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Recent Advances in Nanocomposites: An overview

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Abstract: *Nanocomposites can be described as "multiphase materials where one or more of the phases have at least one dimension of order 100 nm or less."In recent years, intensification in research of nanostructure materials has occurred primarily due to their attractive potential, that is mechanical and physical properties significantly improved compared to the original grain materials. Expected benefits from nanocomposites include improvement in modulus, flexural strength, heat distortion temperature, barrier properties, and other benefits. Nanocomposites are becoming very popular today due to the enormous benefits being derived from it, this explains its acceptability and why leading manufacturing companies are spending millions of dollars on its research and development. The objectives of the project is to conduct a thorough research on the topic and then look for better approach to manufacture better and more durable nanocomposite products for oil and gas pipelines, that will serve as better alternatives to metal and other conventional materials. Therefore, nanocomposites promise new applications in many fields such as mechanically-reinforced lightweight components, non-linear optics, battery cathodes and ionics, nanowires, battery cathodes, nanowires, sensors and numerous other systems.*
Keywords: *composites, nanofiller, polymers, metals, ceramics.*

I. Introduction

As we are familiar with 'Composites' that are formed by combining materials together to form an overall structure with properties that differ from the sum of individual components. Mainly composites are made out of a matrix(binder) which is a soft material and reinforcement which is stiff and strong and is main load bearing element usually in form of fibres/particles[1]. Nanocomposites differ from traditional composites because of the smaller size of particles in the matrix material and also the reinforcing material can be made up of particles(e.g.exfoliated clay sheets, minerals, clay slacks, carbon nanotubes)[2] .(Nanocomposites means nano-sized particles(i.e. metals ,semiconductors, dielectric materials) embedded in different matrix materials (ceramics, glass, polymer). Small size may cause higher chemical reactivity of grain boundaries[3-5]. Nanoparticles have an extremely high surface to volume ratio which dramatically changes their properties when compared to their bulk sized equivalents[2]

Nanoscience has advanced and improved the properties of existing classes of materials. Okpala(2013) deprived nanocomposites "rapidly expanding field is generating many exciting new materials with novel properties.[2] As experimented almost all types and classes of nanocomposite materials gives new and improved properties thus providing business opportunities for all sectors of industry, in addition to being environmentally friendly.

A significant amount of industrial and governmental research has been conducted on nanocomposites. The main purpose of the researches is to conduct a thorough study on the topic and then look for better approach to manufacture better and more durable nanocomposite products for oil and gas pipelines that will serve as better alternatives to metal and other conventional materials.

When the particle size gets less than a particular level, changes in particle properties called 'critical size' shown in (Table 1)[5]

Table 1. Feature sizes for significant changes in properties reported in nanocomposite systems [reproduced from reference 5 with the kind permission of the author and the Japan Society of Powder and Powder Metallurgy].

Properties	Feature size (nm) at which changes might be expected
Catalytic activity	<5
Making hard magnetic materials soft	<20
Producing refractive index changes	<50
Producing super paramagnetism and others electromagnetic	<100

phenomena	
Producing strengthening and toughening	<100
Modifying hardness and plasticity	<100

As dimensions reach the nanometric level, interactions at phase interfaces become largely improved, and thus it enhances materials properties. In this context, the surface area/volume ratio of reinforcement materials employed in the preparation of nanocomposites is crucial to the understanding of their structure–property relationships[5]

Similarly as in microcomposites, nanocomposite materials can be classified, according to their matrix materials, in three different categories as shown in Table 2[5].
- ❖ Ceramic Matrix Nanocomposites (CMNC)
- ❖ Metal Matrix Nanocomposites (MMNC)
- ❖ Polymer Matrix Nanocomposites (PMNC).

Table 2. Different types of nanocomposites.

