

Current Advances with Potential Role of Nanotechnology in Generation of Fuel Cells and Solar Cell Batteries

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Abstract

Batteries are becoming an essential component of many different applications, such as memory backup, clocks, calculators, lighting, portable electronic devices, and photographic equipment, advancements in the electronics sector. Pure metal nanoparticles can be created either destructively or constructively using metal precursors. Because of the plasma resonance feature, it has special opto-electrical properties. Size, shape, and fact govern the metal nanoparticles replicate. Silver, gold, iron, cobalt, zinc, copper, and cadmium nanoparticles are the most prevalent metal nanoparticles. The electrical characteristics of the flower-shaped nanostructure when connected to the Pt nanoparticles are noticeably better than the typical electro-catalytic characteristics of the spherical nanoparticles. Transitional metal oxides are considered vital materials in industry because of their vast variety of magnetic, thermal, chemical, and electrical characteristics, as demonstrated by the evaluation of functional inorganic solids. The corrosive resistance of the metal at high voltages should be taken into account. Al and Ti are therefore excellent options because of the inert layer that forms on their surfaces at high potential. Building a porous metal current collector is therefore crucial to stabilizing alkali metal anodes with improved cycle and safety performance.

Keywords: Pure metal nanoparticles, constructively, gold, iron, cobalt, zinc, copper, cadmium.

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INTRODUCTION

Batteries and fuel cells continue to be essential power sources in the twenty-first century for a variety of consumer, business, and defense applications. Batteries are becoming an essential component of many different applications, such as memory backup, clocks, calculators, lighting, portable electronic devices, and photographic equipment to advancements in the electronics sector. More utility power freedom is now possible. Batteries have several advantages over other power sources, such as being easily tailored to match user demands and being generally easy to use, dependable, efficient, and self-contained [1,2]. While other fuel cell types utilize hydrogen or alcohol as fuel,

the MFC uses wastewater to generate energy through microbial metabolisms. When there are microorganisms present, MFCs are frequently run at low temperatures and need a lot of energy. The hydrogen produced by the microorganisms oxidizing the substrate crosses the membrane and joins oxygen in the external circuit to form water and electrons. Even though this specific fuel cell has a special and flexible technology that enables it to clean wastewater while still providing energy, the power generated is less than that of other types of fuel cells [3,4].

The process of steam reforming is used in the current techniques of creating hydrogen. Using this technique, hydrogen is produced by heating water to a

very high temperature. Because this process uses natural gas, it produces carbon dioxide and carbon monoxide pollution in the air. Electrolysis is a different process used to produce hydrogen [4,5]. Photoelectrochemical hydrogen production is the long term for one of the nanotechnology-based methods of creating hydrogen. A

layer of nanoparticles, about 30 nm in diameter, deposited atop a conducting glass layer is the functional component of a photoelectrochemical hydrogen generation system. A semi-conducting metal oxide makes up the nanoparticles [5,6].

