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An In-Depth Study on the Classification and Uses of Nanocomposites

Reena[1] and Dr. Yatendra Kumar Gupta[2]
Research Scholar, Department of Chemistry[1]
Associate Professor, Department of Chemistry[2]
Sunrise University, Alwar, Rajasthan, India

Abstract: *Materials known as nanocomposites are heterogeneous or hybrid materials created by combining nanoscale particles from ordinary materials with particular combinations of properties. Complex structures will be present in nanocomposites. The content, structure, and interfacial interactions of each individual component will determine the overall structure of the nanocomposites. The growing need for nanocomposites makes them a viable choice for industrial use in both small- and large-scale manufacturing sectors. The superior performance of nanocomposites in the automotive, construction, electronics, and information technology sectors from food packaging to biomedical applications has led to a major increase in their uses. Various experimental methodologies are used to synthesise nanocomposites, depending on parameters such as analysis, cost control measures, and improved procedure. The purpose of this review is to learn about the many kinds of nanocomposites, their characteristics, and their uses. This overview covers the advantages, features, and uses of nanocomposites.*

Keywords: nanocomposites, chemical behavior, heat resistance.

I. INTRODUCTION

Composites are made up of two or more components. Since they are created by fusing several functional group materials with their enhanced properties, they offer a variety of uses. Solid structures called nanocomposites are created by adding nanosized particles 0.5–5% by weight to a normal material matrix. by which the material's qualities might be improved. According to Camargo et al., 2009, material characteristics "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". Nanocomposites are used in various combinations of metal-metal oxide, mixed metal oxides, polymers combined with metals or metal oxides, or carbon nanotubes mixed with metals, metal oxides, or polymers. They are also employed as active materials in gas sensors. The characteristics of nanocomposites may be altered in comparison to their original composition because of their high surface-to-volume ratio. Because nanocomposites are 1000 times more durable than bulk component materials, they are employed in a variety of sectors, including the food packaging, fuel cell, and thin-film capacitor industries in computer chips. Nanocomposites therefore have a wide range of significant technical applications. Physical, mechanical, electrical, optical, chemical, and magnetic characteristics are possessed by nanocomposites. By altering their internal architecture, they may be created from any traditional material, including ceramics, metals and alloys, and polymers. Liquid metallurgy, solid state processing methods, and other fundamental science synthesis pathways may all be used to create nanocomposites. Nanotechnology is used to create products that are environmentally friendly. Based on their characteristics, nanocomposites are referred to as structural and functional materials.

Classification of Nanocomposites:

Nanocomposites may be made using a variety of methods; they are categorised into many kinds according to the kinds of reinforcing material used. Nanocomposites are classified as (1) Ceramic Matrix Nanocomposites based on the kind of reinforcements or filler used. There are five types of nanocomposites: (2) metal oxide-metal oxide, (3) polymer-based, (4) carbon-based, and (5) noble-metal based. Nanocomposites may generally be classified as polymers or nonpolymers. Metal/metal, metal/ceramic, and ceramic/ceramic nanocomposites are the three categories of non-polymer-based nanocomposites.

Metal/Metal Nanocomposite: Bimetallic nanoparticles with a wide range of catalytic and optical capabilities will be used as alloys or as shells. Chemical and biosensors use metal oxide nanoparticles and nanowires, which have semiconducting characteristics, as fillers and gas sensing materials. Semiconductor metal oxides are less costly, readily distributed, and stable in air.

Metal/Ceramic Nanocomposites: These nanocomposites have enhanced mechanical, electrical, magnetic, and chemical characteristics. Metal nanoparticles may be dispersed via solvent chemistry or coated on the ceramic supports by evaporating metal on the chosen substrate metal nanoparticles. Novel processing methods, such as electrospinning, scanning probe electrochemical methods, template synthesis, etc., are used for complex nanocomposites. Ceramic/Ceramic Nanocomposites: These nanocomposites are used in artificial joint implants for fracture failure problems to extend patient mobility and avoid the high cost of surgery. For instance, alumina-toughened zirconia.

