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Nanocomposites – An Overview of classification and Applications

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Abstract

Nanocomposites are materials that are heterogenous or hybrid synthesized by incorporating nanosized particles obtained from standard material with unique property combinations. Nanocomposites will have complicated structures. The overall structure of the nanocomposites will be based on the individual component composition, structure, their interfacial interactions. Increased demand of nanocomposites makes them a potential option in industrial application from small scale to large scale manufacturing industries. Applications of nanocomposites are increasing significantly due to their high performance in areas of automobile, construction, electronics, information technology sectors, food packaging to biomedical applications. Nanocomposites are synthesized by different experimental techniques based on the factors like analysis, cost control methods, refined process. Aim of this review is to know about the different types of nanocomposites and its classification, properties with its applications. This review includes the classification of nanocomposites, properties, and benefits applications. Nanocomposites are of lightweight, they are scratch-resistant, they possess higher heat distortion performance characteristics. The high heat resistance and low flammability of some nanocomposites also make them good choices to use as insulators and wire coverings and environmentally friendly. The study indicates the methods of nanocomposite synthesis, techniques used for the synthesis of nanocomposites. Different methods of synthesis influence the physical nature; its chemical behavior, interaction, optical properties and cost of production. Outcome of this study is to identify the possible better method for the synthesis of nanocomposites. Hence the present review is made to have a broad outlook on the techniques used for synthesis of nanocomposites, their applications.

Keywords: nanocomposites; chemical behavior; heat resistance

Introduction

Composites consist of two or more materials. They have multipurpose applications as they are derived by combining the different functional group materials with their improved characteristics [1]. Nanocomposites are solid structures in which nanosized particles in the range of 0.5 to 5% by weight are added into a matrix of standard material. By which the properties of the material can be enhanced. As per Camargo *et al*., 2009 properties such as material " strength, toughness, dimensional stability, modulus, electrical conductivity, decreased gas, the permeability of water and hydrocarbon, flame retardancy, thermal stability, chemical resistance, surface appearance, optical clarity, catalysis, separation, sorption and fuel cells" [2]. Nanocomposites have applications as active materials in the gas sensors, it is used in different combinations of metal-metal oxide, mixed metal oxides, polymers mixed with metals or metal oxides, or carbon nanotubes mixed with metals, metal oxides or polymers [3]. Due to the high surface-to-volume ratio, the properties of nanocomposites can be varied compared to that of the original composition. Nanocomposites are 1000 times tougher than the bulk component materials, hence they are used in various fields such as they are used as thin-film capacitors in computer chips; in fuel cells, food packaging industries. Thus, nanocomposites have many technological important applications. Nanocomposites have owing physical, mechanical, electrical, optical, chemical and magnetic properties. They can be produced from all conventional materials such as polymers, metals/alloys, ceramics by modifying their internal structures. Nanocomposites can be manufactured by solid state processing techniques, liquid metallurgy and also with other basic science synthesis routes. Environmentally friendly materials are synthesized with nanotechnology [4]. Nanocomposites are termed as functional and structural materials based on their properties.

Classification of Nanocomposites:

Nanocomposites can be prepared by various techniques, based on the types of reinforcement material, nanocomposites are classified into different types. Depending on the type of filler or the type of reinforcements nanocomposites are divided into (1) Ceramic Matrix Nanocomposites (2) Metal oxide–metal oxide-based nanocomposites, (3) Polymer-based nanocomposites, (4) Carbon-based nanocomposites, and (5) Noble-metal–based nanocomposites [2,5]. In general, nanocomposites can be put under polymer and non-polymer classification. Non-polymer-based nanocomposites are of three types: metal/metal nanocomposites; metal/ceramic nanocomposites and ceramic/ceramic nanocomposite.

Metal/Metal Nanocomposite: Bimetallic nanoparticles will be used in the form of alloy or in the form of shell form will have extensive catalytic and optical properties. Metal oxide nanoparticle, nanowires which possess the semiconducting properties are used as fillers gas sensing materials in chemical sensors and biosensors. Semiconductor metal oxides are stable in air, they can be easily dispersed and are less expensive.

