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Nanocomposite-The Reinforced Matrix Material: An Overview

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Abstract

In recent years, the emphasis, ingenuity and close analysis of scientists and engineers has been on the field of nanocomposite materials. Nanocomposites have features that are superior to conventional microscale composites and can be synthesized using simple and inexpensive methods. Solid structures with nanometer-scale dimensional repeat distances between the various stages constituting the structure can be called nanocomposites. Usually, such materials consist of an inorganic (host) solid that contains an organic component or vice versa. The mechanical, electrical, optical, electrochemical, catalytic, and structural properties of nanocomposite materials can be different from those of each individual component. For any particular property of the material, the multifunctional behaviour is always more than the sum of the individual components. Nanocomposites present several interfaces between the constituent intermixed phases due to the high surface area of nanostructures. Special characteristics of nanocomposite materials frequently emerge from the interaction of their interfacial phases. In this paper, the classification, fabrication and their prospective application in the field of organic toxic dye degradation and the removal of toxic metals from water sources are reviewed again.

Key Words: *Nanocomposite, Matrix, Photocatalyst, Adsorbent, Dye Degradation*

Introduction:

Nanocomposite is a blend of two or more solid materials in which the dimension of one of the components is nano scale, i.e. 10 to 100 nm**[1]**. The principle of nano-composite is to enhance the physical-chemical properties of the multiphase solid, such as mechanical, electrical, thermal, optical, electrochemical, catalytic properties, then the corresponding component content. The various applications of nanocomposites such as catalytic activity (less than 5 nm), hard magnetic material (less than 20 nm), shift in the refractive index (less than 50 nm), super paramagnetic and mechanical reinforcement (less than 100 nm) are commonly discussed in modern nanotechnology, depending on the size limit of the nanoparticles. Due to extremely high surface to volume ratios or extraordinarily high aspect ratios, nanocomposite materials vary from traditional composite materials. Composite material often consists of one or more discontinuous phases distributed in a single continuous phase. Hybrid components are those of various natures with several discontinuous phases. The discontinuous phase is typically more complicated than the continuous phase and has superior mechanical properties.The continuous phase is referred to as "matrix," and the discontinuous phase is referred to as "reinforcement or strengthening of material." (Figure1)

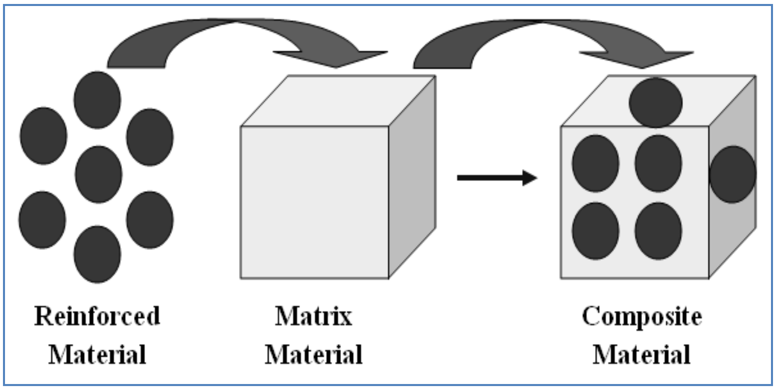

Figure: 1. Matrix and reinforcement in a composite material.

Classification of Nanocomposites:

Based on their electrical, magnetical, optical and mechanical properties, they are classified as;

(1) Functional materials.

(2) Structural materials.

Again, on the basis of the component existence of the composite, they are further categorized as**[2-4]**:

1. Polymer based nanocomposite.
2. Non polymer based nanocomposite.

Polymer based naocomposites are further categorized as:

a. Metal – metal nanocomposite.
b. Metal – ceramic nanocomposite.
c. Ceramic – ceramic nanocomposite.

Non polymer based nanocomposites are categorized as:

a. Polymer – ceramic nanocomposite.
b. Inorganic – organic polymer nanocomposite.
c. Inorganic – organic hybrid polymer nanocomposite.

d. Polymer – layered silicate nanocomposite.
e. Polymer – polymer nanocomposaite.
f. Biocomposite.

On the basis of reinforce materials; nanocomposite**[5-7]** is further classified as:

a. Metal oxide based nanocomposite.
b. Polymer based nanocomposite.
c. Carbon nanotube based nanocomposite
d. Noble metal based nanocomposite.