The following are examples of polymer-based nanocomposites: polymer/layered silicate nanocomposite; polymer/polymer nanocomposite; inorganic-inorganic nanocomposites; organic-organic nanocomposites; polymer/ceramic nanocomposites; inorganic/organics polymer nanocomposites; inorganic/organic hybrid nanocomposites. Polymer nanocomposites are made up of a 100 nm filler and a polymer matrix. Clay with a high ratio of nanotubes and a moderate ratio of nanoparticles is often used as filler.Organic polymers may be easily processed with nanoparticles to create a variety of devices. The following are possible uses for nanofilled polymers:

Ceramic/polymer nanocomposite: They are made up of single ceramic layers that are 1 nm thick and evenly distributed to create a continuous matrix. Because of their dipole-dipole interaction, ceramic layers align themselves parallel to one another. Because ceramic powder has a high dielectric constant and is made of extremely flexible polymers, polymer-ceramic nanocomposites, which are made using ceramic nanopowders and polymer matrices, offer benefits when it comes to embedding capacitors. Because of their higher dielectric constant, polymer/ceramic nanocomposites—polymer matrices packed with ceramic nanopowders—represent a viable material for embedded capacitors.

In these kinds of nanocomposites, metal clusters ranging in size from 1 to 10 nm are scattered throughout a polymer matrix. These nanocomposites may be either inorganic or organic. The mobility of metal atoms on the polymer surface is determined by the size and structure of the nanocomposite. For instance, in polymethyl methacrylate polymers, the amount of crosslinking determines the cluster size, and the mobility of the metal atoms is dependent on the degree of crosslinking.

Furthermore, polymer/metal nanocomposites—polymer matrices scattered with metal nanopowders—may be able to compete favourably with more conventional ceramic-filled polymer composites thanks to advancements in nanotechnology. Inorganic/Organic Hybrid Nanocomposite: These are heterogeneous nanocomposites, which are homogenous systems consisting of monomers and miscible organic/inorganic components.

Polymer/Layered Silicate Nanocomposites: Compared to virgin polymer and traditional composites, PLS nanocomposites have exceptional characteristics.

Polymer/polymer Polymers have always had difficulty being chipped and given property profiles in nanocomposites. Block co-polymer self-assembly and provide nanostructured plastic with as-yet-undiscovered combinations of attributes are getting closer to each other. Even when their monomer is combined homogeneously, mixtures of different polymers often phase segregate.

Biocomposites: Orthopaedics, dentistry, and other load-bearing applications use metals and metal alloys. Collagen comes in a variety of forms and is rather plentiful.

Carbon nanotube-oriented Nanocomposites: Carbon nanotubes have uses in nanoelectronics devices, composites, chemical sensors, and biosensors because of their mechanical and electrical qualities. They have uses in components that need to release electrostatic potentials since they are conductive in nature. These electrically conductive carbon nanotube-based nanocomposites are appropriate for uses where the capacity to release electrostatic potentials is necessary. There are two different kinds of carbon nanotubes: multiwalled nanotubes and single walled nanotubes: With a diameter ranging from 1mm to 3nm, a cylindrical single graphite nanostructure sheet is rolled to make SWNTs, whereas MWNTs are made up of concentric single nanotubes arranged in a coaxial pattern.

Noble metal-based nanocomposites: Melted or dissolved metal nanoparticles are combined with a polymeric matrix. With its tuneable porosity, strong chemical stability, low-temperature encapsulation, little swelling, mechanical and biodegradable stability, and high sensitivity at lower working temperatures for the detection of reducing and oxidising gases, porous metal oxide nanocomposites are readily manufactured.

