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A REVIEW ON NANOCOMPOSITES

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Abstract: This article overviews classification of nanocomposite according to their matrices, reinforcement, dimensional morphology and on the basis of their method of synthesis. . Nanocomposites are multiphase materials with one or more phases in nanoscale dimensions Nanocomposite materials have emerged as suitable alternatives to overcome limitations of microcomposites and monolithics Nanocomposites, a high performance material exhibit unusual property combinations and unique design possibilities. Being environmentally friendly, thermally stable and mechanically strong applications of nanocomposites offer new technology and business opportunities for several sectors of the aerospace, automotive, electronics, biomedical, tissue engineering, wound healing, drug delivery, gene therapy and food packaging .Nanocomposites themselves encompass a very broad category of materials. The classification of nanocomposites according to their matrices shows the existence of three main categories of materials: metal matrix, ceramic matrix and polymer matrix nanocomposites. On the basis of reinforcement nanocomposites are classified as fibre, laminar and particulate reinforced nanocomposites. According to the dimensions nanocomposites may be classified as nanoparticles, nanotubes, nanowires and layered silicates.

Keywords: Nanocomposites, matrix, polymer, nanoparticle.

1. Introduction:

. The properties of composite materials like mechanical strength, high toughness corrosion resistance and electrical or thermal conductivity Optical clarity Chemical resistance Surface appearance may be improved by lowering fillers size, leading to the development of nanocomposites. Nanocomposites are multiphase materials with one or more phases in nanoscale dimensions (1 nm = 10^{-9} m) like nanoparticles, nanotubes, or lamellar nanostructures are embedded in a metal, ceramic, or polymer matrix **[1]**. They are expected to show unusual improved properties emerging from the combination of each component. The improvement of the properties by the addition of particles can be achieved when there is adequately good interaction between the nanoparticles and the matrix and good dispersion of particles within the matrix **[2]**. Nanocomposite materials have emerged as suitable alternatives to overcome limitations of microcomposites and monolithic.

In nanocomposites the matrix and filler components may be bonded together by covalent bonds, ionic bonds, Vander Waals forces, hydrogen bonding. The general idea behind the addition of the nanoscale second phase is to create a synergy between the various constituents, such that novel properties capable of meeting or exceeding design expectations can be achieved. The properties of nanocomposites rely on a range of variables, particularly the matrix material, which can exhibit nanoscale dimensions, loading, degree of dispersion, size, shape, and orientation of the nanoscale second phase and interactions between the matrix and the second phase **[3]**. These nanocomposites show potential to be used in variety of different biomedical applications such as tissue engineering, therapeutic delivery, stem cell modulation and medical devices. Nanocomposites are reported to be the materials of 21^{st} century in the view of possessing design uniqueness and property combinations that are not found in conventional composites **[4]**.

2. Classification of nanocomposites

The two main constituent materials of nanocomposites are matrix and reinforcement. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart special physical properties like mechanical and electrical to enhance the matrix properties.

2.1 Based on matrices

The matrix is the continuous monolithic material into which the reinforcement is embedded. On the basis of the nature of the matrices, nanocomposites can be classified into three major categories:

Metal matrix nanocomposites (MMNC)

Metal matrix nanocomposites (MMNC) refer to materials consisting of a ductile metal or alloy matrix in which some nanosized reinforcement material generally ceramic is implanted. These materials combine metal and ceramic features such as ductility and fracture toughness with high specific strength and modulus, lower coefficients of thermal expansion and high wear resistance. Therefore metal matrix nanocomposites are suitable for production of materials with high strength in shear/compression processes and high service temperature capabilities. The reinforcements are in the form of particulates, whiskers or fibres, for example TiC, SiC or alumina particles are used in AlMMCs and carbon fibre used in MgMMCs. Some of MMCs for aerospace applications are copper based matrices, which have been reinforced by carbon fibres **[5]**.

