

## DEVELOPMENT OF METHODS FOR POLIMER NANO COMPOSITES

**Gorikapudi Maniteja**  
Research Scholar  
Shri JJT University  
Rajasthan.  
manitejagp@gmail.com

**Dr. Srinivasarao T**  
QA. Manager  
Satyadivis  
Pharmaceuticals Pvt. Ltd.  
Hyderabad.  
Prof.tumati@gmail.com

**Dr. Rakesh Kumar**  
Professor  
Shri JJT University  
Rajasthan

### Abstract

*This review is designed to be a comprehensive source for polymer nanocomposite research, including fundamental structure/property relationships, manufacturing techniques, and applications of polymer nanocomposite materials. In addition to presenting the scientific framework for the advances in polymer nanocomposite research, this review focuses on the scientific principles and mechanisms in relation to the methods of processing and manufacturing with a discussion on commercial applications and health/safety concerns (a critical issue for production and scale-up). Hence, this review offers a comprehensive discussion on technology, modelling, characterization, processing, manufacturing, applications, and health/safety concerns for polymer nanocomposites.*

### Keywords

*Polymer nano composite; Nanofiller; Processing Characterization; Mechanical and physical properties*

### Introduction

Nanocomposites are composites in which at least one of the phases shows dimensions in the nanometer range. These are high performance materials that exhibit unusual property combinations and unique design possibilities and are thought of as the materials of the 21st century. With an estimated annual growth rate of about 25% and huge demand for engineering polymers, their potential is so promising that they are useful in several applications ranging from packaging to bio-medical. Literature survey reveals that about 18,000 publications, including papers and patents, have been published on nanocomposites in the last two decades. It has been reported

that at the nanoscale (below about 100 nm), a material's property can change dramatically. With only a reduction in size and no change in the substance itself, materials can exhibit new properties such as electrical conductivity, insulating behaviour, elasticity, greater strength, different colour, and greater reactivity-characteristics that the very same substances do not exhibit at the micro- or macro scale.

### Preparation of polymer nano composites

Preparation of good quality polymer nano composite samples using a proper processing method is critical to achieve high performance of polymer nano composites. The processing techniques developed for preparation of polymer nanocomposites include: melt mixing, solution mixing, in situ polymerization, in-situ particle processing and other approaches. Creation of one universal technique for preparing all types of polymer nanocomposites is impossible due to the physical and chemical differences between polymers and various available types of facilities. Each polymer system needs specific processing conditions based on processing efficiency, nano-scale filler type and desired properties. In general, different processing technologies do not yield equivalent results

### Properties of polymer nanocomposites

Polymers have relatively insufficient modulus and strength as engineering

materials. Inorganic inclusions such as fibers, whiskers, platelets or particles are often employed to improve their mechanical properties. Traditionally, polymer composites are reinforced with micron-sized inclusions. In recent years, the inclusion size is allowed to go down to nanoscale. Research work is still ongoing and a definite conclusion is not yet clear on the effect of nano filler size on properties of polymer systems. The properties of polymers that can be enhanced dramatically by introducing nanoscale fillers at fairly low concentration include mechanical properties, thermal stability, heat distortion temperature, fire retardancy, gas barrier properties, ionic conductivity and magnetic properties etc. In this section, the effects of nanoscale filler incorporation on these properties of polymer nanocomposites are discussed.

### **Mechanical properties**

#### **Layered nanofiller/polymer nanocomposites**

Clay minerals have a layer structure with a typical thickness of  $\sim 1$  nm. If properly exfoliated, clay can reach to platelets having a high aspect ratio (an average length of 120 nm reported). Organoclay/nylon 6 nanocomposites are made via direct melt compounding using a conventional twin screw extruder. The strength of the nanocomposites is significantly increased and shows much higher values than that of glass fiber composites [155]. The yield strength of nylon-6/organoclay nanocomposites increases dramatically with the increase of organoclay content and has a higher value than the nylon-6/glass fiber composites with a higher weight percentage as shown in Table 2, [155]. Moreover, the modulus of nylon 6/organoclay nanocomposites

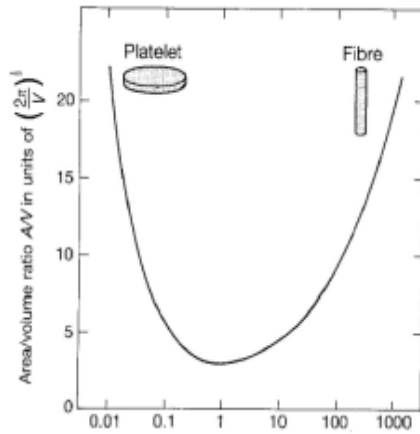
increases dramatically with the increase of organoclay content as. This can be explained in terms of platelet aspect ratio. The platelets resulting from exfoliation of clay minerals have a high aspect ratio in the nanocomposites. As shown previously for short fiber reinforced polymer composites, the composite strength and modulus generally increases with the increase of filler aspect ratio [156,157]. So a high aspect ratio of clay platelets is important to the achievement of the high strength and modulus. Table 3 shows that the tensile strength and Young's modulus of clay/nylon 1012 nanocomposites increases dramatically with increasing the particle content [158]. Similar results are obtained for polyurethane/clay nanocomposites

