MEDWIN PUBLISHERS
Committed to Create Value for Researchers

Nanomedicine & Nanotechnology Open Access
ISSN: 2574-187X

Nanotechnology in Renewable Energy: Prospects and Challenges

Poobalan B[1,2]* and Natarajan M[3]

[1]Faculty of Electronic Engineering Technology, Universiti Malaysia Perlis, Malaysia

[2]Department of MicroSystem Technology, Centre of Excellence, Universiti Malaysia Perlis, Malaysia

[3]Faculty of Dentistry, AIMST University, Universiti Malaysia Perlis, Malaysia

Editorial
Volume 8 Issue 3
Received Date: September 19, 2023
Published Date: September 25, 2023
DOI: 10.23880/nnoa-16000260

***Corresponding author:** Banu Poobalan, Faculty of Electronic Engineering Technology, MicroSystem Technology, Centre of Excellence (CoE), University of Malaysia Perlis (UniMAP), 02600, Arau, Perlis, Malaysia, Tel: +6016-4126144; Email: banu@unimap.edu.my

Abstract

Nanotechnology ranges from the study of the fundamental physics, biology, chemistry, and other technology of nanometer-scale matters. Recently, nanotechnology has been extended to the renewable energy field. Renewable energy has been defined as energy produced through natural sources that renew more quickly than it is consumed, such as solar energy, wind power, and other renewable energy resources. The growing human population and advances in technology in today's world have resulted in a greater need for energy usage. Nanotechnology applications in renewable energy are expected to solve the energy demand shortage problem. This article intends to introduce some key applications of nanotechnology in renewable energy systems. The main focus has been given to the utilization of nanoparticles in the context of hydrogen production, fabrication of solar cells, Nano composites for energy storage and nanotechnology for biotechnology. Additionally, the article also discusses the opportunities and problems of nanotechnology applications in the field of renewable energy. With this, the application of nanotechnology in the energy sector is expected to provide efficient and sustainable energy solutions in order to create a low-carbon economy with reduced greenhouse gas emissions.

Keywords: Nanotechnology Applications; Hydrogen Storage Systems; Nanosized Cerium Oxide

Abbreviation: CNTS: Carbon-Based Nanotubes.

Introduction

Nanotechnology refers to the modification of substances at a size comparable to the atomic level, with the aim of creating novel structures, materials, and devices [1]. Generally, nanomaterials range in length from 1 to 100 nanometers [2]. The development of nanotechnology-based products is applied in numerous industries, including healthcare, consumer goods, materials, energy, and production [3].

In this article, the application of nanotechnology is discussed in the field of renewable energy which includes energy generation and storage. Renewable energy refers to the utilisation of energy derived from renewable resources that possess the inherent capacity for replenishment within a timeframe relevant to human activities [4].

Solar energy, cascading water, wind the heat generated from the earth (geothermal), plant matter (biomass), ocean waves and currents are examples of renewable resources [5]. Renewable energy methods encompass the conversion of various resources into power and electricity, hence generating power, heat, or mechanical energy [6].

To date, research linked to nanotechnology primarily focuses on hydrogen, solar and biomass energy. Nanotechnology permits the creation of both portable energy systems and large-scale, high-efficiency energy systems. The advancement of affordable alternative energy technologies will contribute to our global community's essential environmental objectives and reduce the detrimental impact of human actions.

The Utilization of Nanoparticles in the Context of Hydrogen Production

Hydrogen is considered an energy carrier rather than serving as a primary energy source. The power is generated by the utilisation of fuel cells, which convert renewable energy sources into usable form [7]. Nanotechnology has the potential to be employed in the process of hydrogen production via artificial photosynthesis [8].

The hydrogen that is generated thereafter undergoes electrochemical processes, wherein it is chemically mixed with oxygen in the absence of burning. The aforementioned chemical reaction yields a flow of electrical current in the form of direct current.

Nevertheless, this particular procedure necessitates a substantial amount of energy and costly catalysts. Nanoparticles have the potential to address these difficulties through the reduction of energy input and enhancement of catalytic activity.

One approach to mitigating the high cost associated with electrodes is achieved through the reduction of the quantity of platinum (Pt) catalyst utilized [9]. Various catalyst supports, including carbon-based nanotubes, nanodiamonds, conductive-based oxides and carbon-based nanofibers are employed to accomplish this objective. Additionally, nanoparticles can be used for collecting and storing solar energy for subsequent electrolysis. In electrolytes, nanoscale range hydrophilic inorganic substances are used to increase the hydrogen ion conductivity of membranes [10]. The performance of membrane fuel cells can be improved by incorporating titania and tin dioxide (SnO_2) into ordinary membranes [11].