Properties of nanocomposites

With considerable attempts to regulate the nanostructures using appropriate synthetic techniques, research on nanocomposites has attracted increased attention in recent years. The parameters of the nanocomposites, including temperature, charge capacity, and magnetic properties, are determined by the morphology and interfacial features of the constituent materials. Because of their high aspect and surface to volume ratios, nanoparticles and nanolayers are perfect for use in conjunction with polymeric materials. These structures have improved mechanical and superconducting qualities for cutting-edge applications by combining the most basic features of each component. This property is considered to be the foundation for creating the polymer matrices in the final hybrid nanocomposites. The electrical and charge transport characteristics of these inorganic nanocomposites are advantageous. They also have excellent mechanical qualities, such as powerful, flexible, and easily processed high dielectric constants. Polymeric materials, although being readily processed, have a low dielectric constant, whereas the most widely used ceramic materials with a high dielectric constant are found to be brittle and need high processing temperatures.

The mechanical qualities of nanocomposites, such as their strength, modulus, dimensional stability, toughness, electrical or thermal conductivity, reduced gas, etc., are superior to those of high-quality materials. Clay, polymers, carbon, or a combination of those materials with nanoparticle building blocks are examples of nanocomposites. They need a surface-to-volume ratio that is very high.

Synthesis of nanocomposites

Both chemical and mechanical processes are taken into account while creating nanocomposites. Using a ball mill, metals are crushed in the mechanical technique to a very fine grain size, creating a homogenous mixture that is employed for alloying in highly metastable structures. This procedure results in alloying, which is utilised to create extremely metastable materials like flexible nanocomposite structures and amorphous alloys. Applications involving gas sensing make advantage of these. Although it was simple to scale up the synthetic materials made by the mechanical alloying method to an industrial level, maintaining the uniformity and purity of the structures proved to be difficult. Additionally, high energy milling will affect the nanocomposites' characteristics.

The creation of nanocomposites is a popular use of sol gel method. For instance, employing aerogels with a high porosity structure is perfect for nanocomposites. The inclusion of a second component is necessary for the assembly of aerogel nanocomposites. Additionally, the reactive gas treatments may have an impact on the aerogel particles' chemical alteration. The second component may be introduced either during the sol-gel processing of the metal oxides before to supercritical drying or after supercritical drying.

In order to create polymer-based nanocomposites, filler is dispersed throughout the matrix; for this process, a mechanochemical approach combined with ultrasonication is recommended. However, the reaggregation of the individual nanoparticles and the equilibrium state, which establishes the dimension distribution of the agglomeration of the dispersed nanoparticles, limit these dispersion techniques. Certain forms of inorganic nanoparticles are limited by temperature and stability.

Ex-situ is a generic method that is unrestricted in terms of the kind of polymer and nanoparticles used. Shell improves particle compatibility. Shell improves the particles' compatibility and facilitates their dispersion inside the polymer matrix.

Using an in-situ technique, the steps involved in creating polymer-based nanocomposite and preparing nanoparticles may be carried out sequentially in a single reactor or all at once. Using an in-situ technique, precursors within the polymer matrix create nanocomposites, which are then converted into the required nanoparticles via the right reactions. Furthermore, the ex-situ strategy has advantages over the in-situ approach. Improved filler dispersion and better compatibility between the filler and the polymer matrix are the results of one-step synthesis. When creating polymer nanocomposites with isotropic inorganic particles, the in-situ method was used.

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Colloids are created by chemical processes involving water or organic solvents and soluble inorganic or organometallic substances. The polymer might be introduced either later on or during the colloid formation. Depending on the situation, the polymer either stabilises or destabilises the particle dispersion. In the first scenario, co-precipitation leads to the spontaneous creation of nanocomposites following colloid formation; in the second scenario, a solvent is added and functions as a co-precipitation agent; casting is then followed by solvent evaporation/spin coating to produce nanocomposites. Solid reaction by-products will occur during the creation of nanocomposites and will get entrenched in them; thus, it is important to segregate these by-products as much as possible. The development of volatile reaction side products occurs when solid reaction by-products from particle manufacturing get incorporated in nanocomposites. A number of surface-modified colloidal powders dissolve easily in liquids and may be combined with dissolved polymers to create nanocomposites that can be easily produced by spin coating or casting, which is followed by solvent evaporation.