Metal/Ceramic Nanocomposites: This type of nanocomposite has improved chemical, magnetic, electric and mechanical properties. Metal nanoparticles can be deposited on the ceramic supports by evaporating metal on the selected substrate metal nanoparticles or by dispersion using solvent chemistry. For complex nanocomposites, novel processing techniques such as template synthesis, scanning probe electrochemical methods, electrospinning, etc.[6].

Ceramic/Ceramic Nanocomposites: These types of nanocomposites are used in artificial joint implants for fracture failure problems for extending the mobility of patients and eliminating the high cost of surgery. Example: Zirconia- toughened with alumina [7].

Polymer-based nanocomposites are of the following types: inorganic-inorganic nanocomposites organic-organic nanocomposites; polymer/ceramic nanocomposites; inorganic /organics polymer nanocomposites; inorganic/organic hybrid nanocomposites; polymer/ layered silicate nanocomposite; polymer/polymer nanocomposite, biocomposite. Polymer nanocomposites comprises of polymer matrix and filler with 100 nm. The fillers are often clay with a high ratio within the sort of nanotubes and a coffee ratio within the sort of nanoparticles.The processing of organic polymers with nanoparticles is easy which is used for the fabrication of many devices. Nano filled polymer can be of following ways:

Polymer/ceramic nanocomposite: They contain 1nm thick single ceramic layers of 1nm thick homogeneously dispersed to form a continuous matrix. Ceramic layers orient parallel to each other due to their dipole-dipole interaction. Polymer-ceramic nanocomposites are prepared with ceramic nanopowders with the polymer matrices, they have advantages in embedding capacitors as the dielectric constant of ceramic powder is high with highly flexible polymers. Polymer/ceramic nanocomposites (polymer matrices crammed with ceramic nanopowders) are a promising material for embedded capacitors due to their enhanced dielectric constant.

Inorganic/ Organic polymer nanocomposites: In these types of nanocomposites, metal clusters of approximately 1-10nm are dispersed into a polymer matrix. The size and the structure of the nanocomposite determine the mobility of metal atoms on the polymer surface. For example, in polymethyl methacrylate (PMMA) polymer the cluster size depends on the amount of the cross-linking of the polymer, the mobility of the metal atoms will be based on the crossing linking of the polymer.

Besides, advances in nanotechnology may enable polymer/metal nanocomposites (polymer matrices dispersed with metal nanopowders) to compete favorably with more traditional ceramic-filled polymer composites.

Inorganic/Organic hybrid nanocomposite: They are homogeneous system with monomers and miscible organic/inorganic components or heterogenous nanocomposites.

Polymer/ Layered Silicate Nanocomposites: Polymer/Layered silicate (PLS) nanocomposites have remarkable properties over virgin polymer and conventional composites.

Polymer/polymer Nanocomposites: Polymers are quite ever struggling to be chip and offered property profiles. The gap between block co-polymer self-assembly and offer nanostructured plastic endowed with still unexplored combinations of properties are becoming narrower. Mixtures of various polymers often phase separate, even when their monomer is mixed homogeneously.

Biocomposites: Metals and metal alloys are used in orthopedics, dentistry, and other load-bearing applications. Collagen is highly abundant and available in wide varieties.

Carbon nanotube-based Nanocomposites: Due to their mechanical and electronic properties, carbon nanotubes have applications in nanoelectronics devices, composites, chemical sensors, biosensors. They are of conductive in nature and their applications are included in the components that require the discharge the electrostatic potentials. These carbon nanotube-based nanocomposites are electrically conductive and are suitable for applications that require the ability to discharge electrostatic potentials. Carbon nanotubes are of two types i.e., Single walled nanotubes (SWNTS) and multiwalled nanotubes (MWNTs): SWNTs consists of cylindrical single graphite nanostructure sheet, rolled in the form of tube of diameter 1mm to 3nm whereas MWNTs consists of coaxial arrangement of concentric single nanotubes.

Noble metal-based nanocomposites: Metal nanoparticles are mixed into polymeric matrix in solution or in the melt form. Porous metal oxides nanocomposites can be easily prepared with tunable porosity, good chemical stability, low-temperature encapsulation, negligible swelling, mechanical and biodegradable stability, high sensitivity at lower operating temperatures for detection of reducing and oxidizing gases.