Class	Examples
Metal	Fe-Cr/Al2O3, Ni/Al2O3, Co/Cr, Fe/MgO, Al/CNT, Mg/CNT
Ceramic	Al2O3/SiO2, SiO2/Ni, Al2O3/TiO2, Al2O3/SiC, Al2O3/CNT
Polymer	Thermoplastic/thermoset polymer/layered silicates, polyester/TiO2, polymer/CNT, polymer/layered double hydroxid

- ❖ Ceramic Matrix Nanocomposites (CMNC): Main part of volume is occupied by a ceramic, i.e. a chemical compound from the group of oxides, nitrides, borides, silicides, etc. Most studies reported so far have confirmed the noticeable strengthening of the Al2O3 matrix after addition of a low (i.e. ~10%) volume fraction of SiC particles of suitable size and hot pressing of the resulting mixture. Nanocomposite from these combinations enhances electrical, optical and magnetic properties as well as anticorrosion and other properties[5-10].

- ❖ Metal Matrix Nanocomposites (MMNC): Developed to take advantage of high tensile strength and electrical conductivity of carbon nanotube materials. Eg.boron nitride reinforced metal matrix composites and carbon nitride metal matrix composites[5-7].

- ❖ Polymer Matrix Nanocomposites (PMNC): Three methods are widely used in the polymer/ clay nanocomposite preparation. The first one is the *in situ*polymerization, second method is solution dispersion and third fusion intercalation, a method developed by Vaia et al. in 1993. However, they have some disadvantages, such as low modulus and strength compared to metals and ceramics. In this context, a very effective approach to improve mechanical properties is to add fibers, whisker platelets or particles as reinforcements to the polymer matrix[5-13]. For example, polymers have been filled with several inorganic compounds, either synthetic or natural, in order to increase heat and impact resistance, flame retardancy and mechanical strength, and to decrease electrical conductivity and gas permeability with respect to oxygen and water vapour.

- ❖ Additionally, discovery of carbon nanotubes (CNTs) in 19916 and their subsequent use to fabricate composites exhibiting some of the unique CNT related mechanical, thermal and electrical properties7-9 added a new and interesting dimension to this area[14].

- ❖ A group led the research in this area until the beginning of 2000, by which time many researchers had joined the field “Cellulose nanocomposites”. They are manufactured using different processes, and these processes affect the composite properties, such as the dispersion, distribution and alignment of the reinforcing phase. Thus, the research and development of the manufacturing process of celluloses nanocomposites is an essential part of the development of cellulose nanocomposites[15-17].

- ❖ Certain developments are also been done in “Elastic” and “Bionanocomposites.”

II. Processing Of Nanocomposites

Both MMNC and CMNC with CNT nanocomposites hold promise, but also pose challenges for real success. Due to ease of production, lightweight and ductile in nature the polymer materials are widely used in industry. Polymer nanocomposites is type of material used for filler processing dimensions on a nanometer scale reinforced into polymer matrix. These material mixes a nanofiller with polymer material, thus the new composite material get produced having the improved physical and mechanical properties than the conventional material. The properties such as mechanical, thermal, flame retardant get enhanced because of higher surface area available with nanofiller[17-20].

