific cell of interest. Dendrimers, nanopolymeric dendritic structures that carry drug molecules, liposomes, quantum dots, and nanoshells are all examples of nanomechanical systems used in biosensors. Quantum dots are tiny light-emitting nanocrystals that can enter small human cells and aid in magnetic resonance imaging of the body when activated. Additionally, the existence of unique membrane features allows them to readily distinguish target cells from other cells. The regulated release of drugs and efficient target selection make these nanoparticles useful chemotherapeutic agents. These traits and talents aid in avoiding the chemotherapy-induced death of healthy cells. Neural stem cell treatment for neurological disorders also makes substantial use of nanotechnology. In addition to assisting with stem cell monitoring, these designed polymeric nanostructures aid in neural stem cell generation, regulation, and targeted distribution. The created nanocomposites boost the efficacy of scaffolds for therapeutic purposes by making tissue engineering more effective.

ROLES OF NANOTECHNOLOGY IN HERBAL MEDICINES

The evolution of active nanostructures revolutionizes the application of phytomedicines in the treatment process. The active nanostructure enables the integration of different technologies into micro- or nanostructures, which are able to fit into any structure and make desired changes. The nanocarriers are framed in this way. The microstructures of the drug carrier molecules facilitate the delivery of drug molecules effectively to the desired target cells. The improved structures of the nanomaterials enable the interaction of drug molecules with the affected cell more effectively than with normal molecules. The nanocarriers act as effective carriers of the bioactive components present in the herbal plants to the target cells through effective tissue-specific delivery characteristics, increased surface charge density, controllable surface chemistry, and increased bioavailability of the components in the affected area. The herbal plant extracts are proven to be more effective than the synthetic chemical extracts, as they are capable of remediating the root cause of the health issues. Nanotechnology induces the immune response of the human body by accelerating the functions of lymphocytes. It also plays significant roles in the treatment of cancerous diseases by facilitating the successful delivery of chemotherapeutic plant extracts into the tumor cells while mitigating the side effects. It also induces an anti-tumor response mechanism during tumorigenesis and increases the tumor's immune defense activities by controlling the immune suppression mechanism in the tumor microenvironment [1]. Nanoparticles are extensively used in in situ diagnostic imaging for their better biodistribution, tissue permeability, cellular uptake, and targeting efficiency. The introduction of a capsule endoscopy camera along with the nanocarriers enables us to monitor the phytokinetic activities of the bioactive components of the plant extracts [2].

The cellular internalization process of nanomaterials depends on their structural characteristics and interactions with cellular membranes. The lipid structures of the cell membranes and the cellular organelles restrict the entry of nanocarriers into the cellular environment. As a result, the pharmacokinetic and

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