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Study of Bio-Nano Composite of Poly-Lactic Acid for Food Packaging- A Review

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Abstract: **The impact of environment, economic and safety challenges have provoked the need to partially substitute petrochemical based polymer with bio degradable ones. [Poly lactic acid] PLA is the leading biodegradable polymer but its applications are limited by its relatively high cost, poor impact strength and barrier properties,which may be improved by adding reinforcing compounds (fillers), forming composites. Most reinforced materials present poor matrix–filler interactions, which tend to improve with decreasing filler dimensions. The use of fillers with at least one nanoscale dimension (nanoparticles) produces nanocomposites. Nanoparticles have proportionally larger surface area than their microscale counterparts, which favors the filler–matrix interactions and the performance of the resulting material.**

Applications of nanomaterials in combination with PLA structures for creating new PLA nanocomposite with greater abilities are also covered. These approaches may modify PLA weakness for some food packaging applications. Nanotechnology approaches are being broadened in food science, especially in packaging material science with high performance and low concentrations and prices, so this category of nano-research is estimated to be revolutionary in food packaging science in the near future. The linkage of the 100% bio originated material and nanomaterial opens new windows for becoming independent, primarily, of petrochemical based polymers and, secondarily, for answering environmental and health concerns will undoubtedly be growing with time.

This study seeks to overcome PLA limitations by reinforcing PLA with nanoparticles and low-cost agricultural residues. The work presented in this thesis focuses on exploration of following relevant aspects:

- **Preparation of PLA nanocomposite from LA [lactic acid].**
- **Reinforcement of various fillers during preparation.**
- **Testing of the formed nanomaterial to study the enhanced properties for sustainable green food packaging.**
- **Comparative study of the newly formed nanocomposites with respect to its properties**

Nanotechnology has demonstrated a great potential to provide important changes in food packaging sector.

Nanocomposites are promising to expand the use of bio-degradable polymer, since the addition of nanoreinforcement has been related to improvement in overall performance of biopolymers, making them more competitive in a market dominated by non-biodegradable materials.

Keywords: **Nanotechnology, nano reinforcement, sol-gel reaction, green packaging.**

1. INTRODUCTION

Poly (lactic acid) or **polylactide** (**PLA**):

biodegradable thermoplastic aliphatic polyester derived from renewable resources, such as corn starch or sugarcane. In 2010, PLA had the second highest consumption volume of any bioplastic of the world.

Properties	
Molecular formula	$(C_3H_4O_2)_n$
Density	1.210–1.430 g·cm^{-3}
Melting point	150–160 °C (302–320 °F)
Solubility in water	Insoluble in Water

Plastics based on synthetic polymers from petroleum resources have been widely used in many fields, including packaging, textiles, service utensils, appliance components, construction materials, agriculture, etc. However, we are facing severe environmental issues due to their non-biodegradability. Besides, petroleum resources are finite. Therefore, there is a great interest in the development of alternative and biodegradable polymers from renewable resources. Depending on the origins and synthesis processes, renewable resources derived biodegradable polymers can be classified into three categories:

(1) Polymers extracted from agro-resources, e.g., starch, protein, cellulose;

(2) Polymers produced by microorganisms, e.g., poly (hydroxyalkanoate) s;

(3) Chemically synthesized polymers with monomers obtained from agro-resources, e.g., poly (lactic acid) (PLA).

There are also some biodegradable polymers based on petroleum derived monomers,

E.g. poly (vinyl alcohol), poly (ε-caprolactone), poly (butylene succinate),

Poly (butylene adipate-*co*-terephthalate). Among these numerous biodegradable

Polymers, PLA is the most attractive and useful one.

PLA has many **advantages**:

(1) lactic acid can be easily produced by the fermentation of renewable sugar based resources, such as starch, sugar cane, cellulose, etc.;

(2) PLA can be processed by conventional thermoplastic processing techniques like extrusion, injection molding, blow molding, and thermoforming;

(3) PLA has shown great potential to produce biomedical materials, textiles, films, auto parts, appliance components, service utensils, and packaging materials;

(4) The production of PLA improves the agricultural economy. However, similar to other biopolymers, PLA has several unsatisfactory characteristics, including low strength and modulus above glass transition/heat distortion temperatures around 60 ºC, low thermal stability, rigidity, poor gas barrier properties, and slow biodegradation rate, which limited its broad commodity applications. Numerous efforts, such as copolymerization, plasticization, and blending, composites and nanocomposites fabrication have been attempted to modify the properties of PLA.

