A review on nanocomposites, it's structure, properties and applications

Ritwik Ghosh, Proloy Sarkar, Anjali Shaw, Tushar Agarwal and Shrey Rungta

September 18, 2019

A review on nanocomposites,it's structure, properties and applications

Ritwik Ghosh*,[1],Proloy Sarkar*,[2],Anjali Shaw*,[3],Tushar Agarwal*,[4],Shrey Rungta*,[5]

1.Department of Electrical Engineering,1st Year,Institute of Engineering and Management, Kolkata

2. Department of ECE,1st Year, Institute of Engineering and Management ,Kolkata

,3. Department of ECE,1st Year, Institute of Engineering and Management, Kolkata

4. Department of Information Technology,1st Year, Institute of Engineering and Management,Kolkata

5. Department of EEE,1st Year, Institute of Engineering and Management,Kolkata

Email:-ritwikghosh2001@rediffmail.com

ABSTRACT

In the large field of nanotechnology, nanocomposites have secured a premiere position for research and development.Nanocomposites are raw materials with one component of nanosize.These materials exhibit unusual property combinations and unique design possibilities,thus they are in great demand in engineering plastics and elastomers.As the materials are environmental friendly,they offer new technologies to emerge out and cater to the needs of business opportunities in many fields.These materials have a wide range of application in construction, electrical equipments, aerospace industry.This review presents forward three types of matrix-based nanocomposites highlighting their needs,their processing methods,some latest results on their structures,properties, perspectives including their applications in future space mission.The uses of materials such as minerals, chrysolites and lignocellulosic fibers have also been brought to light in this review.

1.INTRODUCTION

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.They are treated as one of the emerging technologies of 21st century because unique design and property combinations that no other conventional composites posses.Nanocomposites have a wide range of application in nature.They are found in human bones,electrical equipments ,aerospace industry,etc.

According to latest reports,there can be changes in particle properties when the particle size is less than particular level, called critical size as shown in Table 1.Thus as the dimensions are of nanometre level,the phase interactions has got improvements and clarity in it,this leads to the enhancement of material properties.In this context it is important to know the surface area/volume ratio of the constituent materials ,required in preparing the nanocomposites to understand vividly their structure-property relationship.The discovery of carbon nanotubes(CNTs) in 1991 and their applications in the field nanocomposites brought to light and extra edge in this area.Nowadays nanocomposites offer adequate number of new technologies and business opportunities for all sectors of industry,moreover they are environmental friendly.

Table 1

Properties	Feature size(nm)at which changes might be expected
1.Catalytic property	<5
2.Making hard magnetic material soft	<20
3.Producing refractive index changes	<50
4.Producing superparamagnetism	<100
5.Producing toughening and strengthening.	<100
6.Modifying hardness and plasticity	<100

Nanocomposites can be broadly classified into three categories,as shown in Table 2:-

1. Ceramic Matrix Nanocomposites (CMNC);

2.Metal Matrix Nanocomposites (MMNC) and

3.Polymer Matrix Nanocomposites (PMNC).

Table 2. Different types of nanocomposites.

Class	Examples
Metal	Fe-Cr/Al_2O_3, Ni/Al_2O_3, Co/Cr, Fe/MgO, Al/CNT, Mg/CNT
Ceramic	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.

2.Structure and properties of nanocomposites

Nanocomposites have unique properties and well designed structure. The structure of nanocomposites usually consists of the matrix material containing the nanosized reinforcement components in the form of particles, whiskers, fibres, nanotubes, etc. A huge number of scientist and researchers have worked out various techniques and equipments for having a detailed analysis of the structures and properties of nanocomposites.some of the notable techniques include Fourier transformed infrared spectroscopy(FTIR),atomic force microscopy(AFM) ,X ray photoelectron spectroscopy(XPS),nuclear magnetic resonance(NMR),small angle X-ray scattering (SAXS),X-ray diffractometry(XRD).AFM is a powerful tool that can even vividly analyse surfaces even down to namometer scaleaccording to the work of Veith.SAXS and XRD have been recently used for quantitative analysis.Moreover various mathematical calculations have also come up to predict strength properties including stress,strain curves of nanocomposites.

2.1 Properties of Ceramic matrix nanocomposites

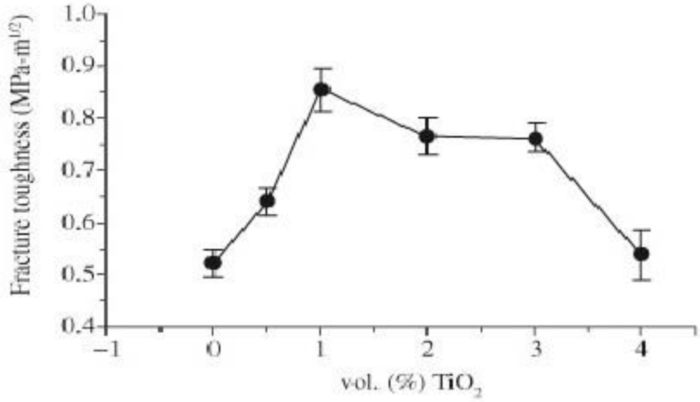
Ceramic matrix nanocomposites are brittle and are prone to fractures but there have been made various attempts to improve their properties and make them suitable for engineering applications.This would lead to their improvements of mechanical properires such as hardness and fracture toughness.They can enhance optical ,electrical and magnetic properties as well. The table below shows some examples of ceramic matrix nanocomposites and their improved properties. NB

Examples of ceramic matrix nanocomposites and their properties.