FabricationStrategy of nanomaterial:

Nanotechnology has experienced significant growth in the previous decade, largely due to the rapid development in nanosynthesis and nanofabrication techniques used to implement nanoscale material and create nanodevices. Assorted methodologies used in nanomaterial formulation may handle solid, liquid, and gaseous precursor materials. Most of these techniques can generally be classified as methods from bottom-up and top-down (Figure 2) and techniques that have components of both.Top-down approaches begin with bulk material and then smash it into smaller components with mechanical, chemical or some other sort of energy.On the other hand, by chemical reactions or self-assembly from atomic or molecular materials, the bottom-up approach is to fabricate the nanomaterials, allowing the precursor particles to expand in size until the desired structure is achieved. **[8]**.

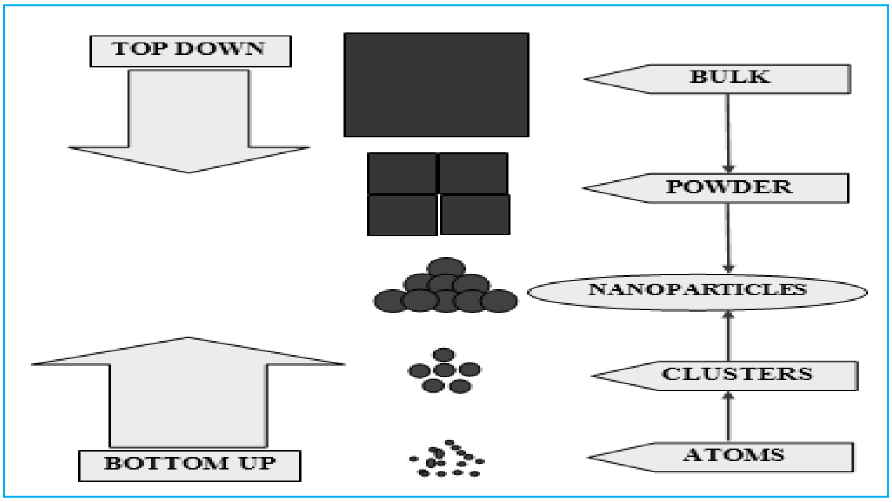

Fig: 2. Schematic representation of the top-down and bottom-up approaches.

Applications:

As compared to their macrocomposite counterparts, nanocomposite materials contribute to new and improved properties. Therefore, in many areas, nanocomposites offer new applications, such as mechanically reinforced lightweight materials, non-linear optics, battery cathodes and ionics, nanowires, sensors, and other structures.With respect to performance and cost, fibre-reinforced nanocomposite pipelines are emerging as a viable alternative to steel pipelines. Nanocomposites used as a plastic blend can be used to reinforce sections of cars where higher performance is required. It is a great challenge to combine the unique properties of nanocomposite and recyclable polymers in order to manufacture light-weight, recyclable and biodegradable polymers. These formulations have been commonly used for the manufacture of automobiles body parts. Layered-silicate nanocomposites, ranging from automotive and aerospace to food packaging and tissue engineering, have great applications. Because of the electric charges in their structure, conductive nanocomposites are able to conduct electric current well. It has also been shown that the existence of nano-level filler incorporation has major effects on film clarity and haze characteristics.Nanoclay incorporation has been shown to dramatically increase clarity and minimize haze in contrast to conventionally filled polymers. The engineering and science realms are shifting from one visionary perspective to another. In a similar way, the environmentally friendly-materials of today's research and development are biopolymers and nanocomposites.

Nanocomposite as Photocatalyst in Toxic Organic Dye Degradation:

Dyes are widely used in the manufacturing sector such as the textile industry, rubber, paper, leather, and cosmetics. However, because of their toxicity, the discharge of dyes may lead to water pollution issues. In order to eliminate such contaminants, several techniques are used. These methods can be sorted into traditional techniques such as adsorption, coagulation, and flocculation; existing methods such as ion exchange, separation of the membrane, and oxidation, and modern techniques such as biodegradation and microbial treatment.Spinel metal ferrites with distinctive structural features and two or more cations along with imperfect oxygen sub lattice along with narrow band gap play a significant role in the photo degradation **[9].**The exercise of metal ferrites as visible light photocatalysts for the degradation of organic dyes in water has gained much attention in current days. One more benefit of using ferrites is their magnetic nature. Since iron (III) oxides are especially much magnetic materials [**10, 11**], and hence ferrites are used alone as photocatalysts in the motive that they can be easily detached from the reaction medium easily **[12].**

