ABSTRACT

When gingivitis is not treated, it can advance to “periodontitis” (which means “inflammation around the tooth”). In periodontitis, gums pull away from the teeth and form spaces (called “pockets”). Goodson et al in 1979 first proposed the concept of controlled delivery in the treatment of periodontitis. Herbal medicines have fewer side effects and are safer to use than conventional medications. It is well documented that medicinal plants confer considerable antibacterial activity against various microorganisms including bacteria’s responsible for dental caries. Phytochemicals for the prevention, treatment and maintenance of periodontal diseases are identified. They may be tannins, terpenoids, flavanoids, alkaloids, etc. Antimicrobial activities of these have been found to be particularly useful for periodontal diseases. The transition from micro particles to nanoparticles yields dramatic changes in physical properties. Nanoscale materials have a large surface area for a given volume. Since many important chemical and physical interactions are governed by surfaces and surface properties, a nanostructured material can have substantially different properties from a larger-dimensional material of the same composition. Therapeuticmodality for achieving better clinical outcomes when used as an adjunct to conventional non-surgical periodontal therapy. Intensive research efforts are now focused on the development of new strategies formore effective treatment.
KEYWORDS: Gingivitis, Periodontitis, Naocomposites, Manufacturing Techniques of Nano composites.

INTRODUCTION
Periodontal diseases range from simple gum inflammation to serious disease those results in major damage to the soft tissue and bone that support the teeth. In the worst cases, teeth are lost. Our mouths are full of bacteria. These bacteria, along with mucus and other particles, constantly form a sticky, colorless “plaque” on teeth. Brushing and flossing help get rid of plaque. Plaque that is not removed can harden and form “tartar” that brushing doesn’t clean.

Gingivitis
The longer plaque and tartar are on teeth, the more harmful they become. The bacteria cause inflammation of the gums that is called “gingivitis.” In gingivitis, the gums become red, swollen and can bleed easily. Gingivitis is a mild form of gum disease that can usually be reversed with daily brushing and flossing, and regular cleaning by a dentist or dental hygienist.

Periodontitis
When gingivitis is not treated, it can advance to “periodontitis” (which means “inflammation around the tooth”). In periodontitis, gums pull away from the teeth and form spaces (called “pockets”) that become infected. The body’s immune system fights the bacteria as the plaque spreads and grows below the gum line. Bacterial toxins and the body’s natural response to infection start to break down the bone and connective tissue that hold teeth in place. If not treated, the bones, gums, and tissue that support the teeth are destroyed. The teeth may eventually become loose and have to be removed. Periodontitis is clinically differentiated from gingivitis by the loss of the connective tissue attachment to the teeth in the presence of concurrent gingival inflammation. Loss of the periodontal ligament and disruption of its attachment to dentin, as well as resorption of alveolar bone occurs. Together with loss of attachment, there is migration of the epithelial attachment along the root surface and resorption of bone. The histopathology of the periodontitis lesion is in many ways similar to that of the established lesion of gingivitis, with a predominance of plasma cells, loss of soft connective tissue elements, and, in addition, bone resorption. Despite the histopathologic similarities between gingivitis and periodontitis, evidence is lacking that would indicate that periodontitis is an inevitable consequence of gingivitis.
Furthermore, the pathogenic mechanisms explaining the progression of gingivitis lesions to periodontitis lesions are not clear, and the factors that lead to the initiation of periodontitis lesions are unknown. Clinical models of disease activity in periodontitis range from a continuous progression of disease during which loss of attachment occurs at a slow rate over long periods of time to an episodic burst model in which loss of attachment occurs relatively rapidly during short periods of disease activity. Clinical data indicate that either mechanism could be operant in different patients or at different sites or at different times within the same patient, implying that the pathogenesis of periodontal attachment loss could differ between the pathologic mechanisms involved still awaits measurement methods that clearly differentiate between active and quiescent disease.

**Bacterial Virulence**

It is widely accepted that the initiation and progression of periodontitis are dependent upon the presence of microorganisms capable of causing disease. Although more than 300 species of microorganisms have been isolated from periodontal pockets, it is likely that only a small percentage of these are etiologic agents. Two major periodontal disease pathogens, *A. actinomycetemcomitans* and *P. gingivalis*, are able to invade into the tissues. *A. actinomycetemcomitans* can pass through epithelial cells into the underlying connective tissues, while *P. gingivalis* can invade and persist in epithelial cells.