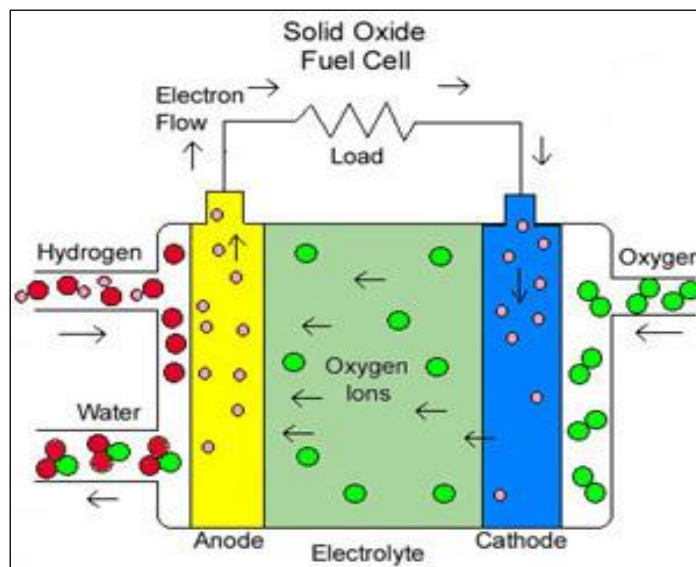


Fig-1: The features of the fuel cell and its structure

Metal nanoparticles are nanoparticles that are formed of metals. Pure metal nanoparticles can be created either destructively or constructively using metal precursors. Because of the plasma resonance feature, it has special opto-electrical properties [7,8]. Size, shape, and facet governs the metal nanoparticles replicate. Silver, gold, iron, cobalt, zinc, copper, and cadmium nanoparticles are the most prevalent metal nanoparticles. Metal nanoparticles with different distinctive features, such as surface area to volume ratio, pore size, structure, surface charge and density, color, and environmental elements in the form of sunlight, moisture, heat, and air, are made possible by their control over size and shape. Materials graphite-graphene is one kind of carbon material that is frequently used as an anode material in MFCs is graphite. A two-species hybridized crystalline

form of carbon atoms is called graphite. Given its potential benefits, graphite is a great material for the anode in metal-free solar cells (MFCs) due to its strength, biocompatibility, and huge surface area. Nevertheless, a few drawbacks, such as its expensive cost and low conductivity, render it inappropriate for meeting the demands of the modern commercial energy market [7, 8]. The utilizing normal carbon as the anode in MFCs is less effective than using graphite materials such sheets or plates, paper, rods, granules, cloth, and brushes. Both rough and flat graphite can be used as an anode in MFCs. Poor electron production was the cause of the comparatively low power output. The presence of unstable elements in the nuclear waste meant that the graphite felt could not sustain bacterial growth over an extended period of time [9,10].

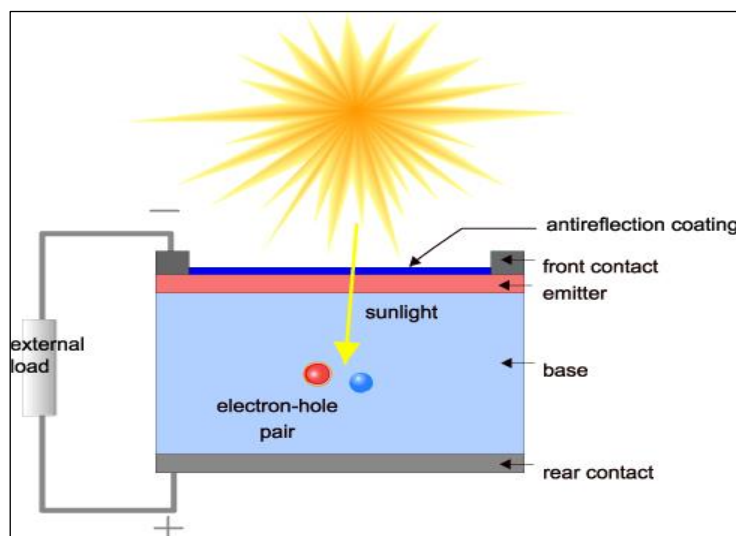


Fig-2: The functional features of the solar cell battery

Potential Nanotechnology aspects in fuel cells and solar cell batteries

The pure catalysts that exhibit good stability in the *in vivo* environment include noble metals and their alloys. The electrocatalytic oxidation of glucose on platinum (Pt) single crystals appears to be a structure-dependent process. Pt-based catalysts can have their reactivity controlled by adjusting the sizes, shapes, and exposure of their crystal facets [11,12]. Numerous studies have shown that defect structures with low coordination atoms, such as steps, kinks, and edges, cause nanocrystals (NCs) surrounded by high-index facets (HIFs) to exhibit high catalytic properties. As a result, Pt-based NCs with HIFs have been extensively studied for numerous catalytic applications. However, because of the high surface energy and active unsaturated atoms, the processes of atom migration. Therefore, keeping Pt-based catalysts' high activity and protecting their HIFs are crucial problems to solve. To prevent aggregation, a suitable material with a broad surface area for Pt distribution is advised [10-12].