Properties of nanocomposites

In recent years, research on nanocomposites has gained more interest with significant efforts of controlling the nanostructures by suitable synthetic methods. Morphology and interfacial characteristics of the materials decide the properties of the nanocomposites such as temperature, magnetic properties, charge capacity. As nano particles and nanolayers have high surface to volume and aspect ratio, they are ideal for usage along with the polymeric materials. Such structures combine the simplest properties of every component to possess enhanced mechanical & superconducting properties for advanced applications. This characteristic is taken into account to be the bottom for forming the matrices for the polymers in resulting hybrid nanocomposites. These inorganic nanocomposites are useful for electronic and charge transport properties. They also possess superior mechanical properties like high dielectric constants which are flexible, easy to process, and powerful. The most commonly used ceramic materials with a high dielectric constant are found to be brittle and are processed at high temperatures, polymeric materials though it can be easily processed, it have low dielectric constant.

Nanocomposites have improved properties over the quality material properties like mechanical properties like strength, modulus, dimensional stability, toughness, and electrical or thermal conductivity, decreased gas etc., Nanocomposites are clay, polymer, or carbon, or a mixture of those materials with nanoparticle building blocks. they need a particularly high surface-to-volume ratio [11].

Synthesis of nanocomposites

In the synthesis of nanocomposites, mechanical and chemical methods are considered. In the mechanical method, metals are ground in a ball mill, into a very small grain size of the homogeneous mixture leading to the alloying used in highly metastable structures [8]. This process leads to alloying used for the highly metastable structures such as amorphous alloys and nanocomposite structures with high flexibility. These are used in gas sensing applications [9]. Scaling up of the synthesized materials using the mechanical alloying process to the industrial level was easily achievable, but the purity and homogeneity of structures is a challenge. High energy milling will also have an influence over the properties of the nanocomposites.

Sol gel technique is commonly used for the preparation of nanocomposites. For example., aerogels that are of high porosity structure are ideal for using nanocomposites. Assembly of aerogel nanocomposites depends on the addition of second component. The second component can be added during the sol-gel processing of the metal oxides before supercritical drying or it can be added into the vapor phase after supercritical drying; Also, the chemical modification of the aerogel particles may be affected through the reactive gas treatments.

Polymer based nanocomposites are fabricated by the dispersion of filler in the matrix for which mechanochemical method along with the ultrasound sonication will be preferred. But these methods of dispersion are restricted by reaggregation of the individual nanoparticles and equilibrium state, which determines the dimension distribution of the agglomerate of the dispersed nanoparticles. Temperature and stability are limiting factors to certain types of inorganic nanoparticles [12].

Ex-situ is a general approach with no restriction for the type of nanoparticles and polymer [12]. Shell increases the compatibility of particles Shell increases the compatibility of the particles in the polymer matrix and makes it easier to disperse them.

The process of polymer-based nanocomposite formation and nanoparticle preparation can be combined as one process or performed as a series of consecutive processes in one reactor using an in-situ approach. In-situ approach, nanocomposites are generated inside the polymer matrix by precursors, which are transformed into desired nanoparticles by appropriate reactions. Also, the benefits of the in-situ approach are moreover the ex-situ approach [12]. One-step synthesis leads to improved compatibility of the filler and the polymer matrix and enhanced dispersion of the filler. The in-situ approach was preferred for the preparation of polymer nanocomposites containing isotropic inorganic particles [13].

Soluble inorganic or organometallic compounds are converted by chemical reactions into colloids using water or organic solvents. The polymer may be added during the colloid synthesis or it may be added later. The polymer either destabilizes or stabilizes the particle dispersion depending on the system. In the former case, nanocomposites form spontaneously by co-precipitation after colloid formation, and in the latter case, nanocomposites are often obtained by the addition of a solvent which acts as a co-precipitation agent, by casting followed by solvent evaporation/ spin coating. During the formation of nanocomposites, there will be the formation of solid reaction by-products which will be embedded in nanocomposites, these by-products should be separated to a greater extent. If the solid reaction by-products arise from the particle synthesis, they will be embedded within the nanocomposites, hence the formation of volatile reaction side products. Several powders of surface-modified colloids disperse well in liquids and can be mixed with dissolved polymers, and subsequently, nanocomposites can readily be obtained by casting followed by solvent evaporation or by spin coating.