Ceramic matrix nanocomposites (CMNC)

Ceramic matrix nanocomposites contain oxides, carbides, and nitrides in combination with metallic or nonmetallic elements. Coatings of transition metal oxides reveal properties better than other metallic or organic oxides even at few nanometer thicknesses, due to their phase stability and fracture toughness. Ceramic nanocomposites have been applied to many industrial applications due to their remarkable properties such as resistant to corrosion, high temperature oxidation, and good wear resistance than that of metals in high-temperature environments. In ceramic matrix nanocomposite, matrix (polycrystalline ceramics, glass) is reinforced by the addition of particles, flacks, fibres or even voids **[6]**. CMCs can be used in medical devices, implants, load bearing structural parts, wear or friction surfaces, and aerospace and power generation applications.

Polymer matrix nanocomposites (PMNC)

Polymers are commonly used matrices for composites and polymeric composite materials represent about 90% of all composites. The polymer matrix system can be a thermoplastic, thermoset, or elastomer. Polymers are ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. These materials are made up of either particle or fiber reinforcement **[7]**. In the case of nanoparticles, the particle size and distribution are of great importance. Depending on the type of nanoparticles added, the mechanical, electrical, optical, and thermal properties of polymer nanocomposites can be altered. In the field of mechanical properties, the changes in modulus and strength depend strongly on the degree of interaction between the particle and the polymer. Application of PMCs in various field include aerospace, boats, electronic and medical industries **[8]**.

2.2 Based on reinforcement

Reinforcing constituents in composites provide the strength and certain additional properties of heat resistance or conduction, resistance to corrosion and rigidity. A reinforcement that embellishes the matrix strength must be stronger and stiffer than the matrix .Reinforcement can be made to perform all or one of these functions as per the requirements. On the basis of the reinforcement form, nanocomposites can be classified into three major groups:

Fibre reinforced composites

Composite materials can be reinforced by organic and inorganic fibers. Almost all organic fibers have low density, flexibility, and elasticity. Inorganic fibers have high modulus, high thermal stability and possess greater rigidity than organic fibers. Generally glass fibers, silicon carbide fibers, high silica and quartz fibers, aluminum fibers, metal fibers and wires, graphite fibers, boron fibers and multiphase fibers are used **[9]**.

Fiber-reinforced nanocomposites can be prepared in two ways one by using nanofibres to reinforce nanocomposite and other by incorporating nanomaterials into fiber-reinforced composites The performance of a fibre composite is judged by its length, shape, orientation, and composition of the fibers and the mechanical properties of the matrix.

Laminar composites

Laminar composites can be described as materials comprising of layers of materials bonded together. These may be of several layers of two or more metal materials occurring alternately or in a determined order more than once, and in as many numbers as required for a specific purpose. Sandwich structures fall under this category.

Particulate reinforced composites

Particulate Composites consist of a matrix body reinforced with a dispersed phase in the form of particles. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category. The type, shape, and spatial arrangement of the reinforcing phase are the key parameters in determining the mechanical behavior of the composite.Particle reinforcing in composites is a less effective means of strengthening than fibre reinforcement. Particulate reinforced composites achieve gains in stiffness primarily, but also can achieve increases in strength and toughness. In all cases the improvements are less than would be achieved in a fibre reinforced composite. Particulate reinforced composites find applications where high levels of wear resistance are required such as road surfaces. The hardness of cement is increased significantly by adding gravel as reinforcing filler. The principal advantage of particle reinforced composites is their low cost and ease of production and forming. Microstructures of metal and ceramics composites, which show particles of one phase strewn in the other, are known as particle reinforced composites. In particulate composites, the particles strengthen the system by the hydrostatic coercion of fillers in matrices and by their hardness relative to the matrix. The composite's strength usually depends on the diameter of the particles, the inter-particle spacing, and the volume fraction of the reinforcement **[10]**. The matrix properties influence the behaviour of particulate composite too.

