INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 6)
Available online at: www.ijariit.com

A review on types of nanocomposites and their applications

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ABSTRACT

The world becomes smaller and smaller due to the development of nanotechnology. The term nanotechnology defines the performance on a nanometer scale with many applications. Nanocomposites are materials made of different components and mixed at nanoscale which draws unusual properties with unique design possibilities. In this present work, various recent applications of nanocomposites were discussed. The potential of nanocomposites is used in various areas ranging from food packaging to biomedical applications. Nanocomposites are environment-friendly so they offer new technology and business opportunities for several sectors of the aerospace, automotive, electronics and biotechnology industries, medical, food industries etc.

Keywords— *Nano composites, Types, Fuel cell applications, Biomedical, Electronics, Aerospace applications*

1. INTRODUCTION

The term "nanotechnology" can be defined as the controlled manipulation of materials with at least one dimension less than 100nm. This technology attempts to integrate chemistry, physics, material science, and biology to create new material properties that can be exploited to develop facile processes for the production of electronic devices, biomedical products, high-performance materials, and consumer articles. The field of nanotechnology is one of the most popular areas for current research and development in basically all technical disciplines. Nanocomposites comprise multiphase materials such as metals, polymers inorganic ceramics where at least one constituent has one dimension less than 100nm.

Nanocomposites are the materials of the twenty-first century having an annual growth rate of 25% due to their multifunctional capabilities as well as with unique design possibilities and properties. The nanocomposite material has been used to encompass a large variety of systems such as one-dimensional, two-dimensional, three-dimensional and amorphous materials made of distinctly dissimilar components and mixed at the nanometer scale. Polymer nanocomposites comprising nanoparticles. The methods used for preparing nanocomposites may vary from mechanical and chemical routes vapor phase deposition, mainly depending on the type of matrix used. Chemical property like resistance or passiveness to corrosion is very important. Being environment-friendly, few nano composites have the possibilities of clean technologies. Proper choice of nanofillers and matrix is key in achieving the desired multifunctional properties that are required by many aerospace applications.

1.1 Types of nanocomposites

According to the matrix materials, nanocomposites are classified as:

- Ceramic Matrix Nanocomposites(CMNC)
- Metal Matrix Nanocomposites(MMNC)
- Polymer Matrix Nanocomposites(PMNC)

Ceramic matrix nanocomposites mainly has Al_2O_3 or SiC system. Most studies reported so far have confirmed the noticeable strengthening of the Al_2O_3 matrix after addithe on of a low (i.e appro: 10%)volume fraction of SiC particles of suitable size and hot pressing of the resulting mixture.

Metal matrix nanocomposites (MMNC) refer to materials consisting of a ductile metal or alloy matrix in which some nanosized reinforcement material is implanted. These materials combine metal and ceramic features.

Polymer matrix nanocomposites are widely used in industry to their ease of production, lightweight and ductile nature. They have some disadvantages such as low modulus and strength compared to metals and ceramics.

Table 1: Different types of nanocomposites

Class	Examples
Metal	Fe-Cr/Al_2O_3, Ni/Al_2O_3, Co/Cr, Fe/MgO, Al/CNT, Mg/CNT
Ceramics	Al_2O_3/SiO$_2$, SiO$_2$/Ni, Al_2O_3/TiO$_2$, Al_2O_3/SiC, Al_2O_3/CNT
Polymer	Thermoplastic/thermoset polymer/layered silicates, polyester/TiO$_2$, polymer/CNT, polymer/layered double hydroxides

Among the structural applications, nanocomposites have been the most studied and used materials because of their application in all sectors from domestic to aerospace. Here applications like fuel cell applications, biomedical applications, and electronic applications and in aerospace are reviewed.