Polymer nanocomposites combine the advantages of the inorganic nanoparticles (e.g., rigidity, thermal stability) and the organic polymers (e.g., flexibility, dielectric, ductility, and processability). Besides, the small size of nanoparticles leads to a significant increase in interfacial area, which creates a large volume fraction of interfacial polymers with dramatically enhanced physical, thermal-mechanical, and processing characteristics.

Generally, only less than 5 wt% nanoparticles are needed for fabrication of polymer nanocomposites with satisfactory properties, while conventional composites require a much higher loading of microfillers about 20-60 wt% . Therefore, polymer nanocomposites are far lighter in weight than conventional composites, and they are more competitive with other materials for specific applications.

The effect of different reinforcements on controlling the degradation of the PLA nanocomposites, the molecular structure and thermo-physical properties is investigated using rheometry, thermogravimetric analysis (TGA), FT-IR spectroscopy, and gel permeation chromatography (GPC), NMR etc. The morphological, mechanical, and barrier properties of PLA nanocomposites.

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Definition and Categories of Biodegradable Polymers:

The biodegradability, defined as the degree to which microbes use organic compounds, is directly correlated to the chemical structure of materials. Indeed, the microbes could attack the polymer chains and degrade the chemical bond or link in the chemical structure, leading to mineralization (Siracusa2008).to biodegrade such polymers , such specific conditions interms of pH ,moisture,presence of oxygen and some metals are needed.

Biodegradable polymers can be produced from various sources; some of them are made from natural sources like corn, wood and cellulose,while some others are derived from petroleum like aliphatic polyester.furthermore there are some biopolymers made from mixing source of bio and petroleum like poly ether urethane[Ligadas 2007]

However nowadays, an increasing attention has been paid to biodegradable and biocompatible polymers originating from renewable sources such as PLA and PGA. Among the renewable source-based biodegradable plastic, PLA has attracted the most attention since it is thermoplastic, biocompatible, biodegradable, while having good processability and transparency after processing.[Ray,2005]

Polylactic acid:

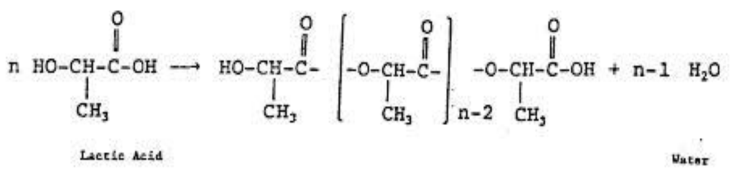
Poly lactic acid is linear, aliphatic thermoplastic polyester that can be either the semi crystalline or completely amorphous state depending on the stereopurity of the polymer backbone (Lima, 2008).

Synthesis:-

Polycondensation Polymerization:

Direct polycondensation (DP) is an approach of polymerization where the end groups of monomers, oligomers or polymers reacts with each other, leading to forming polymer having relatively low molecular weight. For the sake of reducing the financial cost, polycondensation of PLA can be conducted in the absence of catalyst, solvent, and initiator (Achmad, 2009). This process can be performed by distilling-out water from 90 % aqueous solution of lactic acid at high temperatures and reduced pressure. During the process, the temperature is gradually raised up to target point, while the pressure continuously decreases. The pressure reduction occurring during polymerization leads to further distilling-out water from the reactor, with the result that the condensation reaction of lactic acid is accelerated and forms the viscous lactic acid oligomers.

The synthesis of PLA through direct polycondensation is schematically shown in Fig



Since polycondensation is an equilibrium reaction, eliminating the trace amounts of water in the last stages of polymerization is difficult, hence low molecular weight polymer chains are obtained (Amar, 2005). Accordingly, it can be concluded that direct polycondensation is an appropriate approach to synthesize low molecular weight PLA with high biodegradation rate which are good candidate for drug delivery purposes (Bamford, 1976; Hyon, 1997).