The initiation and propagation of most forms of gingivitis are dependent upon the presence and persistence of bacterial plaque. The histopathology of the gingivitis lesion and its stages are consistent with the following pathogenic mechanisms. Plaque bacteria contain or produce substances capable of causing inflammation.

Such substances can have direct effects on the vasculature and on leukocytes, inducing vasodilatation, increased GCF flow and emigration of neutrophils. Substances in bacterial plaque may also interact with host systems involved in inflammatory responses and thereby exacerbate clinical and histological parameters of inflammation. In more advanced stages of disease it is likely that bacterial antigens, via their ability to gain ingress to the periodontal tissues, activate host cells such as monocytes, lymphocytes and fibroblasts and thereby induce pathological changes that are consistent with a chronic inflammatory response.

2. Although a high proportion of sites that experience periodontal attachment loss display signs of gingival inflammation, there is little evidence demonstrating that gingivitis lesions
will always progress to become destructive periodontitis lesions. Furthermore, the pathologic processes that is operant during the initiation of attachment loss, whether alterations in the bacterial flora, fluctuations in host defense mechanisms or other factors, are not well defined.

3. The pathology of periodontitis lesions is characteristic of, and consistent with, a subversion of host defenses against bacterial plaque pathogens and subsequent activation of bacterially-induced host-mediated processes that destroy periodontal tissues. Data indicate that pathogenic plaque bacteria have virulence characteristics that can prevent their efficient detection and elimination by the host, disable host cells and humeral factors, and directly adversely affect the tissues. The predominance of a Gram-negative bacterial flora, in combination with the cellular and cytokine profiles of the lesions indicate the likelihood that bacterial LPS activation of monocytes and subsequent production of tissue destructive cytokines are likely a major pathway for connective tissue attachment loss and bone loss in most forms of periodontitis. Such cytokines can cause tissue destruction via mobilization of tissue metalloproteinase, a major pathway for destruction of soft and hard connective tissues.

4. Emerging data indicate that individual susceptibility to some forms of periodontal disease may be heritable. However, no definitive data in this regard are available. On the other hand, many inherited and acquired diseases characterized by diminished protective function of inflammatory and immunologic pathways are associated with more severe periodontal disease.

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**Fig.1: Various stages of Periodontal Disease.**
Risk Factors

1. **Smoking.** Need another reason to quit smoking? Smoking is one of the most significant risk factors associated with the development of gum disease. Additionally, smoking can lower the chances for successful treatment.

2. **Hormonal changes in girls/women.** These changes can make gums more sensitive and make it easier for gingivitis to develop.

3. **Diabetes.** People with diabetes are at higher risk for developing infections, including gum disease.

4. **Other illnesses.** Diseases like cancer or AIDS and their treatments can also negatively affect the health of gums.

5. **Medications.** There are hundreds of prescription and over the counter medications that can reduce the flow of saliva, which has a protective effect on the mouth. Without enough saliva, the mouth is vulnerable to infections such as gum disease. And some medicines can cause abnormal overgrowth of the gum tissue; this can make it difficult to keep teeth and gums clean.

6. **Genetic susceptibility.** Some people are more prone to severe gum disease than others.

Who gets gum disease?

People usually don’t show signs of gum disease until they are in their 30s or 40s. Men are more likely to have gum disease than women. Although teenagers rarely develop periodontitis, they can develop gingivitis, the milder form of gum disease. Most commonly, gum disease develops when plaque is allowed to build up along and under the gum line.[1-6]
CONVENTIONAL TREATMENT

I. LOCAL DRUG DELIVERY SYSTEMS Goodson et al in 1979 first proposed the concept of controlled delivery in the treatment of periodontitis. It has been observed that the local route of drug delivery can attain 100-fold higher concentrations of an antimicrobial agent at subgingival sites compared with a systemic drug regimen. This reduces the total patient dose by over 400 fold thereby reducing the potential problems with the use of systemic antibiotic drug regimens and development of drug-resistant microbial populations at non oral body sites.