2. APPLICATIONS

2.1 Fuel cells

Fuel cell applications involve polymers in the proton exchange membrane, binder for the electrodes and matrix for bipolar plates. The electrodes are of carbon black particles with Pt catalyst particles and a polymeric binder(Nafion). Nanoparticles play a major part in fuel cells. Pt nanoparticles deposited onto single-walled carbon nanotubes with Nafion as a binder to improve performance over the conventional carbon black based electrodes. Nanoparticles incorporation in the proton exchange membrane has been noted in numerous publications to improve mechanical properties as well as to enhance proton conductivity. Nanoparticles have been used to reduce methanol crossover. Heteropolyacids have been added to proton exchange membrane to yield improved proton conductivity at a higher temperature. Silica nanoparticle in proton exchange membranes gave lower methanol crossover. Nano clay modified Nafion and montmorillonite membranes have been reported to offer improvements over the unmodified controls. Zirconium phosphate, Zirconium hydrogen phosphate, and $\mathrm{Ti}O_2$ in proton exchange membranes exhibited promise in direct methanol fuel cells. These are mthe ain application of nanocomposites in fuel cells.

2.2 Biomedical applications

The use of nanocomposites in biomedical applications is one of the growing fields in nanotechnology. One area intense research involves electrospinning or producing bio restorable nanofiber scaffolds for tissue engineering applications. Another area involving nanofibers is the utilization of electrically conducting nanofibers based o conjugated polymers for regeneration of nerve growth in a biological system. Nanoparticle silver, silver oxide, and silver salts have been incorporated into polymer matrices to provide antimicrobial activity. Polymer nanocomposites based on hydroxyapatite $[Ca_{10}(PO_4)_6(OH)_2]$ have been investigated for bone repair and implantation. Hydroxyapatite, a major constituent of hard tissue exhibits undesirable mechanical properties if directly employed thus polymer-based matrix nanocomposites are desired. Collagen derived gelatin and poly-2-hydroxyethyl methacrylate/poly (3-caprolactone) nanocomposites based on hydroxyapatite are examples of systems studied for bone repair systems. Electrospinning of biodegradable polymer solutions is a popular method to produce nanofiber scaffolds for tissue engineering applications. Poly (L-lactic acid)/exfoliated montmorillonite clay/salt solutions were electro spun followed by salt leaching/gas foaming. Polymer matrix nanocomposites have been proposed for drug delivery/release applications. Iron oxide nanoparticles have been used for various applications including drug delivery, magnetic resonance imaging contrast enhancement, immunoassay, and cellular therapy. Iron and cobalt nanoparticles encapsulated in polydimethylsiloxane have been noted for treating retinal detachment disorders.

2.3 Electronics

Nanotechnology is deeply embedded in the design of advanced devices for electronic and optoelectronic applications. The dimensional scale for electronic devices has now entered the nano range. The utility of polymer-based nanocomposites in these areas is quite diverse. One specific nanocomposite types involve conjugated and carbon nanotubes. It has potential applications includes photovoltaic cells, photodiodes, superconductors, sensors, light emitting diodes, and field effect transistors. Silicon-based photovoltaic devices offer high efficiency, excellent stability and proven commercial utility. Organic/polymer based PV devices offer the potential for lower cost and more flexible manufacture but some improvements in both efficiency and long-term stability. The emerging interest of graphene in electronics applications parallels which occurred with carbon nanotube discovery. Conjugated polymers with various nanoscale filler inclusions have been investigated for sensor applications including gas sensors, biosensors, and chemical sensors. A nanocomposite of SWCNT yielded a gas sensor sensitivity similar to SWCNT alone. The sensing capability of these nanocomposites can be based on conductivity changes due to gas or chemical interactions with either the nanofiller or the conjugated polymer.

2.4 Aerospace applications

In some applications, apart from being lightweight, high performance is of prime importance in aerospace structures e.g., equipment enclosures, aircraft interiors, coatings, cockpit, crew gear, space durable mirrors, nozzles and solar array substrates. Nanocomposite materials offer chemical stability and fire resistance apart from the advantage of low operating cost due to their lightweight. Aerospace structures are subjected to a diverse environment that includes variations in moisture and temperature. They are also subjected to contact with jet fuel, deicing fluid, and hydraulic fluid. The coatings should withstand lightning strikes, ultraviolet exposure, and erosion.

3. CONCLUSION

Nanocomposites are realizing many key applications in numerous industrial fields, an array of technical and economic barriers exists to their widespread commercialization. The application of nanocomposites in four different fields is reviewed through this paper. Thus the idea about nanocomposites in various fields is gained.

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