Characteristics Behavior of Composite Materials with the Incorporation of Nanotechnology: A Review

Reshmi S Nair, Jerrin Thadathil Varghese, M. Chithirai Pon Selvan

Abstract: ***Nanotechnology delivers a unique podium for the development of novel components in various industrial andmanufacturing arenas. Due to its new processing techniques and variety of applications the nanometric composites have technologically advanced from a research scale to commercial sector where it can be extensively implemented for longer reliability and dedicatd usage. Among the ennumerable multi-phase solid composites displaying significant roles in the grounds of material science refining the property of the materials. They consist of polymeric and inorganic nanoparticles of portraying uniform geometrical structure. The intention of this publication is to deliver a scholastic research on polymer nanometric composite with respect to their characteristics and focus on the effectual characteristic features of nanoscale structure of the composites enabling the synthesis of a nanostructured composite material inhibiting an overwhelming performance in their respective practical applications and implementations. The excellence of nanotechnology in augmenting unique characteristic features and making them more devastated in their characteristics is also illustrated here. Furthermore, the challenges encountered and future stance for the research opportunities entitles great interest in the field of nanotechnology and aerospace engineering***

Keywords— Nanometric composites, multiphase, polymer composites, Aerospace, Nanotechnology, Mechanical Characteristic features, Applications

I. INTRODUCTION

The scholastics of nanotechnology involves in a comprehensive array of applications in each grounds of technology [1]. The charatertistic features pertaining to this magical science depicts unique features when the particle size gets reduced from macro or micrometers to nanometer, thus exhibiting invariable applications in inter-disciplinary fields. Since early 1900's, nanotechnology has given a setback in developing targeted drug delivery for specific sites and enhancing bioavailability. This reduces the possible adverse effects of the oral administration of drugs and also, the interaction of active pharmaceutical ingredients (APIs) within the human body [2]-[4].

Organic cum inorganic fillers have become inexorable with respect to polymers. The polymeric composites have been synthesized for implementation in enormous sectors which are automobiles, electronic industry, sports materials, components for aerospace and so on. The development of polymeric nanometric composites have occupied a tremendous role in the filler materials made up of nanometer range materials.Ultimately the product that we achieve are not essentially in the nanometric order but can be of a few microns in size [6]. In the early 1970s, this outburst in the grounds of nanotechnology has been a highly sustained through the introduction of characterization methodologies like skimming channeling microscopy and perusing probe microscopy. Generally, we notice the extraordinary arrangement of nano-structured components with unique characteristic features are resulting in extra-ordinary change in any system of technology. This fundamental concept is utilized in the field of polymer system as well.

The use of nanometric composites has been a part of material technology in the previous decades from the natural environment and scholoars develop the concept of bio mimic in order to develop a green technology. Chemistry scholars udegoing their research in Britain issued an editorial titled 'Nano sandwiches' in the year 1998 [6], declaring the fact of, 'Nature is the magical source with explicit characteristic features and applications' which enabled the use of natural components utilizing polymers and natural medium such as biomolecules (Carbs, proteins, lipids), and natural composites which are stronger than the conventional forms such as wood, bullets and bones. Such nanometric composites are produced by combining solid phases such as layers or fibers with any of the phases to be of nanometer range. With the aid of atomic level analysis, the science of nanotechnology has advanced in the field of characterization and system modelling [5]. The Toyota Laboratories located in Japan performing strenuous research on nanometric composites has reported an interesting work with nanometric composite with Nylon-6 [5], in which it was observed that innovative thermal and mechanical characteristic features were displayed with small amounts of nano filler. "The characteristic features of nanometric composite system highly depends on their morphology and interfacial characteristics other than their individual parent material of nano filler and nylon", declares Kanertzidias [7].

As an exceptional physiognomy of nanotechnology is the overwhelming funding aid extended for research credentials have improved immensely since the commencement of the National Nanotechnology Initiative (NNI) in the year 2001 from $464 million to an amount of $982 million in the year 2005. The budget request released in the year 2006 by President of The

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United States of America, Mr. Bush was of a total of $1.052 billion of the NNI [9]. These funding prospects are focussed towards the novel and augmented products in various industrial applications and manufacturing arenas.