One inexpensive class of helpful materials for bacterial colonization is nanocellulose. To make this compound conductive for use in MFCs, a wide variety of metal, polymer, and carbon-based materials can be applied to them and changed. BC-based porous hydrogel anodes covered with conductive polymers that were manufactured. germs were able to permanently access nutrients due to the capillary effect between the BC nanofibers, which also prevented germs from spoiling and blocking pores. When compared to the graphite plate, the bio-anode greatly increased the tested MFCs' power density. The bacteria were able to adhere to the anode more successfully, which facilitated electron

transfer, thanks to the biocompatibility of both BC and the conductive polymers. Additionally, the bioanode increased redox activity; future research should examine the mechanism behind this. The good conductivity of the modified might have been attributed, in part, to the low pH values of the wet hydrogel electrode in the bio-anode that used [13, 14].

In order to eliminate or reduce the usage of ecologically hazardous materials, there is an urgent need for the development of clean energy storage and conversion systems due to industrialization and the growing number of byproducts and residues released from industrial activity. In this instance, materials derived from nature offer a great deal of promise as catalysts and nanofillers for the creation of electrodes and nanocomposites for the conversion and storage of energy. These materials are inexpensive, have large surface areas, extensive porous structures, significant mechanical and thermal stability, and an abundance of reserves [15, 16].

In recent decades, heavy metals have become a significant inorganic pollutant and health and environmental risk. The environment and public health can only be safeguarded by eliminating them from wastewater that contains metals before releasing them into aquatic streams. Since most heavy metals are rapidly becoming industrialized and sustainable over the long term, they should be regarded as highly valued recyclable resources. For this reason, advanced oxidation techniques including photocatalytic degradation have been assessed for their ability to remove metal ions efficiently [9-11].

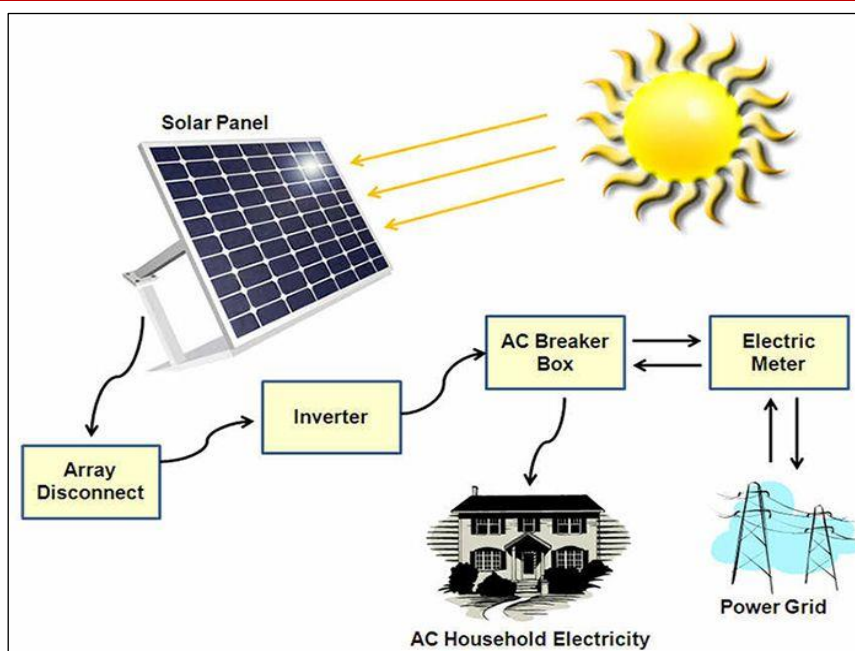


Fig-3: The applications with various aspects of the solar cell battery

The possibility of recovering heavy metals from wastewater (such as acid mining and electroplating) and generating energy simultaneously is prevalent in a novel photoelectrochemical cell (PEC). But as BESSs, both its rehabilitation and electrical production are inadequate. This problem normally addressed by the development of a novel technique that uses PECs and MFCs together to efficiently remove refractory organic pollutants as such for phenol and aniline from wastewater and recover energy for on-site usage [15-17].