Nanocomposites of insoluble polymers with thin films or swelling behavior are based on dispersion by colloids by diffusion in the polymer films. Some nanoparticles can be isolated as powders disperse in polymer melts without agglomeration of the primary particles, especially colloids that are coated with a layer of organic molecules. This affords a simple technique for the preparation of nanocomposites by direct mixing of particles and polymers [14]. High energy sonication, chemical polymerization of monomers in the presence of carbon nanotubes, electrochemical synthesis of polymers CNT's electrode, solution- evaporation processing, surface assisted processing through the formation of a colloidal intermediate, functionalization of nanotubes with the polymer matrix, and high shear mixing are the best ways considered for processing of nanotube composites [15].

To obtain nanocomposite using a solvent evaporation method, nanotube homogeneous dispersion is mixed with a solution of the polymer. The solvent is then evaporated, if the viscosity of the polymer solution is low, nanotubes move freely through the matrix. The solution mixing approach for polymers is capable of dissolving in solvents. Polymers can soften and melt upon heating. Also, the behavior of composite alters due to filler dispersion in the polymer matrix reduces the possibility of nanotube entanglement [16]. Nanotube aggregation within the polymer system harms the stiffening ability [17]. Hence functionalization of nanotubes with the groups that facilitate their incorporation into material will be through covalent bonding [18]. Conducting polymers are not fusible and are insoluble in the common solvents. There are two main forms of nanosized composites of conducting polymer with metals: metalcore nanoparticles covered with conducting polymer shell, chemical and electrochemical polymerization of a thin layer of conducting polymer onto to the metal colloidal particles are considered for preparation.

Secondly, nanocomposites are based on the metal nanoparticles embedded onto the conducting polymer matrix, here chemical reduction of metal ions from the respective salt solution on the conducting polymer/ solution interface [19]. Conducting polymers in their reduced form has significantly high reducing power compared to some metals; some of the high positive redox potential metals such as gold, silver, platinum, and copper are often reduced at a layer of conducting polymer. Conducting polymer-based composites are novel materials with and the optimization of their physical properties (such as electrical conductivity and colloidal stability) are yet to be achieved, while both their commercial availability shortly and a big leap forward for materials science are expected with their appropriate utilization. This review is focused on the different classifications of nanocomposites in general, properties, and applications. Also, the potential uses of nanocomposites and the opportunities they provide, along with perspectives for the future and market and safety aspects are presented [5].

Using in situ polymerization, nanocellulose/polyaniline nanocomposites obtained will be coated with 40% polyaniline have promising applications as electrochromic materials. Graphene has several applications in fabrication and applications of two-dimensional materials. Similar to graphene, molybdenum disulfide also shows high band gap and it has applications in the fields of electronic and optoelectronic devices [20].

Discovery of graphene has enhanced scientific interests in the development of two-dimensional materials, graphene like material, molybdenum disulfide (MoS_2) shows high band gap compared to that of graphene. Due to which, MoS_2 has applications in electronic and optoelectronic devices.

Potentials and opportunities in nanocomposites

Ceramics possess high thermal and chemical stability along with good wear resistance but they are brittle due to the low toughness strength. This can be overcome by converting into ceramic matric nanocomposite, resulting in the significant enhancement on mechanical properties which can be achieved. For example, the incorporation of energy-dissipating components like whiskers, fibbers, platelets, or particles within the ceramic matrix may cause increased fracture toughness. The reinforcements rebound the crack and create bridging elements, thus delaying the further opening of the crack. Toughening and strengthening processes is based on the crack bridging role of the nanosized matrix. Incorporation of high strength nanofibers into ceramic matrices led to advanced nanocomposites with high toughness.

Characterization of Nanocomposites

Characterization of structural morphology is important to obtain an effective understanding of the structural property of the nanocomposites. Obtaining such structural information, however, is experimentally challenging [21]. Nanocomposites are characterized by different techniques to know about the morphology, particle size, phase, composition, thermal stability, optical, magnetic, electrical, and thermal properties.