Ring-opening Polymerization (ROP):

Since the ultimate molecular weight obtained by direct polycondensation is restricted, ringopening polymerization of PLA has gained most interest. Ring-opening polymerization is a type of addition polymerization, where the terminal end of polymer acts as a reactive center. In *ROP*, cyclic monomers attach together by ionic propagation to form longer polymer chains. The treatment of some cyclic compounds with catalyst results in a cleavage of the rings followed by polymerization that produces high molecular weight polymer chains. In this approach, a cyclic lactide (dimer) is synthesized from lactic acid, and the ring-opening polymerization is carried out using the lactide monomer.

A continuous process of PLA production by a new technology developed by Cargill Dow LLC has decreased its production cost and enlarged its range of applications. In addition to economic advantages resulting from PLA synthesis

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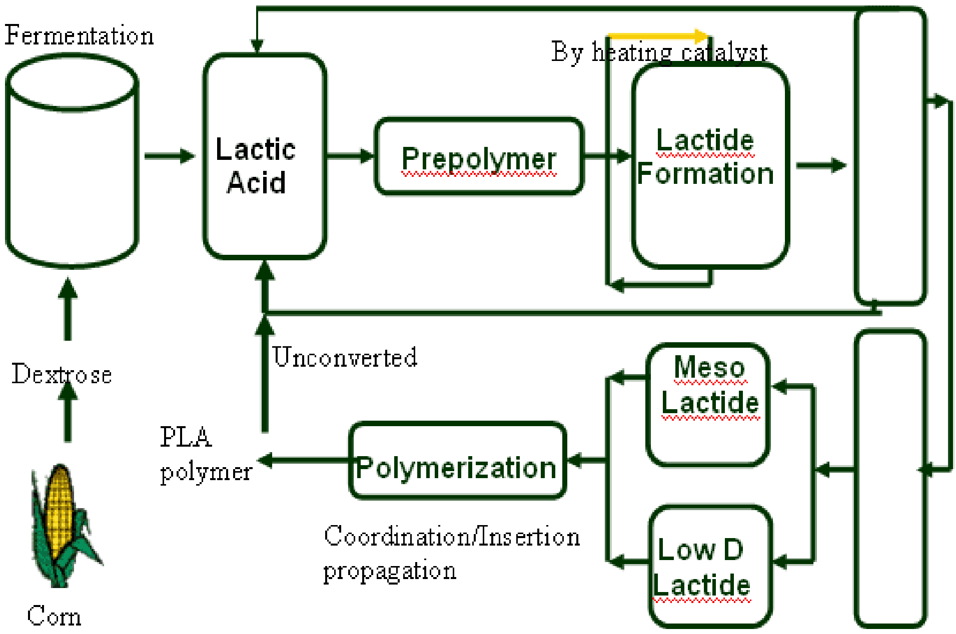
in the melt rather than solution state, the substantial environmental benefits arising from the absence of solvent is also considered in this approach.

The solvent-free synthesis of PLA is depicted in Fig

Non solvent process to prepare PLA [8]



The lactic acid obtained from fermentation of plant substances is used as a feed to synthesize PLA. Then, a continuous condensation reaction of aqueous lactic acid is carried out in order to provide the PLA prepolymer having a low molecular weight.

Nanocomposites:

Nanocomposites are a new class of composites that are particle-filled polymers for which at least 1 dimension of the dispersed particles is in the nanometer range. Three types of nanocomposites include isodimensional nanoparticles (with 3 nano dimensions), nanotubes or whiskers (with 2 nano dimensions), and polymer-layered crystal nanocomposites (with 1 nano dimension).

PLA nanocomposites:

The combination of PLA and montmorillonite-layered silicate may result in a nanocomposite with good barrier properties that is suitable for film packaging material. The modulus of PLA would be increased by the addition of montmorillonite. However, the incorporation of the montmorillonite clay into PLA could decrease the toughness of the PLA composites. There are various technical approaches to achieve a balance of good strength and toughness for PLA nanocomposites. The addition of poly ethylene glycol could act as a good plasticizer in a PLA/clay systems (Shibata and others 2006).