#### **Varieties of polymer nanocomposites**

Almost all types of polymers, such as thermoplastics, thermosets and elastomers have been used to make polymer nanocomposites. A range of nanoreinforcements with different shapes have been used in making polymer nanocomposites. An important parameter for characterizing the effectiveness of reinforcement is the ratio of surface area (A) of reinforcement to volume of reinforcement. A plot of A/V against aspect ratio [defined as the ratio of length (l) to diameter (d)]. It can be seen from figure 1 that the predicted optimum shape for the cylindrical reinforcement to maximize A/V is

- $a \gg l$  (a fiber), and
- $a \ll l$  (a platelet).

Therefore, it can be understood that the two main classes of nano reinforcement are fibers (e.g., carbon nanotubes) and platelets (e.g., layered silicate clays).



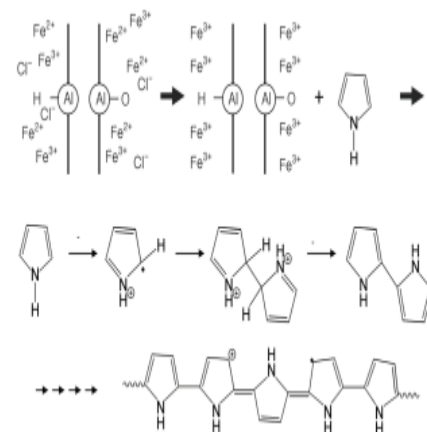
a(long scale)

Fig. 1. Surface area to volume ratio  $A/V$  of a cylindrical particle of given volume, plotted versus aspect ratio  $a=l/d$  (from McCrum et al., 1996) Polymer-layered inorganic platelet nanocomposites are bio-inspired materials. Mother of pearl (nacre) is a bio-nanocomposite made of: 95 percent aragonite (calcium carbonate), a brittle ceramic, and 5 percent flexible biopolymer (conchiolin). But, it is several times stronger than nylon; its toughness is almost equal to silicone. It is built like a "brick-and- mortar" structure, where millions of ceramic plates stacked on top of each other with each layer of plates glued together by thin layers of the biopolymer (Figure 2). Mixture of brittle platelets and the thin layers of elastic biopolymers make the material strong and resilient. The "brickwork" arrangement also inhibits transverse crack propagation.

### Synthesis of nanocomposites

Basically there are three methods to prepare nanocomposites. They are: solution casting, melt blending and in-situ polymerization. In solvent casting, a polymer, a solvent and nanoreinforcement are combined and thoroughly mixed by ultrasonication and the solvent is allowed to evaporate leaving behind the nanocomposite typically as a thin film. The solvent chosen should completely

dissolve the polymer as well as disperse the nanoreinforcement. The solvent used will help in the mobility of the polymer chains which in turn helps in the intercalation of the polymer chains with the layered nanoreinforcement. In the case of melt blending, extruder or an internal mixer is used. Polymer and nano reinforcement are added in the extruder and subjected to intensive mixing for some time and nanocomposite comes out from the die. In this method, polymer mobility simply comes from thermal energy. In case of in-situ polymerization, which is widely used for PLS nanocomposite synthesis, initially the monomer and nano reinforcement are mixed. The monomer is allowed to intercalate between the silicate layers. Once the monomer is intercalated it is polymerized .The polymerization may be due to some surface modification at silicate surface or due to any functionalities present which catalyze the reaction (Alexandre and Dubois, 2000). There have been numerous reports on the synthesis of conducting polymer nanocomposites (Fang et al., 2008; Gangopadhyay and De, 2000). In an interesting work by polypyrrole coated imogolite was synthesized by exposing  $FeCl_3 \cdot 6H_2O$  absorbed imogolite to pyrrole vapor under ambient conditions.



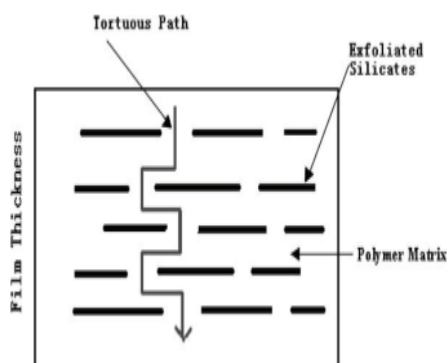
**Scheme to prepare polypyrrole-**

## imogolite in a doping state with an acceptor dopant (FeCl<sub>3</sub>)

### Properties of polymer nanocomposites

#### Barrier properties and flame retardancy

The search for non-halogenated flame retardants has led to nanoclays, one nm thick by 1000 nm diameter. Initial research showed that the addition of as little as 5% of nano-sized clay particles could produce a 63% reduction in the flammability of nylon-6. More recent studies have shown that flame retardancy in many other polymers can be boosted by dispersing clay at the molecular level. Clays are believed to increase the barrier properties by creating a maze or 'tortuous path' (Scheme 8) that retards the progress of the gas molecules through the matrix resin (Neilson, 1967). For example, polyimide/layered silicate nanocomposites with a small fraction of O-MMT exhibited reduction in the permeability of small gases, e.g. O<sub>2</sub>, H<sub>2</sub>O, He, CO<sub>2</sub>, and ethyl acetate vapours.



