Silver: Characteristics and Modern Applications

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Abstract: Silver is one of the most significant and extensively utilized precious metals due to its remarkable physical and chemical properties. Its outstanding electrical and thermal conductivity, high reflectivity, and strong antimicrobial activity make it indispensable in a wide range of industrial and technological applications. This study reviews the fundamental characteristics and chemistry of silver, as well as its extraction and recycling processes, toxicity aspects, significance of its nanoparticles and contemporary applications. The findings highlight the considerable economic value of silver and its growing importance across various sectors. Today, silver plays a vital role in photography, catalysis, advanced technologies, and medical applications, underscoring its continued relevance in modern industry and scientific development.

Keyword: *Silver, Silver Compounds, Characterization, Recent Applications.*

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I. INTRODUCTION

Silver is a chemical element with the symbol Ag, derived from the Latin word *argentum*, and an atomic number of 47. Under standard conditions, it exists as a solid metal characterized by its bright white color, metallic luster, high density, softness, malleability, and ductility. Although silver is more abundant in nature than gold, it remains one of the most valuable precious metals due to its unique physical and chemical properties. Historically, silver has been extensively used in coinage, jewelry, and ornamental objects because of its attractive appearance and excellent reflectivity. It occurs naturally in mineral ores, either as native metallic silver or in association with other metals such as gold and copper. Despite its wider availability compared to some precious metals, its relative scarcity contributes significantly to its economic importance. In contemporary society, silver has become indispensable in numerous technological, industrial, and medical fields. Its exceptional electrical and thermal conductivity make it a key material in electronic devices, conductive components, and electrical circuits. Silver is also widely employed in photography and advanced technologies. Furthermore, its antimicrobial properties, resulting from the release of silver ions that inhibit bacterial growth even at very low concentrations, have led to its extensive use in wound dressings, medical instruments, and healthcare products [1]. Beyond these applications, silver continues to be highly valued in jewelry and decorative industries. It also plays a critical role in renewable energy and environmental technologies, including solar cells [2], batteries, and water purification systems. These diverse applications highlight the growing importance of silver as a strategic material in modern industrial and technological development.

II. PHYSICAL CHARACTERISTICS AND CHEMISTRY

Silver is a highly malleable and ductile metal, allowing it to be readily formed into thin sheets or drawn into fine wires without fracturing. These properties make it particularly useful in a wide range of industrial, technological, and decorative applications. In addition, silver possesses the highest electrical conductivity and one of the highest thermal conductivities among all metals, making it an essential material in electrical circuits, electronic devices, and conductive components. One of the most distinctive characteristics of silver is its bright white color and exceptional reflectivity. Its attractive metallic luster contributes to its widespread use in jewelry, mirrors, decorative objects, and reflective coatings. Furthermore, silver exhibits excellent resistance to corrosion under normal atmospheric conditions, although it can tarnish upon exposure to sulfur-containing compounds, forming a dark layer of silver sulfide on its surface. Silver has several isotopes with mass numbers ranging from 105 to 111. Among these, the naturally occurring stable isotope is ^{109}Ag, while isotopes such as ^{105}Ag, ^{106}Ag, ^{107}Ag, ^{108}Ag, ^{110}Ag, and ^{111}Ag are produced artificially through nuclear reactions. The synthesis of silver isotopes is typically achieved in research laboratories using particle bombardment techniques, including neutron or proton irradiation of suitable target materials. Numerous radioactive silver isotopes have been generated in nuclear reactors and particle accelerators; however, most of these isotopes are unstable and undergo radioactive decay to form more stable elements. Although artificial production of silver isotopes through nuclear transmutation is scientifically feasible, the process is costly and inefficient for large-scale production. Consequently, the primary source of silver remains the extraction of naturally occurring deposits through mining and metallurgical processes. The combination of silver's unique physical and chemical properties, together with its economic significance, continues to support its extensive use in modern industry, technology, and scientific research.

Chemically, silver is a noble metal, a group 11 element, and a transition metal. Although it is more reactive than gold, it has a relatively modest reactivity and can tarnish when exposed to airborne sulfur compounds. Silver frequently reacts in the following ways: (i) The formation of insoluble silver halides through reaction with halogens (iodine, bromine, and chlorine) [3]. (ii) Silver nitrate and nitrogen oxides are produced through reaction with nitric acid. (iii) The formation of silver sulfide through reaction with sulfur, which results in tarnishing. (iv) Silver oxide is produced by a weak reaction with oxygen.