UV-Vis analysis: UV-Vis absorbance spectrum of the sample was recorded by UV-Vis spectrometer [22].

X-ray Diffraction (XRD): From XRD measurement crystalline phase and Crystallite size will be were characterized using a powder X-ray diffractometer [22]. To know about the phase determination and for unit cell information of nanocomposites under investigation Powder, X-ray Diffraction (XRD) is used. This technique is employed to determine the particle size using Scherrer's formula:

$D=K\lambda\beta cos\theta$ --- (1)

where D (nm) is the mean size of the crystalline domains,
K is the dimensionless shape factor whose value is close to unity,
λ is x-ray wavelength,
β is line broadening referring to FWHM and
θ is Bragg angle.
This equation is used when nanocomposites have a definite crystalline structure only.

In the majority of cases, the phase determination is the usual information obtained from the PXRD technique especially when comparing the synthetic approach or effect and presence of doping in the matrix structure. Further, the technique is also helpful in determining the nanoscale dispersion in polymer matrix when used in combination with TEM but when used independently the low loading in the matrix structure might lead to negative results as the diffraction peaks are usually not observed. This technique is used for determining the presence and absence of impurities from a matrix structure by the appearance of peaks in the matrix. With X-ray diffraction (XRD) crystal structure of the samples is characterized.

FT-IR analysis: Functional group of materials was confirmed by Fourier Transformation Infrared spectrometer in the transmittance mode in the range of 4000 to 400 cm-1 using KBr pellet [22]. Structural properties of the sample can also be analyzed by FTIR along with XRD [22].

Microscopic techniques: The techniques include scanning electron microscopy (SEM), atomic force microscopy (AFM), and transmission electron microscopy (TEM). SEM is employed for analyzing the surface morphology of the nanocomposites but requires the surface to be electrically conductive. In the case of the non-conducting sample, a thin layer of gold or carbon is coated. The resolution of SEM is around 1-2nm.

TEM technique is preferred as it offers good resolution i.e., 0.1-0.2nm. With TEM analysis, the core-shell structure of nanocomposites, morphology due to doping effects, particle size, impact of gelling agents, dispersion of nanoparticles, layering in structure, roughness on surface, etc., can be predicted. But the only demerit of this technique is sample preparation which requires low film thickness.

Surface imaging of conducting and non-conducting materials at atomic resolution level is characterized by AFM, by determining the forces between the atom of sample and AFM tip. It can work under different modes i.e., contact mode, tapping mode, and conductive mode. Using AFM, 2D, 3D, and line profile data are obtained indicating the dispersion of the nanoparticles, the height of nanoparticles dispersed in the matrix, and the height of the matrix. Using AFM, the surface roughness of the nanocomposite membrane can be determined.

EDX analysis: The energy dispersive X-ray spectrometer was performed by an EDX spectrometer to determine the elemental composition of the nanocomposites [22].

Thermal stability: The thermal analysis includes the following: thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), dynamic mechanical thermal analysis (DMTA), thermal-mechanical analysis (TMA), etc. They are used to determine the stability of the nanocomposite materials and changes occurring due to doping, curing, and annealing. As these will lead to thermal decomposition of the nanocomposites, endothermal or exothermic nature of decomposition process, solvent/ moisture loss, weight loss at each step, final decomposed matter, etc.

Benefits of nanocomposites

In general, nanocomposites exhibit improvements in the barrier, flame resistance, structural, and thermal properties yet without significant loss in impact or clarity. Nanocomposites are tightly bound structure in a polymer matrix which will be impermeable to gases and liquids, due to this it has good barrier properties over the native polymer. Improved mechanical properties such as stability have contributed to an increase in heat deflection temperature, example polymer-clay nanocomposites have a large reduction in gas and liquid permeability and solvent uptake. Nanocomposites are used as insulators because of their high heat resistance and low flammability. Nanocomposites are less porous than plastics, hence they can be used in the packaging of foods and drinks, vacuum packs, and to protect medical instruments, film, and other products from external contamination. They possess significant weight reductions, greater strength, and increased barrier performance [23].