A comprehensive review is provided by Sinha Ray and Okamoto (2003) for the preparation, characterization, materials properties, crystallization behavior, melt rheology, and foam processing of pure polylactide (PLA) and PLA/layered silicate nanocomposites. They concluded this new family of composite materials frequently exhibits remarkable improvements in its material properties when compared with those of virgin PLA. Improved properties can include a high storage modulus both in the solid and melt states, increased tensile and flexural properties, decreased gas permeability, increased heat distortion temperature, and increased rate of biodegradability of pure PLA.

The special characteristics of PLA can make it a good fit for some applications but may also require modifications for some others. For example, the oxygen and moisture permeability of PLA is much higher than for most other plastics, such as PE, PP, and even PET. However, the applications of PLA are limited by several factors such as low glass transition temperature, weak thermal stability, and low toughness and ductility (Harada and others 2007).

Addition of different fillers to polymers for improving their performances like their strength and stiffness, barrier properties, resistance to fire and ignition, and also decreasing their price has always been a common objective in packaging technology. Traditionally, mineral fillers such as clay, silica, and talc are incorporated in film preparations in the range of 10% to 50% by weight to reduce film cost or to improve its performance in some way. However, mechanical strength of such films, in general, decreases when fillers are present. Recently, nanocomposites have received significant attention as an alternative to conventional filled polymers (Rhim 2007).

Nanocomposite food packaging:

Conventional food packaging systems are supposed to passively protect the food, that is, to act as a barrier between the food and the surrounding environment. On the other hand, an active food packaging may be defined as a system that not only acts as a passive barrier but also interacts with the food in some desirable way, e. g. by releasing desirable compounds (antimicrobial or antioxidant agents, for instance), or by removing some detrimental factor (such as oxygen or water vapor). The consequences of such interactions are usually related to improvements in food stability.

2. SCOPE AND LIMITATIONS

Scope:

The production of PLA has numerous **advantages** including:

(a) Production of the lactide monomer from lactic acid, which is produced by fermentation of a renewable agricultural source corn;

(b) Fixation of significant quantities of carbon dioxide via corn (maize) production by the corn plant;

(c) Significant energy savings;

(d) The ability to recycle back to lactic acid by hydrolysis or alcoholysis;

(e) The capability of producing hybrid paper-plastic packaging that is compostable;

(f) Reduction of landfill volumes;

(g) Improvement of the agricultural economy; and

(h) The all-important ability to tailor physical properties through material modifications.

PLA has unique properties like good appearance, high mechanical strength, and low toxicity; and good barrier properties have broadened its applications. Numerous researchers have studied the different properties of PLA alone and in combination with other polymers as blend or copolymer.

One of the most important factors in food packaging polymers is their barrier or permeability performance against transfer of gases, water vapor, and aroma molecules.

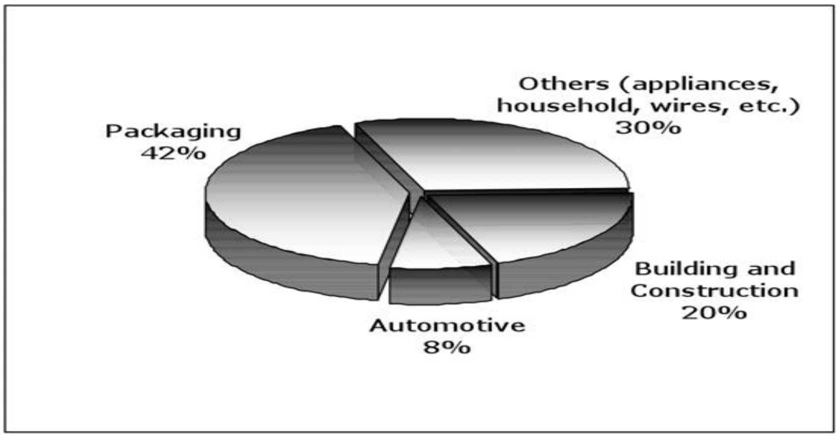
PLA is a growing alternative as a “green” food packaging polymer.

Very limited migration can be expected from PLA into foods that it contacts during the intended conditions of use. The small amount of any material that might migrate from PLA into food will be lactic acid, or its dimers (lactoyl lactic acid and lactide) and oligomers that will be subsequently hydrolyzed in aqueous systems to lactic acid.