The basis for insoluble polymer nanocomposites with thin layers or swelling behaviour is colloidal dispersion by diffusion inside the polymer films. Certain nanoparticles, particularly colloids covered in an organic layer, may be separated as powders that disperse in polymer melts without the original particles clumping together. This provides a straightforward method for directly combining particles and polymers to create nanocomposites. The most effective methods for processing nanotube composites include high energy sonication, chemical polymerisation of monomers in the presence of carbon nanotubes, electrochemical synthesis of polymers using CNTs as an electrode, solution-evaporation processing, surface assisted processing via the creation of a colloidal intermediate, functionalization of nanotubes with the polymer matrix, and high shear mixing.

A solution of the polymer is combined with a homogenous dispersion of nanotubes to create a nanocomposite using solvent evaporation. After that, the solvent is evaporated; if the polymer solution has a low viscosity, the nanotubes may pass easily through the matrix. Polymers may dissolve in solvents when they are mixed in a solution. When heated, polymers may melt and become softer. Furthermore, filler dispersion in the polymer matrix modifies the behaviour of the composite and lessens the likelihood of nanotube entanglement. The stiffening ability is impaired by nanotube aggregation inside the polymer system. Therefore, covalent bonding will be used to functionalize nanotubes with the groups that make it easier for them to be incorporated into materials. Conducting polymers are insoluble in most solvents and are not fusible. There are two primary ways to create nanoscale conducting polymer composites with metals: first, metalcore nanoparticles coated in a conducting polymer shell; second, a thin coating of conducting polymer is produced by chemical and electrochemical polymerisation onto metal colloidal particles.

Second, metal nanoparticles implanted into a conducting polymer matrix serve as the basis for nanocomposites; in this case, metal ions from the appropriate salt solution are chemically reduced on the conducting polymer/solution interface. When compared to some metals, conducting polymers have a notably higher reducing power in their reduced state. Metals with high positive redox potential, such copper, silver, platinum, and gold, are often reduced near a layer of conducting polymer. Conducting polymer-based composites are new materials whose physical properties still need to be optimised. However, with the right application, they should become commercially available soon and contribute significantly to the field of materials science. This study focuses on the many categories of nanocomposites in general, as well as their characteristics and uses. Additionally, the commercial and safety elements are highlighted, along with future views and the possible applications and prospects that nanocomposites provide.

The nanocellulose/polyaniline nanocomposites that are produced by in situ polymerisation and coated with 40% polyaniline show great potential as electrochromic materials. There are several uses for graphene in the production and use of two-dimensional materials. Molybdenum disulphide has potential in the domains of electrical and optoelectronic devices and exhibits a high band gap, much to graphene.

Since graphene was discovered, scientists have been more interested in creating two-dimensional materials that resemble graphene. Molybdenum disulphide has a higher band gap than graphene. MoS2 is hence useful in optoelectronic and electrical devices.

Potentials and opportunities in nanocomposites

Ceramics are fragile because of their low toughness strength, but they also have excellent wear resistance and great thermal and chemical durability. By transforming into a ceramic matric nanocomposite, this may be resolved and a significant improvement in mechanical characteristics can be attained. For instance, adding energy-dissipating elements to the ceramic matrix, such as whiskers, fibbers, platelets, or particles, may result in a higher fracture toughness. By creating bridge parts and rebounding the fracture, the reinforcements prevent the crack from opening further. The basis for toughening and strengthening procedures is the nanoscale matrix's function as a fracture bridge. High strength nanofibers were incorporated into ceramic matrices to create sophisticated, very durable nanocomposites.