Hydrogen storage systems represent a second application of nanotechnology. Hydrogen is difficult to store because it must be liquefied with elevated pressures and reduced temperatures. Alternatively, hydrogen storage is performed employing physisorption [12] and chemisorption [13] techniques. Both applications can be made more efficient through the application of nanotechnology. Physisorption is a process which involves the chemical binding of molecules through weak interactions between adsorber and adsorbent. The efficiency of physisorption is further enhanced in large surface regions and porosity of nanomaterials. In physisorption, carbon-based nanomaterials such as carbon nanotubes, carbon aerogels and carbon nanofibers are typically employed [14].

The Utilization of Nanomaterials in the Fabrication of Solar Cells

The creation of nanomaterials for solar cells is seen as a very promising domain within the field of nanotechnology for renewable energy. These materials have the potential to enhance the efficiency, stability, and cost-effectiveness of the process solar-to-electricity conversion process. Solar cells in photovoltaic systems are capable of transforming photons derived from light into electrical current [15]. The scientific term used to describe this phenomenon is known as the photoelectric effect. First-generation solar cells employ a thick coating of crystalline silicon [16], while second-generation solar cells employ thin film coatings of semiconducting compounds with a thickness of 1 to 2 nanometers [17].

The utilisation of nanomaterials such as silicon-based nanoparticles, nanocrystal-based quantum dots and carbon-based nanotubes (CNTs) are potential nanomaterial types for enhancing the efficiency of second-generation solar cells [18]. Carbon nanotubes (CNTs) improve the performance of solar cells by enhancing the mobility of electrons. It is reported that quantum-based dots exhibit a higher electron emission per photon in comparison to conventional materials, hence enhancing the efficiency of solar cells [19]. In the dye-sensitized solar cells, the enhanced light absorption characteristics of solar cells are attributed to the substantial surface area shown by titanium nanoparticles [20]. In addition to carbon nanotubes, graphene, and perovskites, various other nanomaterials have been found to possess the capability to augment the efficiency and lifetime of solar cells.

The Utilization of Nanocomposites for Energy Storage

The development of nanocomposites for energy storage is the third renewable energy application of nanotechnology. Energy storage is crucial for regulating the supply and demand of intermittent renewable sources like wind and solar. Nanocomposites are materials created by combining nanoscale particulates with other substances, such as polymers, metals, or ceramics [21]. These materials can improve the functionality and properties of batteries, supercapacitors, and fuel cells [22]. For instance, nanocomposites can increase the amount of energy efficiency, capacity for power, cycle duration, and reliability of lithium-ion batteries [23]. Additionally, they can enhance the conductivity, capacitance, and stability of supercapacitors.

The Utilization of Nanotechnology in Biotechnology

Bioenergy is defined as the energy produced by the chemical interactions of biological matter (biomass), for example, algae, plants and organic waste [24]. Biomass is favourable due to its abundance in the natural world. It provides carbon-free energy sources that are inexpensive and environmentally beneficial. Biofuel, biogas, vegetable oil, biodiesel, and biodiesel are bioenergy sources [25]. Biomass is converted into bioenergy sources via the fermentation process, transesterification, digestion in anaerobic Conditions, esterification, gasification and pyrolysis [26]. Combustion of bioenergy produces significantly fewer greenhouse gas emissions than combustion of fossil fuels. Nanotechnology is primarily concerned with the catalysis of biomass conversion reactions and the reduction of hydrocarbon discharges. Nanosized cerium oxide substances in biodiesel, for instance, reduce hydrocarbon and greenhouse gas emissions.

Prospects and Challenges of Nanotechnology in Renewable Energy

There are challenges and risks that must be addressed. The scalability and cost-effectiveness of nanomaterials and devices is one of the greatest obstacles. Synthesis, fabrication, and integration of nanomaterials necessitate the use of sophisticated techniques and equipment that are not always broadly available or accessible. In addition, neither the environmental nor health effects of nanomaterials are entirely understood nor regulated. Due to their toxicity, persistence, and accumulation, some nanomaterials may pose a risk to humans and ecosystems. Therefore, additional research and regulation are required to ensure the development and use of nanotechnology in a safe and responsible manner.

Nanotechnology is an exciting and emerging discipline that can provide new opportunities and solutions for the production and storage of renewable energy. Hence, it is of utmost importance to increase the efficacy, dependability, and affordability of solar cells, hydrogen production, and energy storage devices by leveraging the unique properties and functions of nanomaterials. However, the challenges and risks posed by nanotechnology and the endeavour to strike a balance between its benefits and costs should be considered.

Acknowledgements

One of the authors would like to acknowledge the Malaysian Ministry of Higher Education (FRGS/1/2020/STG05/UniMAP/02/7(9003-00862)) and Universiti Malaysia Perlis for their support throughout the work.