1. FIBRES: Fibres have been developed as a non–degradable dosage form only. Fibres, or threadlike devices, are reservoir–type systems, placed circumferentially into the pockets with an applicator and secured with cyanoacrylate adhesive for the sustained release of trapped drug into the periodontal pocket. The prototype for the use of fibre–like devices to deliver to the periodontal pocket was introduced by Goodson et al (1983), using cellulose acetate dialysis tubing. The release of the tetracycline from the cellulose acetate fibres by diffusion mechanism is rapid. Hollow fibres containing 20% (v/v)chlorhexidine, when placed into periodontal pockets, exhibited a prompt and marked reduction in signs and symptoms of periodontal disease. The disadvantage of the hollow fibres served was that they permitted rapid evacuation of the drug. To retard drug release, drug – impregnated monolithic fibres were developed by adding drug to molten polymers, spinning at high temperature and subsequent cooling. Several polymers such as polycaprolactone (PCL), polyurethane, polypropylene, cellulose acetate propionate and ethyl vinyl acetate (EVA) have been investigated as matrices for the delivery of drug to the periodontal pocket. Hence monolithic fibres were essentially developed to retard the drug release. Outcomes included reduction of periodontal pathogens, reduction of bleeding on probing decrease in probing pocket depths and increase in probing attachment levels. Actisite, as an adjunct to SRP, showed significantly greater reductions in probing depths, bleeding on probing and significant reduction in A. a and P. Gingivalis levels. than SRP alone. Bio-resorbable form of fibre commercially available as PERIODONTAL PLUS AB offers the advantage of no second appointment for removal as it biodegrades within 7 days. A new generation of semi-synthetic tetracycline compounds called glycylcyclines has recently been developed which are effective not only against tetracycline-sensitive bacteria, but also against tetracycline-resistant gram-positive and negative microorganisms.
2. CHEWING GUM: A chewing gum formulation is an excellent choice for acute medication. Studies have shown that even non-medicated chewing gums stimulates saliva flow and increases plaque pH, which prevents tooth decay.1 Today, improved technologies have made it possible to develop and manufacture medical chewing gum with pre-defined properties, such as release of the active substance, taste, and texture. A number of active substances in chewing gum formulations are available commercially. Medicated chewing gum is now a well-established dosage form described in the European pharmacopoeia. It offers a number of advantages, including fast onset of action, avoidance of hepatic first pass metabolism for substances absorbed via buccal route and possibly lower dosage requirements and hence a fewer side-effects.

3. FILMS: The most widely used intrapocket delivery device has been the film or slab from. It has been prepared either by solvent casting or direct milling. This form enhances the physical properties. The dimensions and shape of the film can be easily controlled to correspond to the dimensions of the pocket to be treated. It can be easily and rapidly inserted to the base of pocket, totally submerged, with minimal discomfort to the patient. If the film is not more than approximately 400μm and physical properties provide it with sufficient adhesiveness, it will remain submerged without any interference with the patient’s eating and oral hygiene habits.4 Films are matrix delivery systems in which drugs are distributed throughout the polymer and release occurs by drug diffusion and/or matrix dissolution erosion. Films of various polymers have been made for the controlled release of therapeutic agents. Sustained release devices composed of cross-linked fish gelatin (bycoprotein) containing chlorhexidinediacetate or chlorhexidine hydrochloride in both degradable and non-degradable forms of films have been developed. [7-12]

A sustained release biodegradable device composed of hydrolyzed gelatin matrix, cross linked with gluteraldehyde, glycerin and water into which 2.5 mg chlorhexidinegluconate has been incorporated named PERIOCHIP have been developed in 1998. It is a small, orange-brown, tombstone-shaped chip (4.0x 0.5x 0.35 mm) and has been approved by FDA19 The adjunctive use of the chlorhexidine chip results in a significant reduction of pocket depth when compared with both scaling root planing alone and the adjunctive use of a placebo chip.20-22 Perio Chip releases chlorhexidine in a biphasic manner, initially releasing approximately 40% of the chlorhexidine within the first 24 hours and then releasing the remaining chlorhexidine in an almost linear fashion for 7–10 days. [12-15]
HERBAL TREATMENT