2.3Based on nanomaterial's dimensional morphology

On the basis of nanomaterial dimension nanocomposites can be classified into following categories **[11-12]**

Zero dimensional nanomaterials such as nanoparticles

Nanoparticles (NPs) are wide class of materials that include particulate substances, which have one dimension less than 100 nm at least**[13].**The importance of these materials realized when researchers found that size can influence the physiochemical properties of a substance e.g. the optical properties. These NPs showed characteristic colors and properties with the variation of size and shape, which can be utilized in bioimaging applications **[14].**

One dimensional nanomaterials such as nanowire and nanotube

A nanowire is any solid material in the form of wire with diameter smaller than about 100 nm and hollow nanowire, typically with a wall thickness on the order of molecular dimensions is nanotubes. The smallest and most interesting nanotube is the single-walled carbon nanotube (SWNT) consisting of a single graphene sheet rolled up into a tube. Nanowire and nanotubes are the most confining electrical conductors **[15].**

.**Two dimensional nanomaterial such as silicate layers**

In recent years, silica films have emerged as a novel class of two-dimensional (2D) materials. The structures consist of tetrahedral [SiO_4] building blocks in two mirror symmetrical planes, connected via oxygen bridges. This arrangement is called a silica bilayer as it is the thinnest 2D arrangement with the stoichiometry SiO_2. With all bonds saturated within the nano-sheet, the interaction with the substrate is based on van der Waals forces. Complex ring networks are observed, including hexagonal honeycomb lattices, point defects and domain boundaries, as well as amorphous domains. The network structures are highly tuneable through variation of the substrate, deposition parameters, and cooling procedure, introducing dopants or intercalating small species **[16].**

Three dimensional nanomaterial such as zeolites

Zeolites are low-density, crystalline aluminosilicate materials referred as molecular sieves. They possess regular micropores with a dimension range of 0.3–2 nm [1]. 232 different zeolite framework types are currently known [2]. Depending on the structure type the zeolite framework composition can be varied and the diversity of zeolitic materials is extremely large, from both structural and chemical points of view. Zeolite structures comprise channels and cages that make the crystalline frameworks accessible to foreign species. Thus they offer great advantages with respect to non-porous solids and the available surface for bulk materials depends on the particle size. Hence, therefore available surface can be increase by decreasing the size of the crystals and respectively increase the portion of the atoms that are on the crystal surfaces **[17].**

2.4 Based on kind of synthesis procedure

On the basis of procedure applied for synthesis of nanocomposite it may be classified into following categories **[18-19]**

- Direct incorporation of nanoscale into a polymer melt or solution, such as addition of several types of metal oxides and hydroxides to polymeric matrix.
- In situ generation of nanoscale building blocks in a polymer matrix (reduction of metal ions in polymer matrix). For example for synthesis of polyaniline /cadmium sulfide, polyaniline was dissolved in dimethyl formamide solution, then dimethyl cadmium was added and simultaneously H_2S was passed through solution.
- Polymerization of monomers in the presence of nanoscale building blocks, such as polymerization of methyl metha acrylate or styrene in present nanoparticles.
- A combination of polymerization and formation of nanoscale building blocks for example intercalation of monomers into layered structures followed by polymerization.

3. Future prospects

Nanocomposite materials continue to be integral parts of our daily lives. Nanocomposites have a wide range of applications from sports equipments to transportation vehicles **[20-21]**. The dimensional scale for electronic devices has now entered the nanorange. The electrical conductivity of carbon nanotubes in insulating polymers has now become a topic of considerable interest. The utility of polymer based nanocomposite in these areas is quite diverse involving many potential applications including photovoltaic cell and photodiodes, super capacitors, sensors, LED'S, field effect transistors, electromagnetic interference shielding, transparent conducting coating, electrostatic dissipators, electro mechanic actuators and various electronic applications **[22]**. The applicability of polymer nanotechnology and nanocomposites to emerging biomedical and biotechnological applications is a rapidly emerging area. The physical properties of polymer nanocomposites make them attractive for a variety of biomedical and pharmaceutical applications like Drug delivery, Wound healing, Tissue engineering and Gene delivery. Due to their biodegradability and biocompatibility they are also finding useful role in Food packaging applications.

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