A central metal atom or ion is joined to surrounding molecules or ions known as ligands [4-11] to form complexes. When silver ions (Ag^+) interact with different ligands to form stable structures, a class of coordination molecules known as silver complexes is created. Silver complexes are extremely useful in many scientific domains due to their diverse range of chemical characteristics and structural variations. Their uses include material science, environmental monitoring, and antibacterial and anticancer treatments. Silver complexes have a variety of forms, including: (i) Mononuclear Complexes, in which a single silver ion is bound to one or more ligands by coordinate bonds. The $[Ag(NH_3)_2]NO_3$ complex, which has a linear shape, is one example. (ii) Two silver ions are joined by bridging ligands to produce structures with greater coordination numbers in dinuclear silver complexes. $[Ag_2(NH_2)_2]NO_3$ is a well-known example that takes on a distorted tetrahedral geometry. (iii) Polynuclear complexes exhibit even more structural complexity, with many silver ions joined by ligands to create bigger clusters. These complexes can have many different forms, such as extensive polymeric networks with multi-dentate ligands connecting the silver centers. (iv) Supramolecular silver complexes are an advanced class in which the creation of massive, complex structures is controlled by non-covalent interactions such hydrogen bonding, π-π stacking, or metal-ligand coordination. These interactions allow for the creation of two-dimensional or three-dimensional networks, which may have amazing characteristics like increased conductivity, magnetism, or optical activity. The structural chemistry of silver(I) coordination complexes, such as halide complexes (F^-, Cl^-, Br^-, I^-), pseudo-halides (CN^-, SCN^-), and the classical non-coordinating anions (NO_3^-, ClO_4^-, BF_4^-, $PF6^-$) has been discussed [12].The stoichiometry of the ligand to silver in the reaction mixture and the reaction circumstances determine the type of structure. The type of solvent and the halide or pseudo-halide ligands used as counterions are other elements that affect the structure of these complexes.

III. EXTRACTION AND RECYCLING

Depending on the type of ore, there are a number of ways to extract silver, as illustrated below. It can be extracted from main silver ores at silver mines or as a byproduct of mining other metals like zinc, copper, and lead.

- Screening process (Mining): Hand-separating silver particles from river sediments like sand and soil was one of the first techniques for extracting silver. This technique is based on the fact that silver has a higher density than nearby materials. It is currently mostly restricted to small-scale or historical application because to its extremely poor yield.
- Cyanide Treatment method: After the ore has been crushed and finely powdered, this technique is frequently employed to extract silver (equations 1 and 2). The silver particles dissolve and form a soluble complex when the ore is exposed to air and treated with a sodium cyanide solution in the presence of oxygen. Because of its effectiveness in removing silver from low-grade ores, this method is frequently employed in industrial mining [13]. The procedure's formula is typically

$Ag_2S + 4NaCN \rightleftharpoons 2Na[Ag(CN)_2]$ Sodium argento cyanide + Na_2S ………… Eq. 1

Silver precipitates and sodium tetra cyanozincate is created when zinc dust and sodium argento cyanide solution mix. We refer to this precipitated silver as spongy silver. Pure silver is produced by fusing spongy silver with potassium nitrate. After that, an electrolytic technique is used to purify the silver.

$Zn + 2Na[Ag(CN)_2] \rightarrow Na_2[Zn(CN)_4] + 2Ag$ ………… Eq. 2

Silver can be recovered from a variety of waste products produced by human activity, such as jewelry making, photographic materials, electronic waste, and some industrial and medicinal items. Since recycled silver can be effectively recovered from scrap materials and reused without significantly losing quality, it makes up a sizable amount of the global supply. Because of this, a lot of jewelry and electronics manufacturers use recycling techniques to reclaim silver, which lessens their impact on the environment and preserves natural resources.

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IV. SILVER NANOPARTICLES (NPS)