PLA brings a new combination of attributes to packaging, including stiffness, clarity, deadfold and twist retention, low-temperature heat sealability, as well as an interesting combination of barrier properties including flavor, and barrier characteristics.

Commercialized PLA products demonstrate this fact that PLA is not being used solely because of its degradability, nor because it is made from renewable resources; it is being used because it functions very well and provides excellent properties at a competitive price. There are many commercialized PLA products in today's market and their variety and consumption are increasing rapidly.

Polymer Global Market



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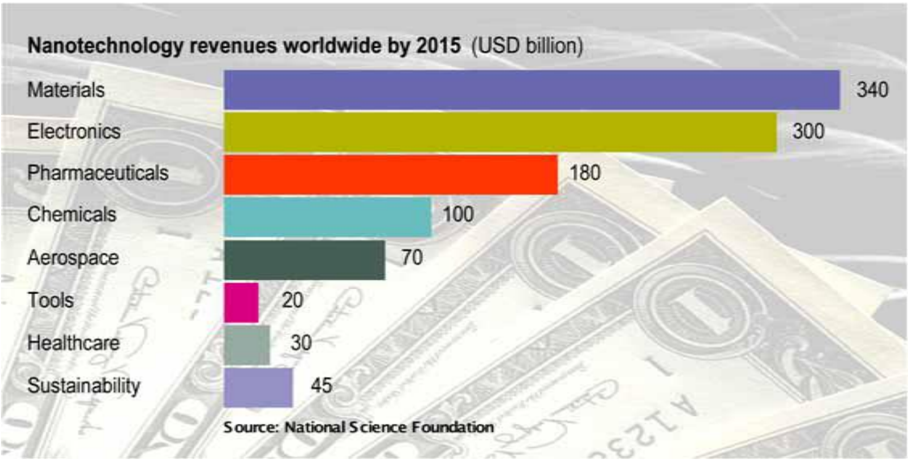

Polymer nanotechnology impacts across all sectors of the global material markets and fits all size companies.

PLA nanocomposites have the potential for enhanced product characteristics

• Fire retardancy

• Mechanical strength

• Barrier properties

• Biocompatibility

• Non toxicity

In industrial sectors where **improved performance together with reduced cost and weight are essential**.

Limitations:-

However, PLA has its own limitations such as

- higher permeability,
- poor thermal stability
- brittleness and
- Lower crystallinity.

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3. AIM & OBJECTIVES

To prepare such a biodegradable nanocomposite for sustainable food packaging which having better dimensional stability, tensile strength, oxygen permeability and with low emission of carbon-di-oxide by incorporation of different reinforcements [fillers] such as inorganic and organic including metal oxides and natural fillers having low cost.

❖ The aim of this paper is to develop a better option for food packaging.

❖ Due to the environmental issue and limited petroleum sources material from renewable agriculture source is developed.

❖ In comparison to other biopolymers, **PLA has numerous advantages:**

a) Production of the lactide monomer from lactic acid, which is produced by fermentation of a renewable agricultural source corn;

b) Fixation of significant quantities of carbon dioxide via corn (maize) production by the corn plant;

c) Significant energy savings;

d) The ability to recycle back to lactic acid by hydrolysis or alcoholysis;

e) The capability of producing hybrid paper-plastic packaging that is compostable;

f) Reduction of landfill volumes;

g) Improvement of the agricultural economy; and

h) The all-important ability to tailor physical properties through material modifications.

i) These biopolymers are abundant, relatively inexpensive, renewable, and biodegradable.

Also this study aims to overcome the drawbacks of PLA, including low glass transition temperature, low thermal stability, slow biodegradation rate, and high cost via **reinforcement** with inorganic nanoparticles such as MgO & TiO2 and low-cost agricultural residues such as wood flour, Soy flour and fly ash etc. and to investigate the structure-property relationships of newly developed PLA composites.

- Uniform disperson of MgO nanocrystals into PLA matrix forming nanocomposite may improve thermal stability compare with pure PLA.
- The PLA matrix in bulk nanocomposite may exhibit decrease in crystallinity with the concentration of TiO2.
- In this study PLA with Soy flour, Wood Flour And Fly ash may improve Mechanical, Thermal, Morphology & Relaxation characteristics of Poly Lactic Acid.

