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Polymer Nanocomposites and their Applications in Electronics Industry

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Abstract

There is a lot of thrill in a new area of research called Nanotechnology. The term nanotechnology describes a range of the technologies performed on a nanometer scale with widespread applications. Lot of research has been going on in finding nanomaterials. An area of research under this field is Nanocomposites. They are material made by mixing of two different materials (with different properties) but one of them having the size in the range of nanoscale. Polymers Nanocomposites which are made up of polymer matrices and carbon nanotubes are a class of advanced materials with great application potential. By inserting the nanometric inorganic compounds, the properties of polymers improve and hence this has a lot of applications depending upon the inorganic material present in the polymers. They have high thermal, electrical and mechanical properties characteristic. In this paper we discuss polymer nanocomposites with carbon nanotubes as fillers and their application in electronics industry.

Keywords: nanotechnology, nanocomposites, polymer Nanocomposites, Electronics.

1. Introduction

Nanotechnology refers to a field of applied science which works on the argument of control of size of matter on an atomic and molecular scale. Generally nanotechnology deals with structures 100 nanometers or smaller, and involves developing materials or devices within that size [1].

Nanotechnology is an extremely diverse and multidisciplinary field, ranging from novel extensions of conventional device physics, to completely new approaches based upon molecular self-assembly, to developing new materials with dimensions on the nanoscale.

Nanotechnology has the potential to create many new materials and devices with wide-ranging applications, such as in medicine, Electronics, and energy production.

2. Nanomaterials

One nanometer (nm) is one billionth, or 10^{-9} of a meter. Thus Nanomaterials are materials in which a single unit is sized between 1 and 1000 nanometers. Nanomaterials research is a field that takes a materials science-based approach on nanotechnology. These materials often have special properties resulting from their size, shape, and chemical composition.

3. Carbon nanotube

They are a recently discovered unique material possessing amazing electronic, thermal, and structural properties. They are highly conductive both to electricity and heat, with an electrical conductivity as high as copper, and a thermal conductivity as great as diamond [3]. They offer amazing possibilities for creating future nanoelectronic devices, circuits and computers. Carbon nanotubes also have extraordinary mechanical properties - they are 100 times stronger than steel, while only one sixth of the weight [2]. Scientists are still working on finding ways to make carbon nanotubes a realistic option for transistors in microprocessors and other electronics.

4. Nanocomposite

A nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanometers (nm), or structures having nano-scale repeat distances between the different phases that make up the material. In the broadest sense this definition can include porous media, colloids, gels and copolymers, but is more usually taken to mean the solid combination of a bulk matrix and nano-dimensional phase(s) differing in properties due to dissimilarities in structure and chemistry. There are 3 major classification of nano composites and table 1 shows different examples in each category.

Ceramic matrix nanocomposites

- metal matrix nanocomposites
- polymer matrix nanocomposites

Different types of Nanocomposites

Table 1

Types	Examples
Ceramic	Al_2O_3/SiO_2, SiO_2/Ni, Al_2O_3/TiO_2, Al_2O_3/SiC
Metal	Fe-Cr/Al_2O_3,Co/Cr, Fe/MgO, Mg/CNT
Polymer	Thermoplastic/thermoset polymer/layered silicates, polyester/TiO2,polymer/CNT, polymer/layered double hydroxides.

The mechanical, electrical, thermal, optical, electrochemical, catalytic properties of the nanocomposites will differ distinctly from that of the component materials. Size limits for these effects have been proposed, <5 nm for catalytic activity, <20 nm for making a hard magnetic material soft, <50 nm for refractive index changes, and <100 nm for achieving super paramagnetism, mechanical strengthening or restricting matrix dislocation movement [4].

5. Polymer Nanocomposites:

Although polymers can be used as structural materials without reinforcement, their usage gets limited due to insufficient mechanical properties. Relatively low strength, coupled with low impact strength, is a characterization of polymer materials.

Polymer nanocomposites represent a new alternative to conventionally filled polymers. Polymer Nanocomposites are materials in which nanoscopic inorganic particles, typically 10-100 A in at least one dimension, are dispersed in an organic polymer matrix such as polyacetylene, poly thiophene, and polypyrrole.