Structures of silver with at least one dimension at the nanoscale, or between 1 and 100 nm, are called nanoparticles (NPs) [14]. One of the significant and quickly evolving areas of contemporary research is nanotechnology. Industry, agriculture, food, energy, the environment, and health are just a few of the areas where this technology is driving innovation. One of the most researched nanomaterials among these developments are nanoparticles (NPs), which range in size from 1 to 100 nm. Based on their origins, NPs are divided into three primary classes: carbon-based structures, inorganic structures, and organic structures. It is possible to customize each lesson to meet various biological and therapeutic needs. Numerous organic and polymer-based NPs have been thoroughly investigated for a variety of biomedical uses. But among these types, inorganic NPs are unique due to their chemical stability, variety of production techniques, and complex physicochemical characteristics. Metal nanoparticles (silver [Ag], gold [Au], copper [Cu]) and metal oxide nanoparticles (iron oxide [Fe_3O_4], zinc oxide [ZnO], titanium dioxide [TiO_2], cerium oxide [CeO_2]) make up the majority of inorganic nanoparticles. In recent years, silver nanoparticles (AgNPs) have emerged as a major area of study within this large class of inorganic NPs [15]. AgNPs can be made via a variety of synthesis techniques, such as chemical, physical, and green synthesis. AgNPs' entire physicochemical profile is shaped by the synthesis process that is selected, which also affects their size, shape, stability, and surface characteristics. Changes in these factors can affect how AgNPs interact with biological systems, how bioavailable they are, and how much of a biological reaction occurs in target tissues. AgNPs have a variety of biological actions, including antioxidant, anti-inflammatory, anticancer, and broad-spectrum antibacterial activity.

V. HANDLING PRECAUTIONS

It is suggested that pure silver does not corrode, is safe for daily usage, and is not hazardous to humans. However, adverse effects could result from consuming too much colloidal silver or from silver compounds. Compared to many other heavy metals, silver compounds are often less hazardous. However, some substances, including silver nitrate and silver fluoride, are caustic and can be dangerous if not handled correctly. (i) Tissue irritation and injury upon direct touch are among the health effects of exposure. (ii) In cases with high exposure, systemic absorption into the bloodstream. (iii) Silver buildup in bodily tissues throughout time. In fact, prolonged exposure can cause Argyria, a disorder marked by blue-gray skin and eye discoloration [14]. Although argyria is usually persistent, it is not usually linked to serious health hazards. Silver compounds should be handled in a controlled laboratory setting for safety, and prolonged or direct exposure should be avoided.

VI. CONTEMPORARY SILVER APPLICATION

- *Actually, a Number of Studies on Silver have been Published; the Most Current Ones are as Follows:*

Microorganisms proliferate and develop excessively in textiles because they are a highly conducive medium. The fast and unchecked microbial growth on textile surfaces is made possible by the presence of bodily fluids and environmental moisture, ideal temperatures, and an abundance of nutrients in the form of contaminants, such as food residues, dead skin cells, bodily secretions (sweat, urine, feces), blood, and others. There is a serious risk of cross-infection among users since these contaminated materials may serve as carriers of potentially harmful germs. The possibility of cross-contamination across various settings, such as the home and the workplace, is especially concerning since it may promote the emergence and spread of new diseases. The use of antimicrobial compounds to functionalize textiles is crucial in light of these risks. In addition to helping to maintain personal hygiene by preventing the formation of bacteria that cause offensive odors, this treatment also effectively protects against potentially harmful pathogens. Because of their broad-spectrum antibacterial activity, silver nanoparticles (Ag NPs) are one of the most used antimicrobial agents for textile treatment [17]. One of the main obstacles to the antimicrobial functionalization of textiles using Ag NPs is the use of materials that are hazardous to human health and the environment during nanoparticle synthesis, as well as the creation of hazardous byproducts. The use of biosynthetic techniques for Ag NPs, which employ natural plant extracts as stabilizing and reducing agents, is a noteworthy development. A novel class of highly cross-linked and hydrated polymers for textile surface modification is known as stimuli-responsive hydrogels. They have great potential to improve wearer comfort through moisture control and thermoregulation.

Silver nanoparticles, or Ag NPs, are minuscule silver particles with sizes ranging from 1.0 to 100.0 nm. Using plant extracts as bio-mediators, the environmentally friendly production of crystalline Ag NPs has been investigated [18]. This study evaluates the benefits and drawbacks of this environmentally friendly strategy in comparison to traditional physical and chemical techniques. The efficiency of many plant extracts in forming stable nanoparticles by reducing silver ions is investigated. The composition of the extract, pH, temperature, and reaction time are among the variables that affect the creation of nanoparticles. The size, shape, and crystal structure of the produced nanoparticles were examined using characterization methods such as X-ray diffraction analysis, scanning electron microscopy, transmission electron microscopy, UV–visible spectroscopy, and Fourier transform infrared spectroscopy. These bio-synthesised Ag NPs' potential uses in industries like environmental remediation, catalysis, and medicine are highlighted. The report also discussed this green synthesis method's repeatability and scalability. All things considered, this critical viewpoint sheds light on the present situation and potential of plant-mediated silver nanoparticle synthesis as a sustainable substitute in nanotechnology.