Characterization of Nanocomposites

To effectively comprehend the structural properties of the nanocomposites, it is crucial to characterise their structural morphology. However, it is difficult to get such structural information experimentally. The shape, particle size, phase, composition, thermal stability, optical, magnetic, electrical, and thermal characteristics of nanocomposites are all determined by a variety of methods. UV-Vis evaluation: A UV-Vis spectrometer was used to record the sample's UV-Vis absorbance spectrum.

Ray Diffraction (XRD): A powder X-ray diffractometer will be used to characterise the crystalline phase and crystallite size based on the XRD measurement. X-ray diffraction is utilised to determine the phase and get unit cell information of the nanocomposites that are being studied. This method uses Scherrer's formula to calculate the particle size:

$D=K\lambda\beta cos\theta$ ....(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.

When nanocomposites only have a distinct crystalline structure, this equation is used.

Phase determination is often the most common information gained from the PXRD method, particularly when comparing the presence of doping in the matrix structure and the synthetic approach or effect. When combined with TEM, the method is also useful for detecting the nanoscale dispersion in polymer matrix; however, when used alone, the low loading in the matrix structure may provide unfavourable findings since the diffraction peaks are often not seen. The appearance of peaks in the matrix may be utilised to determine whether or not impurities are present in a matrix structure. The crystal structure of the samples is described using X-ray diffraction.

FT-IR analysis: Using KBr pellet, a Fourier Transformation Infrared spectrometer operating in the transmittance mode between 4000 and 400 cm-1 was used to validate the functional group of the materials. Together with XRD, FTIR analysis of the sample's structural characteristics is also possible.

Microscopic techniques: Transmission electron microscopy atomic force microscopy and scanning electron microscopy are among the methods used. SEM is used to examine the nanocomposites' surface morphology, but it needs an electrically conducting surface to function. A small coating of carbon or gold is applied to the non-conducting sample. SEM has a resolution of around 1-2 nm.

The TEM method is recommended because it provides excellent resolution. The core-shell structure of nanocomposites, doping-related morphology, particle size, gelling agent impact, dispersion of nanoparticles, layering in structure, surface roughness, etc., may all be anticipated by TEM analysis. However, this technique's only drawback is sample preparation, which necessitates a thin coating.

AFM characterises surface imaging of conducting and non-conducting materials at the atomic resolution level by measuring the forces between the sample's atom and the AFM tip. It operates in three separate modes: conductive, tapping, and contact. AFM is used to acquire 2D, 3D, and line profile data that show the height of the matrix, the dispersion of the nanoparticles, and the height of the nanoparticles in the matrix. AFM may be used to measure the nanocomposite membrane's surface roughness. EDX evaluation: The elemental composition of the nanocomposites was determined using an energy dispersive X-ray spectrometer.

Thermal stability: Thermogravimetric analysis differential scanning calorimetry dynamic mechanical thermal analysis thermal-mechanical analysis and other techniques are included in thermal analysis. They are used to assess the stability of the components that make up the nanocomposite as well as any alterations brought on by doping, curing, and annealing. Due to the fact that they will cause the nanocomposites to thermally degrade, the decomposition process to be either endothermic or exothermic, the loss of solvent or moisture, weight loss at each stage, the final decomposed materials, etc.

Benefits of nanocomposites

Nanocomposites often show increases in structural, thermal, barrier, and flame resistance without sacrificing much of their impact or clarity. Nanocomposites have superior barrier qualities than native polymers because of their firmly bonded structure inside a polymer matrix that is impervious to gases and liquids. The temperature at which heat deflection occurs has increased due to improved mechanical qualities like stability. For instance, polymer-clay nanocomposites have much lower solvent absorption and gas and liquid permeability. Because of their low flammability and great heat resistance, nanocomposites are employed as insulators. Since nanocomposites are less porous than plastics, they may be used to vacuum pack, package food and beverages, and shield other things like film and medical equipment from outside contamination. They had higher strength, improved barrier performance, and significant weight reductions.

