Nanomaterials in Environmental Protection

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Abstract:
Developments in nanotechnology have led to the formation and use of carbon nanomaterials. These advance materials have wide range of engineering applications owing to chemical features, electronic properties, mechanical robustness, thermal stability, and physical characteristics. Carbon nanomaterials have also been employed in broad technological perspectives such as renewable energy sources, waste water treatment, air pollution monitoring, and biotechnology. This review focuses great potential of carbon nanomaterials in various environmental fields. Contribution of carbon nanomaterials in terms of large scale application, low cost, and potential hazards have been discussed.

Keywords: Nanomaterial; properties; renewable energy; water treatment; pollution

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1. Introduction

Carbon nanomaterials have revolutionized the future nanotechnology area. Benefits of nanomaterials depend on the fact that it is possible to tailor the structures for light weight, low cost, and specific high performance and properties. The nanocomposites have been prepared using nanocarbon and matrix materials [1-3]. Nanocarbon possess fine sensitivity, hybridization states, and exceptional physical, chemical and electronic properties [4-6]. Nanomaterials have been successfully employed in new technologies and applications. Nanomaterials are used to design commercial products relying on nanoscale features and processes. Nanoscale additives and surface treatments may provide cost-effective, weight less, strength, wear resistance, thermal stability, electrically conductive, and low bacterial growth. Thus, nanomaterials have unique and tunable properties for potential environmental systems [7-10]. Nanomaterials have been used to design flexible nanoscale sensors, electronics, rechargeable batteries, supercapacitors, and solar energy devices. The materials must have efficient waste water reuse, pollutant sorption, optimum environmental degradation, and energy efficiency. Future of nanotechnology will offer promise of developing multifunctional materials for automotive, aerospace, and efficient space vehicles. In this article, current solicitations of nanomaterials in renewable energy devices, waste water treatment, air pollution intensive, and biotechnology have been explored. Green nanocomposite design with better compatibility, biodegradability, recyclability, low cost, physical properties, and large scale applications were also focused.

2. Nanomaterials in environment

Carbon nanomaterials have found great success in renewable energy sources (Fig. 1). These nanomaterials are essential to meet the needs of advance renewable energy technologies [11-20]. Advance photovoltaic devices generally have drawbacks of high cost and low stability. Carbon nanomaterials can be employed in semiconductor-based photovoltaic devices [21-30]. Besides, nanocarbon has also been researched for developments in hydrogen storage. In green energy technologies, hydrogen has been used as a clean fuel compared with the conventional fuel. Environmental friendly electrochemical capacitors or supercapacitors have been used to substitute traditional batteries. Green supercapacitors have high surface area thin layered electrolyte or electrode. Such devices may produce high power density, high energy density, and long cycle life. Carbon nanotubes and other nanocarbon have also found potential in air pollution. Nanocarbon has fine electrochemical, electrical, and optical properties. Nanocarbon has potential application in sensing of toxic gases in environment [31-35]. Nanocarbon-based gas sensors offer advantages over conventional gas sensors [36-40]. These gas sensors possess high sensitivity, low power consumption, and low operating temperature. Fig. 2 shows nanomaterial-based gas sensor. The sensor has shown changes of resistance or conductance upon direct gas contact.
Renewable Energy

Fig. 1 Renewable energy sources.

Fig. 2 Gas sensor.
It is a worldwide concern to improve the quality of water. Carbon nanomaterials have also been used in waste water treatment [41-45]. These materials may remove non-degradable, highly toxic, and carcinogenic heavy metal ions. The carbon nanotubes are excellent and effective adsorbent for eliminating toxic agents such as lead, cadmium, and mercury from water. Fig. 3 shows removal of contaminants from water through sorption behavior. This method has been used to purify water discharged from domestic, industrial or agricultural sources. These nanomaterials have high surface area, active sites, pore size distribution, and exceptional sorption capability [46-50].

![Sorption behavior of nanosorbents.](image)

The adsorption capacity of nanocarbon relies on surface functionalities and nature of the sorbate. The nanomaterials have specific adsorption capacity towards non-polar aromatic hydrocarbons [51-55]. Carbon nanomaterials have been assessed in biotechnology [56-58]. Advancements in biotechnology has led to the development of biological fuel cells or biofuel cells. It is a new environmental friendly technology. Fig. 4 shows biocatalytic activity of biofuel cell to generate electricity. The use of nanocarbon electrodes has increased the power production owing to high conductivity and large surface area [59-61]. Nanocarbon materials must have superior chemical and physical properties crucial for the development of electrodes. Different CNT-based composite electrode membranes in have been studied in such systems. Improvements are needed to control effluent quality and overcomes the involved deficiencies. Future studies may lead to microbial fuel cells and enzymatic biofuel cells to generate higher electric power.
3. Design of renewable nanocomposite

Despite of the use of nanocomposites, synthetic polymer wastes may cause undesirable impact on the environment [62]. Modern efforts have focused the better product design and recycling/re-use of waste plastics [63]. Non-renewable petroleum-based polymers have been replaced with biodegradable polymers having great commercial value. Green nanocomposites have been prepared using biodegradable polymers for next generation materials [64]. Nanocarbon-nano-reinforcement has been employed in biodegradable polymers to offer enhanced durability, mechanical properties, and thermal stability. The biodegradable polymer/nanocarbon nanocomposite must possess better nanofiller alignment, dispersion, and interfacial adhesion between matrix/nanofiller [65]. Thus, green nanocomposite rely on natural renewable resources with better recyclability and degradability. After nanocomposite degradation, the recovered nanocarbon may be used as reinforcement filler for producing new nanocomposite.
4. Summary

In this article, applications of carbon nanotube nanocomposites have been discussed for environmental systems. The nanocomposite-based ecofriendly electronics, batteries, fuel cell, and capacitors have been employed as an alternative way to replace traditional devices. In the case of green energy production, challenges have been tried to overcome in the case of biofuel cell, solar cell, photovoltaic device, batteries and supercapacitor. In environmental pollution monitoring, CNT-based gas sensors have been developed. For waste water treatment, nanotubes have been employed as nanosorbent materials for the removal of toxic pollutants in water. In green environmental materials, reuse, recyclability, and large scale use have been promoted. Since the health implications of CNT-based nanomaterials, environmental and human exposure to nanotube have also been focused. Modified nanoparticles have been efficiently used in environmentally safe materials. However, critical developments are needed to meet the long term environmental protection challenge.

References