Ayurveda is a medical system primarily practiced in India that has been known for nearly 5000 years recommends a combination of lifestyle management and treatment with specific herbs to cure various diseases. There are approximately 1,250 medicinal plants being used in formulating beneficial measures. Herbal medicines have two special characteristics that distinguish them from chemical drugs; use of crude herbs and prolonged usage. Experience has shown that there are real benefits in the long-term use of whole medicinal plants and their extracts, since the constituents in them work in conjunction with each other. Several popular conventional drugs on the market are from various herbs. Herbal medicines have fewer side effects and are safer to use than conventional medications. It is well documented that medicinal plants confer considerable antibacterial activity against various microorganisms including bacteria’s responsible for dental caries. Phytochemicals for the prevention, treatment and maintenance of periodontal diseases are identified. They may be tannins, terpenoids, flavanoids, alkaloids, etc. Antimicrobial activities of these have been found to be particularly useful for periodontal diseases. The biggest challenge and problem is the lack of information about the effect of herbs on oral tissues, mechanism of action, and side effects. Various herbal formulations like aloevera, neem, tulsi, propolis, cocoa husk, pomegranate, cranberry etc. are being used widely these days. These products have shown promising results with no side effects and are economical as well.4Moulari et al, showed improved bactericidal activity of the Harunganamadagascariensis leaf extract (HLE) on the oral bacterial strains implicated in dental caries and gingivitis infections. Examples: Aloe vera, Black Cohosh (RhizomaCimicifugaeRacemosae), Chamomile (Matricariarecutita), Clove Oil (Syzygiumaromaticum), Bloodroot (Sanguinariacanadensis), Caraway (Carumcarvi), Garlic (Allium sativum), Ginger (Zingiberofficinalis), Haritaki (Terminaliachebula), Liquorice (Glycyrrhizagalabra).[33-49]

Composites are a combination of two materials in which one of the material is called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other material called the matrix phase.

Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material.
Fiber Phase
Requirements for the fiber
• The small diameter fiber must be much stronger than the bulk material.
• High tensile strength (whiskers, fibers, wires).

Matrix Phase
Functions
• Binds fibers together.
• Acts as a medium through which externally applied stress is transmitted and distributed to the fibers.
• Protects fiber from surface damage.
• Separates fibers and prevents a crack from one fiber propagating through another.

Properties of material are highly anisotropic due to the orientation of fibers
– Strength perpendicular to the direction of alignment is considerably less (the fibers do not contribute).
– Loss optical/electrical/chemical (barrier) properties.

A broad class of materials, with microstructures modulated in zero to three dimensions on length scales less than 100 nm.
• Materials with atoms arranged in nanosized clusters, which become the constituent grains or building blocks of the material.
• Any material with at least one dimension in the 1-100 nm range.
Constituents have at least one dimension in the nanometer scale.

- Nanoparticles (Three nano-scale dimensions).
- Nanofibers (Two nano-scale dimensions).
- Nano clays (One nano-scale dimension).

**Why nanocomposites?** →

1. Multifunctional,
2. Small filler size and distance between fillers,
3. High surface to volume ratio,
4. Mechanical Properties,
5. Increased ductility with no decrease of strength,
6. Scratching resistance,
7. Optical properties,
8. Light transmission characteristics particle size dependent.

The use of organic or inorganic filler has become ubiquitous in polymeric systems. Polymer composites are manufactured commercially for many diverse applications such as sporting
goods, aerospace components, automobiles, etc. In the last 20 years, there has been a strong emphasis on the development of polymeric nanocomposites, where at least one of the dimensions of the filler material is of the order of a nanometer. The final product does not have to be in nanoscale, but can be micro- or macroscopic in size. This surge in the field of nanotechnology has been greatly facilitated by the advent of scanning tunneling microscopy and scanning probe microscopy in the early 1980s. With these powerful tools, scientists are able to see the nature of the surface structure with atomic resolution. Simultaneously, the rapid growth of computer technology has made it easier to characterize and predict the properties at the nanoscale via modeling and simulation in general, the unique combination of the nanomaterial’s characteristics, such as size, mechanical properties and low concentrations necessary to effect change in a polymer matrix, coupled with the advanced characterization and simulation techniques now available, have generated much interest in the field of nanocomposites. In addition, many polymer nanocomposites can be fabricated and processed in ways similar to that of conventional polymer composites, making them particularly attractive from a manufacturing point of view.

**Background**

The transition from micro particles to nanoparticles yields dramatic changes in physical properties. Nanoscale materials have a large surface area for a given volume. Since many important chemical and physical interactions are governed by surfaces and surface properties, a nanostructured material can have substantially different properties from a larger-dimensional material of the same composition. In the case of particles and fibers, the surface area per unit volume is inversely proportional to the material’s diameter, thus, the smaller the diameter, the greater the surface area per unit volume.