The predominant evolution of nano system ans its allied technology has give rise to excellent characteristic features in the industrial product market thus potraying the techniques to be a magical science. The unique property of nanomaterials is displayed with larger surface area to volume ratio, thus enhancing its overall surface entity 10]. As surface characteristic features support many of the significant physical and chemical characteristic features, the increase in surface area has a greater impact to this niche technology [5]. For fibers and smaller particles, the material diameter is always inversely proportional to surface area/unit volume, therefore, it will result in greater surface area for a smaller diameter particle, precisely for nano range particles [10]. Figure 1 depicts the generic geometrics of particles. It is observed that in case of fiber and material with layers by the first term of the equation to be predominant. The consecutive term (2/1 and 4/1) is preferably compared to previous term and always had a negligible influence over the same. Thus, when we compare the shift, the following changes like reduction in particle diameter, layer thickness, and surface morphology [11]. Being a niche filed of science and technology, there are numerous forms of the nanomaterials under research including carbon nanotubes, nano precipitation particles, nano fibers, nanowires, nano rods, and fullerenes. All these materials are classified based on three different categories: Type of particle, layers formed, and fibrous material [11][12]. For instance, for a layered nanomaterial like organosilicate, the filler will be of nanometer range with an aspect ratio as high as 30-1000 [13].

2. RESULTS

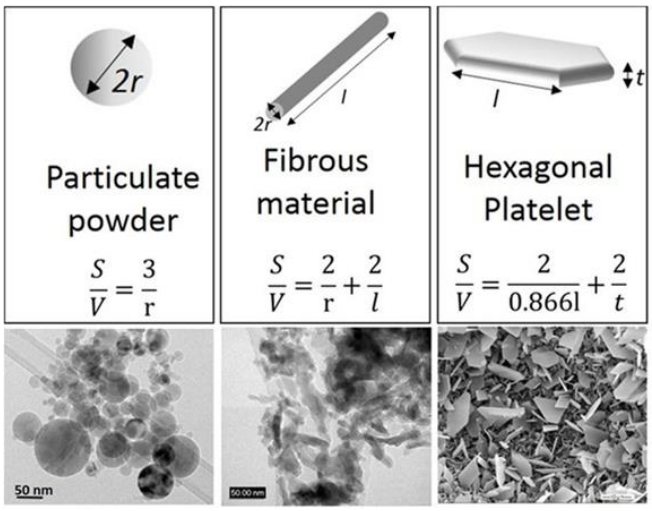

Fig. 1: Schematic portrayals of various Nano-reinforcements indicating Surface area/volume relations for a diversified reinforcement geometries [31]

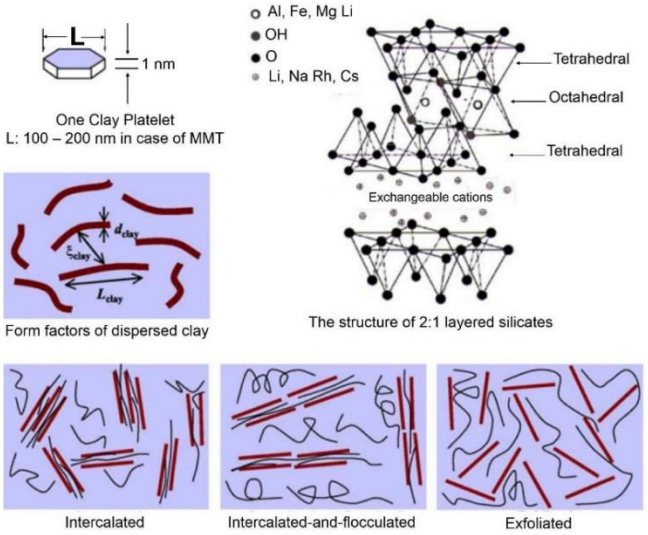

Fig. 2: Bond Structure and grain structure of 2:1 phyllosilicates and schematic graphics of dispersed clay with their form factors along with various thermodynamically viable polymer/layered silicate nanometric composites [32]

The fundamental concept pertaining to the nano range will always have a sophisticated reinforcing efficiency due to its greater aspect ratio [10]. Liable to size and shape of the material, along with the degree of combination of two phases, the characteristic features of the nanometric composite system is highly influenced. Composites for layered silicate materials is shown in Figure 2. A phase separate composite is produced displaying similar characteristic features that of the micro composites [13]. A well-ordered monodisperse multilayer structure is obtained in case the above mentioned condition is enhanced by penetrating a single polymer chain to the silica layers thus forming an intercalated structure. An exfoliated/ Delaminated structure is accomplished only if the silicate layers are dispersed in a uniform pattern [13].