Applications:

Improved characteristics, less solid waste, and increased production capacity are all offered by nanocomposites. Nanocomposites are used to create novel materials and improve the functionality of electronics including fuel cells, sensors, and coatings. Even if there isn't much application of nanocomposites in industry, there has been a significant shift from research to industry, and this trend will continue in the future. The environmental, agricultural, and medical fields have all generally acknowledged the uses of nanocomposites in various fields. Numerous industries, including the aerospace, electronics, and optical sectors, are impacted by nanocomposites. Because of their increased qualities, nanocomposites offer various advantages, including less solid waste and greater production capacity, especially for packaging applications. Nanocomposite systems have great promise for a wide range of applications, including the creation of novel materials and, therefore, the improvement of well-known devices such as sensors, fuel cells, and coatings. Applications for nanocomposites include data storage technologies, optoelectronic devices, sensors, and catalysts. They are used in the electronics sector for optical fibres, amplifiers, and high-performance ferroelectric devices. They are used in the food packaging business and in the medical area.

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

Nanocomposite materials are of great interest in many automotive and general/industrial applications due to improvements in their mechanical properties. Because they provide a noticeable improvement in the qualities of oxygen, carbon dioxide, moisture, and odour barrier, as well as enhanced stiffness, strength, and heat resistance, while maintaining film clarity and impact strength, nanocomposites are becoming more and more popular. A new generation of composites with improved characteristics and a broad variety of applications is influenced by nanotechnology. as well as many uses. The unique chemical and material principles that underpin these state-of-the-art nanocomposites are promoted by the steps involved in their processing, characteriszation, and applications. Nanocomposites are finding a lot of important uses in industry, but there are a number of significant technological and financial obstacles in the way of their broad commercialisation. These include methods for attaining and quantifying nanofiller dispersion and exfoliation in the polymer matrix, intricate formulation interactions, and impact performance. Therefore, improved methods and appropriate tools are necessary for the synthesis of nanocomposites.

Current status and Challenges:

Although there is a great deal of promise for commercial use, the actual application of nanocomposites is happening relatively slowly. Frequently, the performance of the created nanocomposites falls short of expectations; for instance, an increase in stiffness could not have any bearing on the synthesised nanocomposite's strength. Put differently, there will be some compromise in the characteristics of the nanocomposites. Therefore, the chemistry of filler modification, as well as the physics and thermodynamics of filler dispersion, are crucial to the synthesis of nanocomposites. The structure and characteristics of the nanocomposites are now assessed at a basic level.

Understanding the right theories and concepts is essential for developing new materials in the investigation of nanocomposites. It is also necessary to investigate the rheological properties, processing, and uses of nanocomposites. The usage of natural polymers with high water permeability and related swelling behaviour when in contact with water is the main issue with biodegradable nanocomposites. Consequently, their mechanical properties will be diminished, making their use in packing applications more challenging.

The water sensitivity and stability of bioplastic are improved by the addition of nano clay sheets to biopolymers. Because clay particles are impermeable to tiny gas molecules, they function as barrier elements. This will impact the movement of molecules. This suggests that well-dispersed barrier components in nanocomposite materials provide mechanical qualities in addition to improved stability and comparatively less ageing effects. In recent years, there has been a surge in the research of nanocomposites across several scientific domains, leading to the development of numerous theoretical and experimental approaches that have redefined the processes involved in nanocomposite synthesis, analysis, and cost control. Therefore, it is crucial to determine the most effective technique, for which the current study is designed to get an overview of nanocomposites based on their uses, characteriszation, and categorisation.