Typical nanomaterials currently under investigation include nanoparticles, nanotubes, nanofibers, fullerenes and nanowires. In general, these materials are classified by their geometries; broadly the three classes are particle, layered and fibrous materials. Carbon black, silica nanoparticle, polyhedral oligomeric silsesquioxanes (POSS) can be classified as nanoparticle reinforcing agents while Nano fibers and carbon nanotubes are examples of fibrous materials. Nanomaterials provide reinforcing efficiency because of their high aspect ratios. The properties of a nanocomposite are greatly influenced by the size scale of its component phases and the degree of mixing between the two phases. Depending on the nature of the components used (layered silicate or nanofiber, cation exchange capacity and polymer
matrix) and the method of preparation, significant differences in composite properties may be obtained. For example, Figure 2 represents three main types of composites for layered silicate materials. When the polymer is unable to intercalate (or penetrate) between the silicate sheets, a phase-separated composite is obtained and the properties stay in the same range as those for traditional micro composites. In an intercalated structure, where a single extended polymer chain can penetrate between the silicate layers, a well-ordered multilayer morphology results with alternating polymeric and inorganic layers. When the silicate layers are completely and uniformly dispersed in a continuous polymer matrix, an exfoliated or delaminated structure is obtained.

**Manufacturing Techniques of Nanocomposites**

An improvement in a property arises when the length scale of the morphology (i.e. Nano) and fundamental physics associated with a property coincide. Two principal factors cause the properties of nanomaterials to differ significantly from other materials: increased relative surface area and quantum effects. Some nanocomposites may show properties predominated by the interfacial interactions and others may exhibit the quantum effects associated with Nano dimensional structures. In the Introduction and Background section, it was mentioned that nanocomposites research is extremely broad; for the real-world applications, instead of a single novel property, a set of properties is of interest.

In some of these areas, fundamental studies of mechanical, electrical, thermal, optical and chemical properties are required along with related research for real applications. For manufacturing of nano-phased structural polymer composite material, the first step will be choice of a fabrication method.

**Some of the widely used methods for manufacturing conventional composite parts are**

1. Wet Lay-Up,
2. Pultrusion,
3. Resin Transfer Molding (RTM),
4. Vacuum Assisted Resin Transfer Molding (VARTM),
5. Autoclave Processing,
6. Resin Film Infusion (RFI),
7. Prepreg Method,
8. Filament Winding,
9. Fiber Placement Technology etc.
1. **Wet lay-up** is a simple method compared to other composite manufacturing methods; it allows the resin to be applied only in the mold, but the mechanical properties of the product are poor due to voids and the final product is no uniform.

2. **Pultrusion** is a low cost continuous process with a high production rate. But near the die assembly, the prepreg or materials accumulate and can create a jam. Voids can be also created if the dies run with too much opening for the fiber volume input. Moreover, a constant cross section is a limitation of this process. But the fibers in pultruded material are generally well aligned. It helps to reduce fiber misalignment in the composite through optimization of manufacturing process variables, such as pull-speed, performer temperature, nanoparticle alignment and/or dispersion.

3. **RTM and VARTM** The RTM is a closed mold operation. In this process, resin flow and fiber wet-out are critical issues; resin flows in the plane as well as in the transverse directions of the preform. Fiber wet-out depends on the fiber architecture and permeability of the preform. Recent developments in textile and resin technology have allowed the designer and manufacturer to use RTM for the fabrication of parts for the primary and secondary structures. Advanced textile technology has helped to increase the wettability of the preforms. A fiber volume fraction of 55–60% can be achieved. Higher toughness can be achieved by using three-dimensional weaving and stitching technology. The VARTM is an adaptation of the RTM; a widely used single-sided tooling process such as open molds are used to make the parts using vacuum. This process has certain advantages like a relatively low cost for high volume production, very large and complex parts are possible with improved surface finish, higher fiber volume fraction than hand lay-up and as it is a closed system, it reduces environmental concerns more than hand layup. Both in RTM and VARTM, if the resin viscosity is high it restricts the flow of resin. The effect of Nano constituents on the matrix resins creates a problem in the altered resin viscosity and cure kinetics, and there is a possibility of dry spots or uneven distribution of resin over the entire volume of the reinforcement.