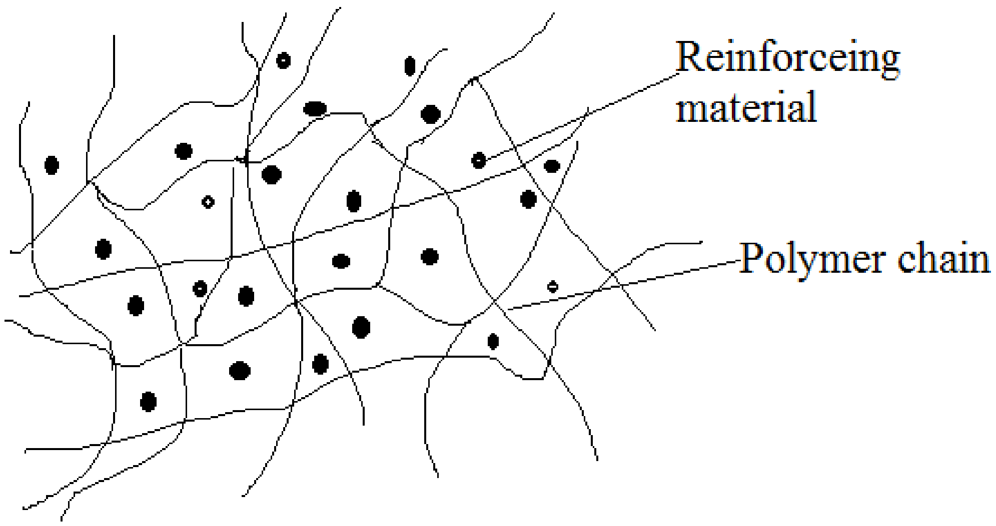

Fig.a: Reinforcement of nanoparticle in polymer

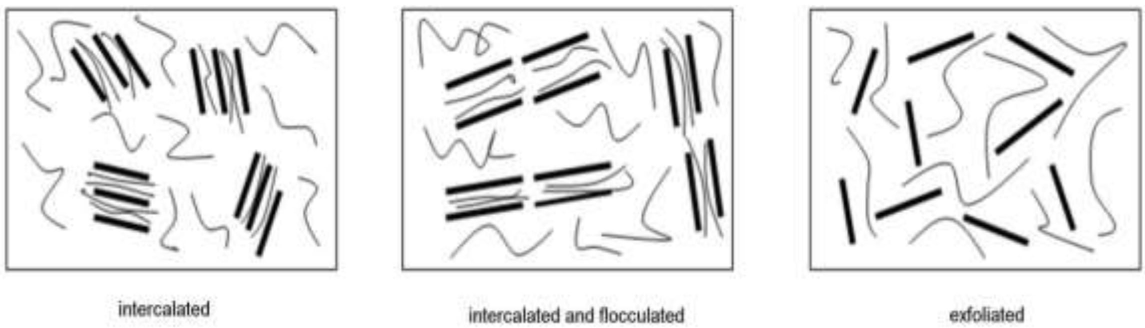

Fig.b: polymer nanocomposites morphology[13]

Nanocomposites forming process includes individual steps for polymerization of each monomers followed by pelletization of each polymer separately. When the individual polymers palletized the formed pallets may be mixed with nanofiller material in extruder to form nanocomposites material. This process is very efficient for formation of nanocomposite. The matrix formed such as one dimensional nanowires, two dimensional lamellar composites three dimensional metal matrix all these shows the various nanomixed and layered materials. The method used for construction combines the properties best properties among the mixing material and formed the new and unique properties for many advanced[2].

Processing methods for different types of nanocomposites (CMNC, MMNC and PMNC) are available, but some of these pose challenges thus giving opportunities for researchers to overcome the problems being encountered with nanosize materials[21-23]. As the properties of nanostructured composites are highly structure/size dependent, many research studies still have to be performed to provide a better understanding of the structure-property relationship in such systems[5-13].

III. Benefits And Applications Of Nanocomposites

- ❖ In today’s era nanocomposites offer new technologies in all the sectors of the industry due to their environmentally friendly nature.