Silver trifluoromethanesulfonate has been investigated as a catalyst for the production of glycosides employing 2-(2,2,2-trichloroethoxy)-2-oxazoline glycosyl donors with d-gluco and d-galacto configurations [19]. Like the sym-collidinium trifluoromethanesulfonate that was previously employed for this purpose, silver trifluoromethanesulfonate enables the glycosylation reaction to be conducted under extremely mild conditions in a neutral medium. Silver trifluoromethanesulfonate, on the other hand, generates target products more effectively than sym-collidinium trifluoromethanesulfonate and aids in preventing undesirable side reactions such polymerization of oxazoline derivatives of sugars and intermolecular aglycon transfer. It has been discovered that an equimolar ratio between the glycosyl donor and the catalyst yields the optimal oligosaccharide synthesis outcomes.

Heterogeneous Fenton process is a promising water treatment technology for sterilization and degradation of organic pollutants, due to the strong oxidation of hydroxyl radicals ($OH^{\cdot}$) generated. However, the low H2O2 activation efficiency and the instability of catalyst leading to low $OH^{\cdot}$ production restricted development of this technology. Herein, we synthesized a novel porous activated carbon-loaded nano silver oxide (nAg2O/AC) catalyst to enhance the activation of H2O2 for removing bacteria (E. coli) and micropollutants (Tetracycline, TC) from water. The high oxidation of hydroxyl radicals ($OH^{\cdot}$) produced by the heterogeneous Fenton process makes it an appropriate water treatment technology for organic pollutant breakdown and sterilization. However, the development of this technique was limited by the poor H2O2 activation efficiency and the catalyst's instability, which resulted in minimal $OH^{\cdot}$ generation. In order to improve the activation of H2O2 for eliminating bacteria (E. coli) and micropollutants (tetracycline, TC) from water, a unique porous activated carbon-loaded nano silver oxide (nAg2O/AC) catalyst was created [20].

Reductive hydroxyl groups on AC expedited the Ag(I)/Ag cycle through facilitated electron transfer in the nAg2O/AC Fenton system, significantly increasing the H2O2 activation efficiency to 73.7% (about 2.9 times that of conventional Fenton). As a result, nAg2O/AC Fenton removed TC and E. coli with up to 6.0 log and 100% efficiency, respectively. Radical scavenging tests and electron spin resonance (ESR) measurements were used to identify and confirm $OH^{\cdot}$ as the primary oxidizing species in the nAg2O/AC Fenton system. The elimination of E. coli and TC continued to reach 5.2 log and 96%, respectively, after four and five cycles of testing, indicating good stability of nAg2O/AC with significant application prospects. According to the study's findings, nAg2O/AC is a promising H2O2 catalyst for the simultaneous elimination of bacteria and micropollutants in an aqueous environment.

For a safer and more efficient kind of treatment, there are two options: oral AgNP delivery and herbal AgNPs. AgNPs have become one of the most intriguing nanomaterials in biomedicine because of their remarkable physical and chemical properties. When producing AgNPs with the appropriate size and shape, a number of factors should be taken into account. In addition to taking into account the effects of reaction variables, such as reaction temperature, time, pH, and extra energy, the production process for the different kinds of precursor salts must also take into account additives like reducing, capping, and stabilizing agents. Apart from these methods, a particularly easy, affordable, dependable, and sustainable option is biological synthesis using bacteria, fungi, and plant extract [21]. Antibacterial, anticancer, vaccine adjuvant, antidiabetic, biosensor treatment, and accelerating bone and wound healing are the main uses for AgNPs. Additionally discussed are the biological mechanisms of AgNPs action, primarily the production of reactive oxygen species (ROS), membrane disruption, and the release of silver ions (Ag^+).