4. **Autoclave processing** is a promising technique to process and manufacture different complex shapes of high-quality composite structures. It has the ability to process both thermoset and thermoplastic composites with uniform thickness and minimum porosity. However, the major difficulty in this process is the higher capitalization cost. But with the increasing requirement for high-performance composite materials for new generation aircrafts, autoclave applications remains one of the most widely used techniques in the aerospace industry.
5. **Resin film infusion (RFI)** is similar to RTM where a thin film or sheet of solid resin is laid into the mold and preform is laid on top of the resin film under heat and pressure.

6. **Prepreg method** Resin impregnated unidirectional or woven fabric (partially cured) is used in the prepreg method with vacuum bagging and autoclave processing. Although the method is labor intensive, resin distribution in preform is usually uniform.

7. **In filament winding**, resin impregnated fibers are wrapped over a mandrel at the same or different winding angles to form a part. Complicated cylindrical parts, pressure vessels, fuel and water tanks for storage and transportation, and pipes can be manufactured by this method. The viscosity-related problems of the resin systems can be eliminated in this technique. But the critical task is programming the wet winding in this technique. Filament winding is a cost-effective alternative for fabricating spherical and cylindrical parts (even those with varying diameters and surface contours). However, it cannot lay tow on a concave surface.

8. **Fiber placement** is one of the technologies developed for automation and affordability of composite manufacturing. Fiber placement developed as a logical combination of filament winding and automated tape placement technique to overcome many of the limitations of each manufacturing method. Although tape laying systems generally are more efficient than fiber placement in making large flat panels and components with simple curvatures, fiber placement can accommodate much more severe curvature as well as complex contours. Fiber placement eliminates the crossover points produced in filament winding, can crimp fibers, and reduce mechanical properties.

**Characterization Techniques for Nano composites**

Characterization tools are crucial to comprehend the basic physical and chemical properties of PNCs. For structural applications, it facilitates the study of emerging materials by giving information on some intrinsic properties. Various techniques for characterization have been used extensively in polymer nanocomposite research. The commonly used powerful techniques are wide-angle X-ray diffraction (WAXD), small-angle X-ray scattering (SAXS), scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

The SEM provides images of surface features associated with a sample. However, there are two other microscopies, scanning probe microscopy (SPM) and scanning tunneling microscopy (STM), which is indispensable in nanotube research. The SPM uses the interaction between a sharp tip and a surface to obtain an image. In STM, a sharp
conducting tip is held sufficiently close to a surface (typically about 0.5 nm), such that electrons can ‘tunnel’ across the gap. This method provides surface structural and electronic information at atomic level. The invention of the STM inspired the development of other ‘scanning probe’ microscopes, such as the atomic force microscope (AFM). The AFM uses a sharp tip to scan across the sample. Raman spectroscopy has also proved a useful probe of carbon-based material properties. Due to the easiness and availability, WAXD is the most commonly used to probe the nanocomposite structure and occasionally to study the kinetics of the polymer melt intercalation. In layered silicate nanocomposite systems, a fully exfoliated system is characterized by the absence of intensity peaks in WAXD pattern e.g., in the range which corresponds to a d-spacing of at least 6 nm. Therefore, aWAXD pattern concerning the mechanism of nanocomposite formation and their structure are tentative issues for making any conclusion. On the other hand, TEM allows a qualitative understanding of the internal structure, spatial distribution of the various phases, and views of the defective structure through direct visualization, in some cases of individual atoms. Therefore, TEM complements WAXD data. Small-angle X-ray scattering (SAXS) is typically used to observe structures on the order of 10Å or larger. The TEM, AFM, and SEM, are also required to characterize nanoparticle, carbon nanofiber dispersion, or distribution. However, X-ray diffraction has found relatively limited success in CNT research. For thermal characterization and to study the cure behavior (typically for thermoset resin systems) of PNCs, the commonly used techniques are differential scanning calorimeter (DSC), thermo gravimetric analysis (TGA), thermo mechanical analysis (TMA), Fourier-transform infrared (FTIR), dynamic modulus analysis (DMA), rheometer, etc. The next section will discuss the structure, properties, processing, and manufacturing of different PNCs with relevant applications. [29-32]

REFERENCES


68. Swaminathan, Rajaram and Ravi, Vijay Kumar and Kumar, Satish and Kumar, Mattaparthi Venkata Satish and Chandra, Nividh Lysozyme: A model protein for amyloid research. *Adv in Protein Chemistry and structural Biology*, 2011; 84. [BookChapter]