- In oil and gas pipeline, high rate of corrosion of metal is occurred and the failure rate of the conventional material is so high. In order to overcome this, nanocomposites are used by use of which the macroscopic properties of the product get improved. The nanocomposites differs from the conventional material mechanically due to they have exceptionally high surface to volume ratio of reinforcing[23]
- Nanocomposites enhances the other properties of material like electrical and thermal conductivity, heat resistance and other mechanical properties like stiffness, strength and resistance to wear than the conventional materials[24].
- Metal matrix nanocomposites are material in which material combines metal and ceramic feature such as strength and modulus. Thus the strength of material in shear and compression get increased. The temperature service capability of material gets increased. These material also shows extra ordinary properties in different areas such as automotive and aeronautical industries and development of structural material[25].
- Ceramic matrix nanocomposites overcome the defect of ceramic such as low toughness as they are brittle .The properties like fracture toughness and strength get increased.
- The large amount of nanocomposites would reduce the uses of gasoline 1.5 billion liters per year and also reduce the emission of CO_2 in more than 5 billion kilogram.h[14]
- The nanocomposites also improves the properties such as colour or transparency, modulus, conductivity, flame retardancy, magnetic properties, corrosion resistance, tensile strength and heat distortion. These properties get increased than the conventional material[2].
- In case plastic material the advantages of nanocomposites don't stop at strength. They also increases the properties like high heat resistance, low flammability. These properties also make the nanocomposites as the good choice for the insulators and wire covering. The other properties of nanocomposites is that the becomes less porous than the regular plastic. It also make the plastic suitable for food packing and to protect medical film, instruments, other product from surrounding contamination[13,14,20].
- The dispersion of silicate nanolayer with polymer matrix results in improvement in properties fire retardancy, thermal stability barrier properties, photo activity and have great application ranging from automotive and aerospace to food packaging and tissue engineering. Epoxy nanocomposites are the primer layer for the aircraft coating for improved anticorrosion properties[4].
- Polymers composites offers multitude desirable properties in aircraft from quarter of century such as high strength, stiffness, dimensional and thermal stability. With the advent and application of nanotechnology, the polymer composites could become even more attractive.
- Biodegradable polymers with nanoreinforcement have high potential for the design of environmentally friendly “Green Material” for future.
- In automotive sector, one of the application is that to improve the functionality such as ecology, comfort, weight reduction, aesthetics, recyclability, improved performance etc. Nanocomposites used as a blend in plastic can be used for strengthening the portion of automobile where high efficiency is required. Details on the commercial usage of nanocomposites in automotive and future development in automotive sector.
- Metal and ceramic nanocomposites have high impact over the industries such as aerospace, electronic, and military, while polymer nanocomposites major impacts will probably appear in battery cathodes[23], microelectronics[24], sensor[25], nonlinear optics[26].

IV. Future scope of nanocomposites

Nanocomposite is a technology which is revolutionizing the world of material. It has high impact in developing the new generation of composites with properties. In the last two three years the worldwide production is exceed 600000 tones and it is covering the areas such as Anticorrosion barrier coating, drug delivery system, UV protection gel, superior strength fibers and films, fire retardant materials.

General Motors was the first industry to use nanocomposites in car, reducing its mass by almost 1 kg. In the past, car parts were made of polypropylene and glass fillers, which had the disharmony with the other car parts as a disadvantage[5][27]. By using lower filler content, as in the case of the nanocomposites, materials with a higher quality was obtained. The development of environmentally friendly, non-foil and better packaging materials can reduce the amount of solid waste, improve package manufacturing capabilities, and reduce the overall logistics burden to users. Nanoclays are expected to have 50% of the total nanomaterials market by 2020[28].

The nanocomposites become popular because of the fact that a little goes a long way. It provides marked increase in O_2 and CO_2, moisture, odour barrier properties, increased impact strength, maintains film clarity, heat resistance.Future trend of nanocomposites include the extension of this nanotechnology to additional types of polymer system, where the development of new compatibility strategies would likely be a prerequisite[29]. Despite these possibilities, there are only limited examples of industrial use of nanocomposite, mainly due to the challenges in processing and the cost involved, particularly for non-structural applications. In fact, one recent review[30] deals with various methods for the preparation of super hard coatings with merits and demerits of each method. However, the intense research in both metal- and ceramic-based nanocomposites suggests that the days are not far off when they will be actually in use.

V. Conclusion

The potential of the nanocomposites is outstanding and can be exemplified by the massive investment from many companies and government throughout the world. Because of these the nanocomposites are expected to generate grate impact on world economy and business. This is very much evident from the publication pouring in, particularly on a variety of properties suited for different applications. Thus this review shows potentials and future technologies in “Nanocomposites”.

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