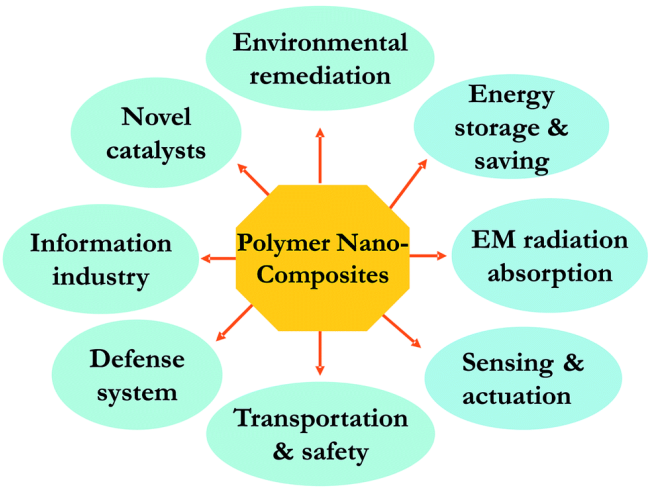

Fig. 3: Practical Applications of Polymeric nanometric composites [33]

1.1 Manufacturing techniques of Polymeric Composites using the Nanometricmaterials

The collaboration of length scaled of the morphology enhances the property in the nano level and the changes the fundamental physics of the materials. The characteristic features shown by the nanometric composites are mainly controlled by the interactions in the interfacial level and the quantum effects in the nano levelled structures [16]. The inclusion of nanotechnology has brought the research department to start thinking how unique and huge the field of science is [4]. In order to go into the depths of nanotechnology in composite materials, a study on mechanical, magnetics, optical, thermal, electrical and physical characteristic features are made. The decision and selection process of the fabrication of nano phased structural polymer composite materials depends on the physical, chemical and biological methods involved in the process. The various methods used for conventional composites are hand layup, pultrusion, resin transfer moulding, vacuum methodology, autoclaving and resin film infusion techniques, fiber placement technology and many more [17].

The process of resin transmission moulding involves a closed mould operation technique [17]. During this progression of the method, the resin flows in transverse directions across the plane of the performance section making the fiber wet out in the precarious dispute. However the recent advancements in the technology of resins and textiles have given the manufacturer the flexibility to use the technology of RTM in the primary and secondary structures [19]. The property of wettability has developed due to the recent advancements in the textile technology. The fiber volume fraction of a fiber is attained to a range of 55% to 60%. The toughness can be even more increased in such polymer composites by the aid of 3-D weaving technology, thereby enhancing structural integrity and being cost effective. The technology of VARTM is a variation of the RTM technology where the fabrication is a single sided tooling to yield the required set vacuum [18]. This methods brings out advantages of producing lower cost materials at higher volumes, which at the same time has better surface morphology and increased fiber volume fraction when compared to the hand layup techniques. The resin flow is restricted in both methods, if the resin viscosity is too high. There is a grave effect of the nano constituents on the resin viscosity and cure kinetics [20], and also may cause the distribution of resin not uniformly over the reinforcement along with the chances of dry spots formed [21].The kinetics and resin viscosity of the matrix-resin is altered in a nano composite due to the presence of nanoparticles 20], and thereby resulting in an uneven distribution and occurrence of dry spots along the entire material volume [21].