Green synthesized ZnOnanorod composite with $NiFe_2O_4$ has remarkable superparamagnetic property can effectively degrade methylene blue under UV and solar radiation and the catalyst can easily separate magnetically[13].Hydrothermally prepared magnetically separable $ZnFe_2O_4$ – graphene composite has amazing degradation potential of methylene blue in prescence of H_2O_2**[14, 15]**. Magnetically recoverable $MnFe_2O_4$/g-C_3N_4/TiO_2nanocomposite has been effectively utilized in the photodegradation of methyl orange under solar irradiation. Silver doped $CuFe_2O_4$/TiO_2 nancomposite effectively degrade different azo dye photocatalytically**[16].**The Pbs quantum dots decorated ZnO/TiO_2photocalyst exhibit a superior aniline blue degradation efficiency and photocatylytic activity **[17]**.

Nanocomposite as Adsorbent in Toxic Metal Removal from Aqueous Medium:

The exponential growth of industry and the drastic population rise are responsible for destroying and damaging the ecosystem. Different pollutants, including heavy metal ions, organic materials, bacteria, viruses, and so on, are released into waste water. Heavy metal ions are non-degradable and permanent, so they are important environmental contaminants, and their toxicity is an increasingly important problem for ecological, evolutionary, nutritional and environmental reasons **[18]**.Many heavy metals such as Pb, Cr, As, Cd, Ni, Hg, Mn, Co, Zn, and Fe are toxic inorganic contaminants in soil, surface and groundwater and, due to their properties, endanger all living organisms and humans in the contaminated environment. The elimination or reduction of heavy metal ions from wastewater is very important for the safety of public health. Heavy metal ions may be extracted from wastewater by a variety of conventional techniques, including chemical precipitation **[19]**, ion exchange **[20]**, reverse osmosis**[21]**, electrolysis**[22]**, membrane filtration**[23]**, adsorption**[24, 25]**. Adsorption is one of the most popular methods of all proposed approaches and is considered to be an effective, efficient and economical method for wastewater purification and is widely used in effluent treatment processes.Lead (Pb) is one of the most hazardous and easily detected metals released by various manufacturing operations, consumer goods, and waste disposal into the environment. Therefore, the removal of Pb from polluted water and waste water is essential in terms of public and environmental health safety. Due to its long biological half-life, Cd(II) is also considered as toxic overwhelming metals to the environment and humans among the different heavy metals**.** The removal of cadmium from waste water has therefore become very important, and extensive research work on this subject is becoming extremely important. Nanostructured adsorbents, such as graphene and carbon nanotubes, metal ferrite based binary and ternary composite showed much higher efficiency and faster water treatment rates compared to conventional materials **[26]**.$NiFe_2O_4$ based ternary composite with bentonite and Chitosan was synthesized in the effective removal of Pb(II) from aqueous medium**[27]**.Successful removal of cadmium (II) from aqueous solution was achieved by hydroxyapatite-encapsulated zinc ferrite (HAP/$ZnFe_2O_4$) nanocomposite**[28]**. Manganese ferrite - graphene oxide magnetic nano hybrid found to exhibit enhanced lead and arsenic adsorption capacity from water**[29].**Zinc ferrite/ polyvinyl alcohol composite can be successfully utilized in the removal of Cr (VI), which is regarded as carcinogenic agent **[30]**.

Conclusion:

Nanocomposites represent a novel class of nanostructures with profound technological significance. Organic/inorganic nanocomposites are generally organic polymer composites with inorganic nanoscale fillers. They combine the advantages of the inorganic materials such as rigidity, thermal stability etc and those of the organic polymers like flexibility, processability etc. Generally, these nanocomposites are endowed with the special properties of the nanofillers, leading to materials with quite innovative characteristics. Recent interest in polymer matrix based nanocomposites has emerged from the interesting observations involving carbon nanotubes, carbon nanofibers, graphene, nanocrystalline metals and a host of additional nanoscale inorganic fillers or fiber modifications. Polymer nanocomposites offer excellent opportunities to explore new functionalities beyond those of conventional materials.

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