Using ultraviolet–visible spectroscopy (UV–visible), scanning electron microscopy (SEM), zeta potential, and energy dispersive X-ray spectroscopy (EDS), silver nanoparticles (AgNPs) stabilized with the biosurfactant generated by Candida lipolytica UCP 0899 were analyzed and morphologically characterized [22]. The greatest UV–visible absorption peak of freshly generated silver nanoparticles was at 400 nm, whereas those that were kept for 120 days showed a shift to 410 nm. A zeta potential of −60 mV indicated that the application of the biosurfactant enhanced the stability of the nanoparticles, which had an average size of 20 nm and a mostly spherical structure, as confirmed by the SEM micrograph. The antibacterial activity of stabilized nanoparticles was evaluated against fungal isolates of Candida albicans and Aspergillus niger as well as bacterial isolates of Pseudomonas aeruginosa, Staphylococcus aureus, Escherichia coli, and Enterobacter sp. AgNPs reduced the development of all target microorganisms in the following decreasing order at a concentration of 16.50 µg/mL: E. coli (95%), S. aureus, C. albicans (90%), A. niger (85%), Enterobacter sp. (75%), and P. aeruginosa (71%). These findings point to the biosurfactant's possible application in several industrial sectors as an antibacterial agent and stabilizer of silver nanoparticles. Additionally, the Tenebrio molitor model was used to assess the biosurfactants' potential for in vivo toxicity. There was no mortality throughout the 24 to 72-hour period after the larvae were treated with concentrations in the range of 2.5, 5.0, and 10 g/L, indicating non-toxicity within the measured concentration range.

It has been reported that adding silver–silica (Ag/SiO_2) hybrid nanoparticles by melt processing is an effective way to

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create antiviral PVC nanocomposites [23]. Two hybrid nanoparticle systems were used: Ag/SiO_2 combined with two organic biocides (zinc pyrithione and triclosan) and SiO2 coated with silver nanoparticles. In addition to antiviral experiments against SARS-CoV-2, thorough morphological, optical, thermal, and mechanical characterizations were carried out to evaluate structure–property correlations. Ag/SiO_2 nanoparticles enhanced the stiffness of PVC while maintaining its impact strength and thermal stability. Because of their plasticizing action, the biocide-containing particles reduced PVC discolouration but had an impact on mechanical qualities. Only 0.5 weight percent of the Ag/SiO2/organic biocide system was required to inactivate SARS-CoV-2, whereas a concentration of 2.5 weight percent of Ag/SiO_2 nanoparticles was required. This indicates a combination virucidal reaction between Ag on the nanocomposite surface and triclosan that is discharged. Performance declines or cytotoxic consequences were caused by an excessive filler content. The promise of these materials for usage in medical devices, personal protective equipment, and surfaces needing antimicrobial protection is demonstrated by the customized functionality made possible by the combination of inorganic and organic antimicrobial agents.

Recent attempts have switched to environmentally friendly methods, like using plant waste extracts, due to the constraints of conventional synthesis and the increasing use of nanoparticles. An innovative project to repurpose green waste from homes and farms for the production of silver nanoparticles (AgNP) provides a low-cost, sustainable solution that tackles both economic and environmental issues. After assessing the multi-round recyclability of Virginia creeper (VC), green tea (GT), and coffee arabica (CA) waste for AgNP synthesis, a thorough physicochemical and bioactivity characterization of the nanoparticles was carried out [24]. In this study, waste from CA, GT, and VC produced by one, two, and three rounds of leftover extractions was used to prepare AgNPs. Transmission electron microscopy (TEM), ultraviolet–visible (UV–vis) spectroscopy, dynamic light scattering (DLS), and X-ray powder diffraction (XRD) were used to characterize the resulting nanomaterials. Their antibacterial efficacy against Gram-positive and Gram-negative bacteria as well as against Aspergillus niger and Cryptococcus neoformans was examined using the microdilution method, and their toxicity on malignant and nonmalignant human cells was assessed using viability assays. A staining technique was used to assess the generation of reactive oxygen species (ROS), and inductively coupled plasma mass spectroscopy was used to detect the silver ion release associated with AgNP. Our results demonstrated that AgNPs could be successfully synthesized using recycled waste materials; however, the type of plant and extraction cycle affected AgNP characteristics, resulting in a distinct mix of stability and nanoparticle size. Although they also affected noncancerous fibroblasts, all AgNPs demonstrated significant toxicity against human cancer cells. AgNPs produced by VC displayed high antifungal properties, but those obtained from GT demonstrated strong antibacterial activity. The enhanced silver ion-releasing capability that led to elevated ROS levels was the cause of the observed bioactivity, which linked with the number of extraction cycles.