Matrix/Reinforcements	Properties
Si_3N_4/SiC	Improved strength and toughness
$MoSi_2$/ZrO_2	-
B_4C/TiB_2,	-
Al_2O_3/SiC	-
MgO/SiC	-
Mullite/SiC	-
Al_2O_3/ZrO_2	-
Al_2O_3/Mo, Al_2O_3/W	-
Al_2O_3/$NdAlO_3$	Improved photoluminescence

2.2 Properties of Polymer-based nanocomposites

The most emerging class of nanocomposites are the polymer-based nanocomposites because of their uniqueness in properties and structures.They exhibit stiffness, strength and dimensional stability in two di-mensions. The below graph shows Variation of quasi-static fracture toughness as a function of volume fraction of TiO_2 nanoparticles in the polyester/TiO_2 nanocomposite, a special polymer based nanocomposites.



(Above graph referred from **A research paper on ‘** *Nanocomposites: synthesis, structure, properties and new application opportunities’.)*

3.APPLICATION OF NANOCOMPOSITES

Thus from above discussions, it is quite evident that nanocomposites may provide numerous benefits such as enhanced properties, reduction of solid wastes [lower gauge thickness films and lower reinforcement usage] and improved manufacturing capability, particularly for packaging applications. It can be observed, the promising applications of nanocomposite systems are numerous, comprising both the generation of new materials and the performance enhancement of known devices such as fuel cells, sensors and coatings. Although the use of nanocomposites in industry is not to a huge extent but their massive switching from research to industry has already started and is expected to show a steep rise in the next few years.

“One of the leading application areas is the automotive sector, with striking impact due to improved functionalities such as ecology, safety, comfort, etc. Details on the commercial usage of nanocomposites in automotives and future developments in this sector (including CNT-based nanocomposites) are now available. For instance, there are reports on the current use of a number of nanocoatings in different parts of Audi, Evobus and Diamler Chrysler automobiles, as well as ongoing trials on fuel cells, porous filters (foams) and energy conversion components, which include nanoTiO2-containing paints. Additionally, light weight bodies made of metal- or polymer-based nanocomposites with suitable reinforcements are reported to exhibit low density and very high strength (e.g. carbon Bucky fibers, with strength of 150 GPa and weight ≈ 1/5th of steel). Also, two-phase heterogeneous nanodielectrics, generally termed dielectric nanocomposites, have wide applications in electric and electronic industries."

The table below shows some more applications of nanocomposites:-

Potential applications of metal nanocomposite systems.

Nanocomposites	Applications
Fe/MgO	Catalysts, magnetic devices.
Ni/PZT	Wear resistant coatings and thermally graded coatings.
Ni/TiO_2	Photo-electrochemical applications.
Al/SiC	Aerospace, naval and automotive structures.
Cu/Al_2O_3	Electronic packaging.
Al/AlN	Microelectronic industry.
Ni/TiN, Ni/ZrN, Cu/ZrN	High speed machinery, tooling, optical and magnetic storage materials.
Nb/Cu	Structural materials for high temperature applications.
Fe/Fe_{23}C6/Fe_3B	Structural materials.
Fe/TiN	Catalysts.
Al/Al_2O_3	Microelectronic industry.
Au/Ag	Microelectronics, optical devices, light energy conversion.

4.CONCLUSION

Nanocomposites are the emerging technologies which can meet the both the scientific and industrial demands.No doubt they are going to dominate the future world of technologies.They are both structural and thermal stability,easy to be manufactured though processing of some of the nanocomposites pose a challenge ,they offer improved performance over monolithic and microcomposite counterparts and are consequently suitable candidates to overcome the limitations of many currently existing materials and devices. A number of applications already exists, while many potentials are possible for these materials, which open new vistas for the future. But at the same time there exists some disadvantages also.They have non-uniform distribution and high viscosity which can cause blunders in some researches and experiments.Thus we need to use nanocomposites wisely.

ACKNOWLEDEGEMENT

We are grateful to the publishers of the journal for publishing this paper and all our Chemistry professor for his guidance and motivation in this work.

REFERENCES

1. **Pedro Henrique Cury Camargo; Kestur Gundappa Satyanarayana*; Fernando Wypych. A research paper on '** *Nanocomposites: synthesis, structure, properties and new application opportunities'.*

2. D.R. Paul , L.M. Robeson .A review paper on '*Polymer Nanotechnology:Nanocomposites'*