High performance and high dispersion Ru-decorated Pt nanoparticles on Nitrogen-doped multiwalled carbon nanotubes are used in direct methanol fuel cells. As the anode of a direct methanol fuel cell, the polymer composition of Pt nanoparticles injected into the MWCNT exhibits superior tolerance and increased electrocatalytic activity [18,19]. On the other hand, the electrocatalytic activity of CNTs is significantly influenced by their morphology and form. The electrical characteristics of the flower-shaped nanostructure when connected to the Pt nanoparticles are noticeably better than the typical electro-catalytic characteristics of the spherical nanoparticles. Therefore, the usage of Pt nanoparticles can accurately represent the catalyst's performance, and Pt nanoparticles can be more widely distributed on the support's surface, increasing the platinum's utilization rate [18, 19].

An electrolyte/membrane and electrodes, on the surface of which bipolar plates and electrochemical processes divide the individual cells, make up a single fuel cell. On the electro surface, hydrogen and oxygen are reduced and oxidized, respectively, in the presence of a platinum catalyst. Water is the byproduct of the combination of protons (from oxidized H₂) and electrons

(from O₂ reduction) at the cathode. In order to create an interconnected membrane with electrodes, or Membrane Electrode Assembly (MEA), the diffusion layer must first be sprayed onto carbon paper. Next, the catalytic layer must be sprayed with catalyst, and both electrodes must be joined with the membrane [17-19]. Because of its cation-exchange capabilities, the commercially manufactured electrolyte—typically Nafion transports H⁺ ions, and the electrons that emerge from the reaction on the electrodes wander via the external system to the receiver, playing a crucial function in the cell. the electrodes' membrane-covered cross-section [19, 20]. It is commonly recognized that the use of fossil fuels today is unsustainable and contributes to the emission of greenhouse gases. It is critically necessary for renewable energy technologies to offer a certain percentage of the world's primary energy supply. In order to harness future energy for a sustainable environment, pertinent technologies including solar cells, hydrogen fuel, biotechnology based on nanotechnology, and pertinent patents are analyzed. Simultaneously, it is noted that the world's eco-energy considerably [21, 22].

The primary driver for the replication of metal oxide nanoparticles is their higher reactivity in comparison to metal nanoparticles. Metal oxide nanoparticle production is altered in a way that makes it more reactive. Iron oxide, zinc oxide, aluminum oxide, silicon dioxide, magnetite, and titanium oxide are the most frequently occurring metal oxide nanoparticles [23]. Based on Polymers: Nanoadsorbents In recent years, a great deal of research has been conducted on polymer nano composites for wastewater treatment and environmental sustainability enhancement. It provides a large surface area for quick decontamination, exceptional stability, enhanced processability, cost

efficiency, and selectivity to get rid of various contaminants in wastewater. Polysaccharides, such as CS cyclodextrin, nano-magnetic polymers, covalent organic polymers, extracellular polymeric compounds, etc., are economical and frequently utilized polymeric adsorbents. Made from cellulose, nanocellulosics have the benefit of being widely available, nontoxic, very effective adsorbents, and easily modifiable on the surface, making them appropriate for wastewater treatment. Nanomaterials generated from lignin have been prepared and shown recently, and they show great promise for treating wastewater and water. They have proven to be successful in the removal of heavy metals, the catalytic degradation of dyes, and the nitroarenes [23-25].

The cycling and rate performance of Cr₂O₃ has been enhanced by a number of techniques, including particle reduction, the creation of porous nanostructures, and composite preparation. Among these techniques, carbon composites have received a lot of attention because carbon can stop metal oxide particle agglomeration in addition to absorbing stress from active material volume expansion and maintaining electrode structural integrity during cycling. Consequently, it is clear that the addition of carbon has improved cycle stability [26,27]. For instance, after 100 cycles, carbon-coated graphene–Cr₂O₃ composites, which were created by a hydrothermal process and then thermally treated, show a reversible capacity. The concurrent formation of a carbon covering and Cr₂O₃ particles allowed for the separation of the particles and the restriction of their development, improving the electrochemical performances. Unfortunately, the high cost and intricate operation of this technique restrict its practical applicability. According to Jiang *et al.*, [18], the Cr₂O₃–C hierarchical core/shell nanospheres outperform pure mesoporous Cr₂O₃ spheres in terms of cycling performance, although they still exhibited poor cycling stability and saw a progressive decrease in capacity with cycling [27, 28].