References

1. Ashok KA, Elisabetta C (2014) Nanotechnology and Its Applications to Animal Biotechnology. In: Verma AS, Singh A (Eds.), Academic Press, Animal Biotechnology pp: 247-263.

2. Adil LR, Retwik P, Mst NK, Moirangthem AC, Lidong L, et al. (2022) Chapter 7-Nanomaterials for Sensors: Synthesis and Applications. In: Sushma D, Jayashankar D, et al. (Eds.), Advanced Nanomaterials for Point of Care Diagnosis and Therapy. Elsevier pp: 121-168.

3. Mohammad ZH, Ahmad F, Ibrahim SA (2022) Application of nanotechnology in different aspects of the food industry. Discov Food 2(1): 1-21.

4. John Palo (2023) John Palo Wants a Geothermal Heat Pump in Every U.S. Home and Building. Energy Efficiency & Renewable Energy.

5. Phebe AO, Samuel AS (2016) A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering 3(1): 14.

6. Dincer I, Bicer Y (2020) Chapter 6-Integration of renewable energy systems for multigeneration. In: Dincer I, Bicer Y (Eds.), Integrated Energy Systems for Multigeneration Elsevier pp: 287-402.

7. (2023) Renewable Energy. Office of Energy Efficiency & Renewable Energy.

8. Kathpalia R, Verma AK (2023) Artificial Photosynthesis an Alternative Source of Renewable Energy: Potential and Limitations. Plant Physiology.

9. Dao DV, Adilbish B, Lee IH, Yu YT (2019) Enhanced electrocatalytic property of Pt/C electrode with double catalyst layers for PEMFC. International Journal of Hydrogen Energy 44(45): 24580-24590.

10. Rosli NAR, Kee SL, Wai YW, Rozan MY, Tian KL, et al. (2020) Review of Chitosan-Based Polymers as Proton Exchange Membranes and Roles of Chitosan-Supported Ionic Liquids. Int J Mol Sci 21(2): 632.

11. Abbaraju RA, Dashupta N, Virkar AV (2008) Composite Nafion Membranes Containing Nanosize TiO_2/SnO2 for

Proton Exchange Membrane Fuel Cells. J Electrochem 155(12).

12. Bnard P, Chahine R (2007) Storage of hydrogen by physisorption on carbon and nanostructured materials. Scripta Materialia 56(10): 803-808.
13. Avery T (2022) Alternative hydrogen storage methods offer higher density, lower cost, ambient temperatures. Scilight (24): 241101.
14. Mohammad MS, Sahar M, Mehrorang G, Hadi H, Roy VAL (2021) Carbon based materials: a review of adsorbents for inorganic and organic compounds. Mater Adv 2(2): 598-627.
15. Fukuda K, Yu K, Someya T (2020) The future of flexible organic solar cells. Adv Energy Mater 10(25): 2000765.
16. Qazi S (2016) Fundamentals of Standalone Photovoltaic Systems. Standalone Photovoltaic (PV) Systems for Disaster Relief and Remote Areas Elsevier pp: 31-82.
17. ElKhamisy K, Abdelhamid H, El Rabaie ESM, Abdel Salam N (2023) A Comprehensive Survey of Silicon Thin-film Solar Cell: Challenges and Novel Trends. Plasmonic.
18. Lina W, Mavd PRT, Ahmad A, Haoshui Y, Ismail KAR, et al. (2022) A holistic and state-of-the-art review of nanotechnology in solar cells. Sustainable Energy Technologies and Assessments 54.
19. Nozik AJ (2002) Quantum dot solar cells. Physica E: Low-dimensional Systems and Nanostructures 14 (1-2): 115-120.
20. Hendi AA, Alanazi MM, Wadha A, Taghreed A, Awad MA, et al. (2023) Dye-sensitized solar cells constructed using titanium oxide nanoparticles and green dyes as photosensitizers, Journal of King Saud University-Science 35(3).
21. Mousumi S (2020) Nanocomposite Materials. Nanotechnology and the Environment.
22. Mishra Ak, Valodkar MC (2017) Polymer Nanocomposites for Energy and Fuel Cell Applications. Properties and Applications of Polymer Nanocomposites pp: 107-137.
23. Beata K, Marita P, Łukasz R, Paweł F (2021)Modern Nanocomposites and Hybrids as Electrode Materials Used in Energy Carriers. Nanomaterials 11(2): 538.
24. Tan DKY, Amthor JS (2013) Bioenergy. Photosynthesis.
25. Bood MR (2023) California lawsuit says oil giants deceived public on climate, seeks funds for storm damage. Britanicca.
26. Osman AI, Mehta N, Elgarahy AM, Al Hinai A, Al Muhtaseb AH, et al. (2021) Conversion of biomass to biofuels and life cycle assessment: a review. Environ Chem Lett 19: 4075-4118.