1.2 Current challenges in Manufacturing cum Synthesis of Composites with the implementation of Nanomaterials

The nanometric composites materials has an interesting property of redefining the nature of the traditional composites with an upsurge in characteristic features hence creating a better condition for the uses. The future of polymeric nanometric composites is huge in terms of replacing the current composite techniques and technology in the field of medical, engineering and electronic industry. However the major setback is in terms of developing the tiny particles in large scales with the cost kept in mind. This hurdle is what the researchers are trying to overcome for healthier and better future. The method of uniformly spreading the nanometric composites with the matrix material is still a grave issue. The tendency of the fine particle of the nanoparticles to agglomerate makes it very difficult to disperse the materials using any of the current or traditional methods [22] [23]. The tendency of using force at the same time can also lead to the possibility of splitting the agglomerate particle hence leading to the premature failure of the composite [23]. To increase the characteristic features such as modulus, toughness, hardnes, reliability, resilience and strength, the most significant factor to be considered is the configuration of nanoparticles within the matrix-composite system [24]. For conventional composites, the strength, functionalk capability and composition is more perplexing than the conventional type of nanos.

The issue of interfacial adhesion and complete dispersion in a carbon nanofibre need to be overcome in order to attain an emergence on the potential of CNF nanometric composite [25]. In a study conducted by McMorrow and Chartoff [25], the two-roll mill for dispersion carbon nanofibres in a vinyl ester resin through continuous shearing was done. The study showed that there is an incomplete dispersion formation of dry and brittle mixture after 6 minutes of milling as a result of viscosity limitations. However they concluded that for lower viscous resin, for compromised temperatures and diluents if added, provides great future using this technology. Therefore the highlight is to decrease the viscosity of the mixture and thereby providing the enhanced characteristic features. However the mechanical and thermal characteristic features were not satisfied.

The nature and features of nanometric composites is significant when adding to the composite integrity. The defective natures of carbon nanotubes were discussed by researches done by Han et al. [21][26][27][28]. The different model configurations of nanotubes [26][27][28] : Single walled nanotube (SWNTs) and Multi walled nanotube (MWNTs). The SWNTs were concluded to be more defect free than when compared to the MWNTs which had more topological and structural based defects. The property of dispersion and compatibility in polymer composites can be improved by the introduction of nanotubes. However more concerns regarding the functioning of nanotubes effecting the property the final product still remains. In terms of radiation tolerances, both conventional form of SWNTs and the buckypaper have depicted greater strength in regard to high energy neutrons, medium energy neutrons and high energy protons, which one would come across in aerospace applications [29]. But Wilkins [29] through his study and research concluded that there might be a limitation of using such materials in the case of composites, as matrix respond varies along with emission charateristics.

II. FUTURE PROSPECTS AND CONCLUSIONS

The perception of nanometric composites in the development areana and in terms of conversion of research into its applications are quite promising and have acquired enormous interests amongst research scholars through out the Orb [5]. Though these applications related to nanotechnology comprising amd embedding the features of composite materials are only very few at the moment, the technology is yet to have a great sway in the forthcoming era. The research on the nanotube-enabled materials are still been conducted by scholars of research in the past 20 years. [30].

The mechanical characteristic features are enriched in nanometric composites for specific reasons like pinning effect which diminishes the grain growth of matrix proactively during sintering thereby upsurging their mechanical characteristic features if the structures which include fracture strength and hardness. The declination in the size of structural refinement fronts to the reduction in flaws, thereby aggregating the strength and consistency of the structural nanometric composite. The polymeric nanometric composites hence have advanced applications. The uses of these nanometric composites has had an significant effect with respect to aerospace structures and its fabrication. As they improve the structural features and afford to be a cheaper, faster and safer unit for transportation and more reliable technique for future. The progression in the frontiers of thermal, optical characteristic features, field emission, mechanical characteristic features have vastly augmented in aerospace due to these nanometric composites [34]

The reduction in heat dissipation due to flammability can also be conquered by nanoparticles of these nanometric composites which defines that the auto-extinguish feature is attained through them. This decline in the total heat discharged during combustion is accomplished through the implementation of nanoparticles and flame retardants [35]. The infusion of carbon nanotubes behave as electromagnetic interference shielding due to the their embedded electrical property thereby increasing its auto extinguishing nature.[36]

Therefore, the nanometric composite technology has proved itself to be a reliable material technology in the grounds of engineering. As discussed throughout the article, the polymeric composite matrix system proves to be much cost effective and momentous material for various applications.

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