For the sorptive removal of aqueous heavy metal ions, several kinds of advanced nanoparticles (NMs) have been produced. A survey of the literature indicates that the most often used metric for evaluating the sorptive removal efficacy of NMs is adsorption capacity. However, the mass of the adsorbent (NMs) utilized in a sorption system and the initial loading concentration (C_{in}) of the adsorbate (contaminants) might interact to alter the adsorption capacity. As an alternate measure, the use of a distribution coefficient has been suggested. K_p is the sorption capacity divided by the amount of sorbate that is left at the maximum (or equilibrium) adsorptive state [29, 30].

By balancing the impact of regulating parameters such as adsorbate/adsorbent as perceived for the partitioning of chemicals between aqueous phases at

equilibrium, i.e., Henry's law, such a measure may be utilized to properly assess the performance of NMs. Instead of using adsorption capacity, K_p has shown to be a useful performance indicator for NMs since it is easily manipulable to produce predicted values and accounts for surface heterogeneity and adsorption process strength [30, 31]. Transitional metal oxides are considered vital materials in industry because of their vast variety of magnetic, thermal, chemical, and electrical characteristics, as demonstrated by the evaluation of functional inorganic solids. Due to its great wear resistance and usefulness in industrial applications, chromium oxide.

The hydrothermal method may be used to create morphologically well-defined chromium oxide nanoparticles with particle sizes varies. In the synthetic process, precipitated xerogels are used to generate chromium oxy-hydroxide nanoparticles, which are then thermally transformed into chromium oxide. Ensuring reliable electrochemical energy conversion and storage systems is among the most challenging problems facing our civilization [32,33]. Nanomaterials offer several desirable properties for electrochemical energy storage devices that set them apart from bulk or micron-sized materials due to their influence on nanoscale size. In particular, constrained dimensions are essential for controlling the properties of nanomaterials, such as active material consumption, strain/stress magnitude, and ion transport kinetics. One of the distinctive one-dimensional nanomaterials, nanowires have the ability to sustain electron transport along the longitudinal plane and to produce a confinement effect throughout the diameter. This means that they present a great deal of promise for a variety of applications in the field of energy storage. It is now essential to use renewable energy and steer clear of environmental problems associated with traditional fossil fuels in order to achieve a globally sustainable energy future [31,32].

In this context, electrochemical energy conversion and storage technologies such as fuel cells, electrolyzers, photo-electrolyzers, metal-air batteries, metal-ion batteries, and supercapacitors have been essential. The efficiency of renewable energy sources needs to be significantly improved in order to compete with the current fossil fuel-based energy supply systems. The precipitation's pH was precisely controlled, resulting in particles that ranged in size varies. The non-aggregated oxy-hydroxide nanoparticles develop in two distinct patterns [32-34].

The metal ions are removed from the metal anode at the negative electrode during AMOB discharge, which causes the alkali metal to oxidize by losing electrons. It is plated as solid metal when it is charged. Gaseous oxygen (O₂) is dissolved in the liquid electrolyte at the cathode and transforms into the discharge product, or metal oxide, which is frequently

generated in the range of few nm to 100 nm [35, 36]. The created metal oxide breaks down during charging, gaseous oxygen is released. An unstable SEI layer will be created by the reaction of alkali metals with high reactivity and thermodynamic instability with electrolytes. Therefore, while choosing metal materials to serve as current collectors, electrochemical stability needs to be taken into account. Due to their superior mechanical and conductivity qualities, metal foils are the most often utilized current collectors in lithium-ion batteries. For the current collector in the cathode, the corrosive resistance of the metal at high voltages should be taken into account. Al and Ti are therefore excellent options because of the inert layer that forms on their surfaces at high potential. The problem is the anode side alloying reaction with alkali at a low voltage of less [34-36].

CONCLUSION

Cu foil is therefore frequently employed as the anode current collector for alkali metal batteries due to its exceptional electrochemical stability at low voltage. Low surface area planar metal electrodes will, as was previously said, cause an uneven distribution of ion flux and current density, which will ultimately result in subpar electrochemical performance. Building a porous metal current collector is therefore crucial to stabilizing alkali metal anodes with improved cycle and safety performance [35, 36].

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