Zingiber officinale (ginger) leaf extract was used as a biogenic reducing and stabilizing agent in a green technique for producing silver nanoparticles (AgNPs) [25]. Because of redox reactions and the presence of functional groups (OH, COOH, and NH_2), the leaf's aqueous extract, which is rich in phytochemicals such as gingerols, shogaols, zingerone, and flavonoids, was found to be effective in reducing Ag^+ ions to elemental Ag^0. The phytochemical capping stopped the agglomeration and enhanced the colloidal stability while the AgO atoms nucleated and aggregated to form well-dispersed AgNPs. UV-Vis spectroscopy, photoluminescence (PL), FTIR, and transmission electron microscopy (TEM) were used to comprehensively describe the nanoparticles after the synthesis was optimized by varying the extract volume (10–30 mL). TEM revealed homogeneous spherical nanoparticles with an average size of 20.8 +/- 0.5 nm, while UV-Vis and PL characterization showed the best production and crystallinity of AgNPs at 20–25 mL of extracts. The involvement of bioactive functional groups in reduction and stabilization was demonstrated by FTIR. The agar well diffusion technique was used to assess the antibacterial effect, and significant inhibitory zones were seen against Bacillus subtilis and Escherichia coli as a result of multi-mechanistic effects like membrane rupture, ROS generation, enzyme inhibition, and DNA interference. The results confirm the potential of ginger leaf extract as an economical, sustainable reagent for the production of stable, biofunctional, and environmentally acceptable AgNPs for use in biomedical and antimicrobial applications.

Legionella pneumophila, nontuberculous mycobacteria (NTM), Pseudomonas aeruginosa, and other drinking water-associated organisms that can infect vulnerable DWPIs appear to be the cause of a rising number of waterborne disease outbreaks. Point-of-use devices like showerheads that include silver, a proven antibacterial substance, are an emerging technique used to lower DWPIs. Three distinct silver-modified showerhead designs were taken into consideration when evaluating the impact of silver-containing showerheads on DWPI density and the wider microbiome in shower water under real-use conditions in a full-scale shower system: (i) silver mesh inside the showerhead, (ii) silver-coated copper mesh in the head and hose, and (iii) silver-embedded polymer composite in comparison to traditional plastic and metal showerheads [26]. Targeted DWPI transcriptional activity in collected water did not significantly differ between silver and non-silver shower head types. However, the metal concentrations, microbial uncommon taxa, and microbiome functionality were all impacted by the presence of silver and how it was integrated into the showerhead. The showerhead

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age (i.e., period following installation) also had an impact on microbial dynamics. The study's findings offer consumers and building managers useful information to take into account when selecting a showerhead designed to lower microorganisms in shower water.

In order to address the growing problem of electronic waste and enable next-generation gadgets, it is imperative to create workable methods for producing transient electronic devices. The additive patterning of conductive layers on commercially available water-soluble nonwoven textiles made of poly (vinyl alcohol) (PVA) was described [27]. Inkjet printing allows for the practical patterning of aqueous inks made from reactive silver precursors on water-soluble textiles. The creation of conductive patterns on a water-soluble fabric using a solution-processable fabrication with aqueous inks is guaranteed by the effective deposition of materials with droplet volumes on the order of picoliters. In order to provide tunability in the substrate's temperature-dependent deterioration, conductive electrode manufacturing and transient behavior are investigated on PVA textiles with two distinct levels of hydrolysis. Resistive heaters are used to illustrate the use of printed conductive pads. At a safe voltage of 3 V, the fabric's temperature can rise to 100 °C in less than 15 seconds. The heater operates steadily under cyclic heating and cooling. For transient device applications, the suggested method offers significant prospects for additive patterning of aqueous solutions and colloidal dispersions across water-soluble substrates.

VII. CONCLUSION

Silver remains one of the most valuable and versatile precious metals due to its exceptional physical, chemical, and biological properties. Characterization techniques, including X-ray diffraction analysis, Scanning Electron Microscope, Transmission Electron Microscope, UV–visible spectroscopy and Fourier Transform Infrared Spectroscopy are powerful techniques to analyze the synthesized nanoparticles' size, shape and crystal structure. The study highlights its unique characteristics, methods of extraction and recycling, toxicity considerations, importance of its nanoparticles and broad range of applications. The findings demonstrate that silver has significant economic importance and continues to be essential in numerous fields, including photography, catalysis, advanced technologies, and medicine. As technological innovation and sustainability efforts advance, the demand for silver is expected to remain strong, emphasizing the need for efficient resource management and responsible utilization of this important metal. It is worth to point out that pure silver is suggested that it is not toxic to humans and safe for everyday use, in contrast, silver compounds may cause side effects such as irritation and damage of tissues and Argyria. For safety, silver compounds should be handled under controlled laboratory conditions, and direct or prolonged exposure should be avoided.

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