Perspectives

The economies of the process may be impacted by the investments that underpin the advanced potential of nanocomposites. In the packaging, coating, and automotive industries, among other industrial sectors, nanocomposites have several uses. Since there is a growing need for high-performance systems, nanocomposites are a promising alternative. However, it may be challenging to commercialise nanoproducts once they have been developed and tested in various applications. Since they fall under the category of consumer goods, it is crucial to determine the expected market. Future advances in nanotechnology are anticipated due to the growing uses of nanocomposites, some examples of which include fuel cells, supercapacitors, batteries, and hydrogen storage. Automobile infrastructure costs may be decreased by using fuel cells. Additionally, nanocomposites' ability to withstand fire may be enhanced, as can their weatherability, coating, and internal combustion engine construction. In the electrical and electronic sectors, conducting materials have been replaced by CNT-based nanocomposites. About 40% of the demand for CNT composites is found in the packaging and automotive industries.

A few other difficulties in using nanocomposites are: finding appropriate reinforcements, such as spinning or non-spinning nanofibers, which will have better strength properties and appear as superior structural components; using nanofibers in a variety of fields, such as biomedical, electrical, and optical, for various functional devices; conducting polymer-based nanomaterials for electrochemical applications; altering the mechanical behaviour of nanocomposites to achieve better performances; altering the surface of polymer nanofibers for their use in polymer matrices to overcome the inadequate interfacial bonding; modelling and simulating the mechanical properties of nanofiber-containing composites, etc.

The utilisation of affordable, widely accessible natural reinforcing materials for a variety of applications is another potential field for low-cost reinforcements. In this instance, the cost of nanocomposite goods may be considerably decreased by carbon nanotubes. Therefore, it is crucial to find novel formulations using readily accessible reinforcements based on common components like hydroxides, layered double hydroxides, and layered hydroxide salts, and materials derived from renewable resources like polylactide and polyhydroxylalkanoates. Choosing these will result in a more ecologically friendly atmosphere. To create novel nanoscale structures, knowledge from multidisciplinary fields like physics, chemistry, biology, material science, and engineering is used. It is difficult to create appropriate production processes for working with nanoscale materials, as well as for characterising and understanding their mechanics to comprehend interactions, while studying structure-property correlations in nanocomposites.

Additionally, nanocomposites find use in the chemical, electronics, aerospace, and transportation sectors, as well as in the fields of environmental protection and health care. As a result, nanocomposites will significantly influence material advancement. It should be emphasised that the qualities of nanostructured composites rely on their size and structure, thus further research is needed to better understand the link between structure and property, which determines the material's characteristics. It will make it possible to build multifunctional materials at the nanoscale for use in engineering. Dispersion, alignment, volume and pace of manufacturing, and cost-effectiveness may all be taken into account. The creation of processes and the mixing of materials with special qualities will provide the basis for the design of nano-based materials. Materials with particular features will also be chosen. The performance index which connects the material qualities for a certain product, defines the characteristics of nanoscale materials. The index grows with the nanocomposites' performance. When working with nanomaterials, there are some safety precautions to take into account. For example, the discharge of nanoparticles into the environment poses a serious risk to public health and safety. Studies on the emission of nanocomposites and their impact on the environment are therefore crucial. This could be because of the potentially harmful properties of products derived from nanotechnology, such as their large surface area, crystalline structure, and reactivity, which may make them easier to transport into the environment or interact with cell constituents, intensifying a number of harmful effects related to their composition. Assessing the possible effects on both human health and the environment is crucial when producing novel nanomaterials.

II. CONCLUSION

A substance that has at least one ingredient whose size is at the nanoscale size scale is called a nanocomposite. The goal of developing nanocomposites is to produce macroscopic components with distinct mechanical and physical attributes. They are used to meet new needs as they are derived from scientific and technical advancements. because of their special qualities, which include gas barrier, flame-related qualities, and very high mechanical characteristics even at modest reinforcement loading. Chemical sensors, from gas sensors to glucose enzyme electrodes, have previously been impacted by nanoparticles, nanowires, and nanotubes of different materials. At the moment, methods based on nanocomposite technology are being used to detect harmful gases, proteins, acids, etc. It is anticipated that sensors based on nanocomposite materials will have a significant influence on environmental monitoring, clinical diagnostics, security surveillance, and food security.

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