### Path Model For Barrier Enhancement Of Nano Composites

Studied multiwall nano tubes in polypropylene. A comparison of heat release rate curves among the three samples. The results show that the heat release rates of the PP/MWNT nano composites are much lower than that of PP even though the amount of MWNTs in PP

is quite small. This reduction in heat release rate is at least as much as what was previously found for clay nano composites in a maleic anhydride modified PP. Kashiwagi attributed the performance of the MWNT more to the presence of the small amount of iron catalyst in the MWNT. This iron may form iron oxides during combustion and iron oxides have been used as flame retardant additives. Another possibility that has been suggested is that the nanotubes function by conducting heat away from the flame zone.

### Applications of polymer nanocomposites.

The improvements in mechanical properties of nanocomposites have resulted in major interest in numerous automotive and general/industrial applications. It includes potential for utilization as mirror housing on various types of vehicles, door handles, engine covers, and belt covers. More general applications include: packaging, fuel cell, solar cell, fuel tank, plastic containers, impellers and blades for vacuum cleaners, power tool housing, and cover for portable electronic equipment such as mobile phones and pagers.

### Nanocomposite structure

In general, the degree of dispersion of the clay platelets into the polymer matrix determines the structure and the final properties of the nanocomposites. Depending on the nature of the components used (layered silicate, organic action and polymer matrix) and the method of preparation, three main types of composites may be obtained, when layered clay is associated with a polymer.

**a. Non mixing composites:** In this case, the interactions between the clay particles and the polymer are very weak and thus, the polymers cannot enter into clay galleries. A phase separated composite is



formed with relatively poor mechanical properties.

**b. Intercalated structures:** in which the polymeric chains are intercalated between the silicate layers resulting in a well ordered multilayer morphology, built up with alternating polymeric and inorganic layers. Intercalation results a separation of about 2- 3 nm between the layers, which is independent of the clay to polymer ratio (Yeh & Chang, 2008). The properties of this type of nanocomposites resemble those of ceramic materials.

**c. Exfoliated or delaminated structures:** in which the clay layers are well separated from one another and individually dispersed in the continuous polymer matrix. In this case, the distance between two platelets may be in the range of 5-10 nm or even more. In such systems, the polymer–clay interactions are maximised leading to significant changes in mechanical and physical properties. It is generally accepted that exfoliated systems exhibit better mechanical properties than intercalated ones.

### Conclusion

Among many highly hyped technological products, polymer nanocomposites are one of those, which have lived up to the expectation. Polymer nanocomposites exhibit superior properties, such as mechanical, barrier, optical, etc. as compared to micro- or macrocomposites. Owing to this, polymer nano-composites have shown ubiquitous presence in various fields of application. Polymer nanocomposites for various applications could be synthesized by proper selection of matrix, nano reinforcement, synthesis method and surface modification of either the reinforcement or polymer (if required). Many products based on polymer nanocomposites have been

commercialized. This review has tried to highlight various types of nano reinforcements and their surface modification procedures, some unique properties of nanocomposites, various technological applications of polymer nanocomposites with some specific examples of commercialized products.

### Reference

1. Alexandre, M. & Dubois, P. (2000). *Polymer-layered silicate nanocomposites: preparation, properties and uses of a new class of materials. Materials Science and Engineering*, 28, 1- 63
2. Chin, I.-J.; Thurn-Albrecht, T.; Kim, H.-C.; Russell, T.P. & Wang, J. (2001). *On exfoliation of montmorillonite in epoxy. Polymer*, 42, 5947–52
3. Choudalakis, G. & Gotsis, A.D. (2009). *Permeability of polymer/clay nanocomposites: A review. European polymer Journal*, 45, 967-984
4. Incarnato, L.; Scarfato, P.; Russo, G.M.; Di Maio, L; Iannelli, P.; Acierno, D. (2003). *Preparation and characterization of new melt compounded copolyamide nanocomposites. Polymer* , 44, 4625–4634.
5. Jiang, T.; Wang, Y-H.; Yeh, J-T. & Fan, Z-Q. (2005). *Study on solvent permeation resistance properties of nylon6/clay nanocomposite. European Polymer Journal*, 41, 459-466
6. Katsaros, F.K.; Steriotis, Th.A.; Sapalidis, A.A. & Favvas, E.P. (2009). *Neutron diffraction studies of polymer/Clay nanocomposites, in BENSC Experimental Reports 2008, A. Rodig, A. Brandt, H.A. Graf (Eds), page 212, Berlin*
7. Lim, Y.T. & Park, O.O. (2001). *Phase morphology and rheological behavior of polymer/layered silicate nanocomposites. Rheologica Acta*, 40, 220-229
8. Magonov, S.N. (2000). *AFM analysis of polymers In: Encyclopedia of analytical chemistry, R.A. Meyers, (Ed), Wiley, Chichester, pp. 7432–7491, ISBN: 9783527293131*