Applications:

Nanocomposites provide enhanced properties, reduction of solid wastes, improved manufacturing capability. Applications of nanocomposites includes generation of new materials and performance enhancement of devices such as fuel cells, sensors and coatings. Though use of nanocomposites in industry are not large, their massive switching from research to industry has commenced and it will be extensive in future The applications of nanocomposites in different sectors had been widely recognized in the field of environment, agriculture/ food, and health/ medicine. Nanocomposites have impact on wide variety of industries such as aerospace, electronics and optical industries [2]. Nanocomposites have many benefits due to their enhanced properties, such as reduction of solid wastes and improved manufacturing capability, particularly for packaging applications. The promising applications of nanocomposite systems are numerous, comprising both the generation of the latest materials and therefore the performance enhancement of known devices like fuel cells, sensors, and coatings [24]. Nanocomposites have applications as catalysts, sensors, optoelectronic devices, data storage technology. They are used in the electronic industry for high-performance ferroelectric devices, optical fibers, and amplifiers. They have applications in the medical field, food packaging industry [2,25].

Future of nanocomposites

The number of commercial applications of nanocomposites has been growing at a rapid rate. The following areas have the applications of nanocomposites

- Drug delivery systems
- Anti-corrosion barrier coatings
- UV protection gels
- Lubricants and scratch-free paints
- New fire-retardant materials
- New scratch/abrasion-resistant materials
- Superior strength fibers and films

Improvements in the mechanical property have resulted in a major interest in nanocomposite materials in numerous automotive and general/industrial applications. The popularity of nanocomposites comes from the fact that it provides a marked increase in oxygen, carbon dioxide, moisture, and odor barrier properties, increased stiffness, strength, and heat resistance, and maintains film clarity and impact strength. Nanotechnology has an impact on developing a new generation of composites with enhanced properties and a wide range of applications. and a wide range of applications. Steps involved in the processing, characterization, and applications promote the special chemical and material principles underlying these cutting-edge nanocomposites. Although Nanocomposites are realizing many key applications in industrial fields, several key technical and economic barriers exist to widespread commercialization. These include impact performance, complex formulation relationships, and routes to achieving and measuring nanofiller dispersion and exfoliation in the polymer matrix. Hence, the proper equipment and better method are essential for the synthesis of nanocomposites [23].

Current status and Challenges:

The actual application of nanocomposites is occurring at a very slow pace event though the potential for the commercial application of nanocomposites is vast. In many cases, the performance of the developed nanocomposites is not up to the prospects for example., increase in stiffness may not be related to the strength of the synthesized nanocomposite. In other words, properties of the nanocomposites will be compromised to a certain extent. Hence, production of nanocomposites depends on the chemistry of filler modification, physics and thermodynamics of filler dispersion. In the present situation, structure and properties of the nanocomposites are evaluated at fundamental level.

With the exploration of nanocomposites, it is necessary to know the proper theories and principles in the development of novel materials. Also, the rheological characteristics, processing and applications of the nanocomposites has to be explored. The major problem associated with the biodegradable nanocomposites is the use of natural polymers with high water permeability and associated swelling behavior in contact with water. This in turn will have a reduced the mechanical characteristics, leading to the difficulty of their usage in the packaging applications.

Incorporation of nano clay sheets into biopolymers have a positive effect on water sensitivity and stability of bioplastic. Clay particles acts as barrier elements due to its non-permeable nature of small gas molecules. this will have an effect on molecular migration. This indicates nanocomposite materials with well dispersed barrier elements indicate mechanical properties along with the increased stability and relatively reduced ageing effects. As the study of nanocomposites in the diverse scientific fields has increased in the past few years, many theoretical and experimental techniques have been emerged and redefining the process of synthesis, analysis and cost control methodologies of nanocomposites [26]. Hence, it is essential to identify the best methodology for which the present work is to know the overview about the nanocomposites based on the classification, characterization and applications.