Because of their nanometer sizes of the inorganic filler Nanocomposites exhibit markedly improved properties when compared to the pure polymers or their traditional composites [5, 6]

6. Enhancement in Properties

Polymer Nanocomposites has revealed clearly the property advantages that nanomaterial additives can provide in comparison to both their conventional filler counterparts and base polymer. Properties which have been shown to undergo substantial improvements include:

- Mechanicals e.g. strength, modulus and dimensional stability
- Improved solvent and heat resistance and decreased flammability.
- Decreased permeability to gases, water and hydrocarbons
- Thermal stability and heat distortion temperature
- Flame retardancy and reduced smoke emissions
- Chemical resistance
- Surface appearance
- Electrical conductivity
- Optical clarity in comparison to conventionally filled polymers

Applications

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 involving many potential applications and have been proposed for their use in various applications.

- They are used in chemical sensors, electroluminescent devices, electro catalysis, batteries, smart windows and memory devices.

- Another potential application includes photovoltaic (PV) cells and photodiodes, supercapacitors, printable conductors, light emitting diodes (LEDs) and field effect transistors [7].
- The electrical conductivity of carbon nanotubes in insulating polymers has also been a topic of considerable interest. The potential applications include electromagnetic interference shielding, transparent conductive coatings, electrostatic dissipation, super capacitors, electromechanical actuators and various electrode applications [8, 9].
- Conjugated polymers with various nanoscale filler inclusions have been investigated for sensor applications including gas sensors, biosensors and chemical sensors. The nanofillers employed include metal oxide nanowires, carbon nanotubes, nanoscale gold, silver, nickel, copper, platinum and palladium particles [10].
- The emerging interest of graphene in electronics applications parallels that which occurred with carbon nanotube discovery. Graphene, in sheet form, may offer promise in replacing silicon as Moore's law limits are achieved [11].
- Polymer-based solar cells have the capability of being used to make cheap large flexible panels. The only downside is substantially low efficiency compared to commercial solar cells [15]. Cadmium chalcogenides such as CdS nanoparticles in polymers have been used to make solar cells.
- Polymer semiconductor nanocomposites offer the promise of a new generation of hybrid materials with numerous possibilities of applications such as in optical displays, catalysis, photovoltaic, gas sensors, electrical devices, mechanics, photoconductors and superconductor devices [12].

7. Conclusion

This is concise introduction to polymer nanocomposites and their application in electronics industry. Although still challenges associated with the fabrication of polymer nanocomposites such as dispersion and alignment of carbon nanotubes but still existing data illustrate that their electrical and thermal conductivity values make them ideal candidates for use as TIMs as well as in those areas were electrically conducting pads are needed. Research efforts are focused in finding better ways to transfer the high thermal and electrical conductivity of carbon nanotubes to the polymer matrix in the nanocomposites. Nevertheless, there is hope that polymer/carbon nanotube nanocomposites might emerge has an amazing nanomaterial which helps in miniaturization of electronic devices.

References

[1] Drexler, K. Eric (1986). Engines of Creation: The Coming Era of Nanotechnology. Doubleday. ISBN 0-385-19973-2.

[2] Gullapalli, S.; Wong, M.S. (2011). "Nanotechnology: A Guide to Nano-Objects". Chemical Engineering Progress 107 (5): 28–32.

[3] Hsu, Hsin-Cheng; Chen-Hao Wang, S.K. Nataraj, Hsin-Chih Huang, He-Yun Du, Sun-Tang Chang, Li-Chyong Chen, Kuei-Hsien Chen (2012). "Stand-up structure of graphene-like carbon nanowalls on CNT directly grown on polyacrylonitrile-based carbon fiber paper as supercapacitor". Diamond and Related Materials 25: 176–9

[4] Kamigaito, O, What can be improved by nanometer composites? J. Jpn. Soc. Powder Powder Metall. 38:315-21, 1991 in Kelly, A, Concise encyclopedia of composites materials, Elsevier Science Ltd, 1994

[5] Mouritz AP, Gibson AG. Fire Properties of Polymer Composite Materials Pub Springer, 2006

[6] Hull TR, Kandola BK. Fire Retardancy of Polymers New Strategies and Mechanisms RSC 2009

[7] Baibarac M, Go´ mez-Romero P. J Nanosci Nanotechnol 2006;6:1–14.

[8] Baughman RH, Zakhidov AA, De Heer WA. Science 2002;297:787–92.

[9] Moniruzzaman M, Winey KI. Macromolecules 2006;39:5194–205.

[10] Sandler JKW, Kirk JE, Kinloch IA, Shaffer MSP, Windle AH. Polymer 2003;44: 5893–9.

[11] Van Noorden R. Nature 2006;442:228–9.

[12] Kothurkar N.K. Solid state, transparent, cadmium sulfide-polymer nanocomposite, University of *Florida 2004*