Perspectives

Advanced potentials of nanocomposites are based on the investments, this might have an influence on the economy of the process. Nanocomposites have many applications in the industrial sectors such as packaging, coating and automotive sectors. As the demand for the high-performance systems is increasing, nanocomposites are of good option, so commercialization of the nanoproducts with its development and testing them in different applications is a difficult task. They are also in included under consumer products; therefore, it is essential to establish the predicted market. As the applications of nanocomposites is increasing, revolutions in nanotechnology are expected in the future, examples in fuel cells, supercapacitors, batteries and in hydrogen storage. With the use of fuel cells, infrastructure cost of automotive can be reduced. Further, fire retardancy capacity can be improved for nanocomposites, improved weatherability, also, coating and internal structure of combustion engines can be improved. CNT based nanocomposites have replaced conducting materials in electrical and electronic industries. The demand of CNT composites in automotive and packaging sectors is about 40% of the demand [27].

Also, some of the challenges faced in the use of nanocomposites include: suitable reinforcements such as nanofibers with or without spinning, which will have higher strength properties, being lighter than their micro counterparts and hence appearing as superior structural components; use of nanofibers in different areas such as biomedical, electrical and optical, for various functional devices; conducting polymer-based nanomaterials for electrochemical applications; modification of the mechanical behavior of nanocomposites to get higher performances; surface modification of polymer nanofibers for their use in polymer matrices to overcome the poor interfacial bonding; modelling and simulation of mechanical properties of nanofiber-containing composites, etc.

Other promising area for inexpensive reinforcements is the use of cheap and abundantly available reinforcing materials of natural origin for various applications. In this case, carbon nanotubes in larger extent can reduce the cost of nanocomposite products. Hence, efforts are essential to identify new formulations with materials of renewable resources such as polylactide, polyhydroxylalkanoates, etc., reinforced with easily available reinforcements based on common elements like hydroxides, layered double hydroxides and layered hydroxide salts. Selection of these will lead to a cleaner environment and ecology. Knowledge from the interdisciplinary areas such as physics, chemistry, biology, material science and engineering to obtain new nanoscale structures. Study of structure-property correlations in nanocomposites is challenging in the development of suitable fabrication techniques for dealing with the nanoscale materials, for their characterization and mechanics in order to understand the interactions [27].

Also, nanocomposites have applications in the electronics, chemical, space and transportation industries, including health care and environmental protection. Hence, nanocomposites will have a high impact in the improvement of materials. It is to be noted that the nanostructured composites are structure / size dependent, hence many studies have to be carried out in providing better understanding of the structure property relationship as it dictates the properties of the materials. It will allow nanoscale design of multifunctional materials for engineering applications. Considerations can be made related to dispersion, alignment, volume and rate of fabrication, cost effectiveness. Design of nano-based materials will be based on the materials having combinations of unique properties or selection of materials with characteristics having specific applications; development of process. Characteristics of the nanoscale materials is defined with performance index (P) which correlates the properties of materials for a given product. Performance of the nanocomposites increases with the index. There are some safety aspects to be considered while dealing with the nano materials, i.e., the release of nanoparticles into the environment is a major health and safety issue. Therefore, studies are essential related to the emission of nanocomposites and their effect on the surroundings, this may be due to the potentially harmful characteristics of nanotechnology products based on their large surface area, crystalline structure and reactivity that may facilitate their easy transport into the environment or interaction with cell constituents, thus intensifying many harmful effects related to their composition. Evaluation of potential impacts on the human health and the environment is important as new nanomaterials are manufactured.

Conclusion:

A nanocomposite may be a material during which a minimum of one among the size of 1 of its constituents is at the nanometer size scale. Nanocomposites are developed to create macroscopic components that have unique physical and mechanical properties. They are obtained based on scientific and technological advances; hence they are used for emerging demands. Because of their unique properties like very high mechanical properties even at a low loading of reinforcements, gas barrier, and flame related properties. Nanoparticles, nanowires, and nanotubes of various materials have already had an impact on the field of chemical sensors, ranging from gas sensors to glucose enzyme electrodes. Currently, nanocomposite-based protocols are being exploited for the detection of proteins, acids, toxic gases, etc. Nanocomposite-based sensors are expected to possess a serious impact on clinical diagnosis environmental monitoring, security surveillance, and ensuring the security of our food.

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