The specific **objectives** are to:

(1) Synthesize PLA nanocomposites by *in situ* melt polycondensation of lactic acid and surface-hydroxylized MgO nanocrystals and investigate the structure, morphology, and thermal properties of the nanocomposites;

(2) Synthesize PLA nanocomposites by *in situ* melt polycondensation of lactic acid and high aspect ratio TiO2 nanowires and investigate the structure and properties;

(3) Develop high performance PLA composites incorporated with low-value agricultural residues (wood flour, soy flour, and distillers dried grains with solubles) and investigate the thermal, mechanical, and morphology properties

The Covalent grafting of PLA chains onto nanoparticle surface will confirm by transmission electron microscopy [TEM], Fourier transform infrared spectroscopy and thermalgravimetric analysis [TGA], and Differential scanning calorimetry [DSC]. Morphological images shows uniform dispersion of nanoparticles in the PLA matrix.

These novel PLA thermoplastic nanocomposite with enhanced properties as a '**green' food packaging**. It brings new combination of attributes to packaging.

1) Very limited migration can be expected from PLA into foods that it contacts during the intended conditions of use.

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2) The small amount of any material that might migrate from PLA into food will be lactic acid, or its dimers (lactoyl lactic acid and lactide) and oligomers that will be subsequently hydrolyzed in aqueous systems to lactic acid. Based on these findings, they concluded that PLA is safe.

Commercialized PLA products demonstrate this fact that PLA is not being used solely because of its degradability, nor because it is made from renewable resources; it is being used because it functions very well and provides excellent properties at a competitive price.

4. METHODOLOGY

NANOCOMPOSITE SYNTHESIS:

Nanocomposites, can be prepared by in-situ synthesis of inorganic particles or by dispersion of fillers in a polymeric matrix. A correct selection of the preparation technic is critical to obtain nanomaterials with suitable properties. The synthesis of polymers nanocomposites usually applies bottom-up or top-down methodologies. In the bottom-up approach, precursors are used to construct and grow, from the nanometric level, well organised structures. Also, blocks-assembly or building block approaches can be used, where already formed entities or nano-objects are hierarchically combined to originate the desirable material. The building block approach has an advantage compared to in-situ nanoparticles formation, since at least one structural unit is well defined and usually does not has significant structural changes during the matrix formation. Chemical processes, such as, sol-gel, chemical vapour deposition (CVD), template synthesis or spray pyrolysis are employed as bottom-up methodologies. Contrarily, top-down approach, bulk material is breaking down into smaller pieces or patterning using in most cases physical methods, as the dispersion layered silicates in polymer matrices.

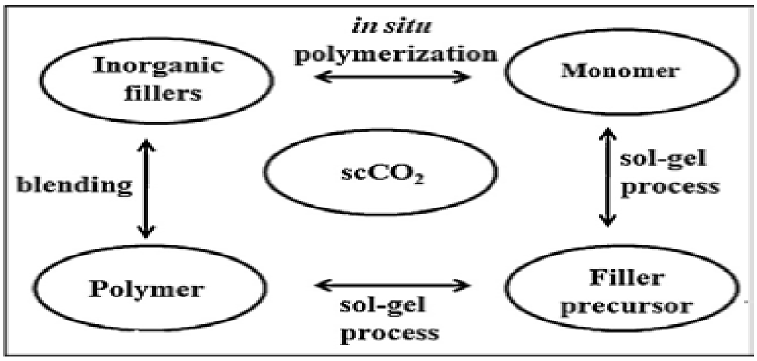
In-situ Nanoparticles Formation:

The in-situ components formation, based on the bottom-up approach, allows us to build well defined multidimensional structures, which have completely different properties from the original precursors. Typically, organic polymer acts as reaction medium where metal and/or metal oxide particles are generated. The desired nanoparticles are then obtained by chemical conversion of the metal precursor. Metals and metal oxide nanoparticles generally are excellent sorbents, catalysts, sensors, reducing agents and bactericides. On the other side, polymers are robust and chemically stable organic materials. Thus, the resulting hybrid nanocomposites exhibit synergetic properties and applications that could not be achieved either by the polymeric material or by the metal nanoparticles individually.

The incorporation of metal nanoparticles into a polymeric matrix can be done using two different approaches: ex-situ or in-situ. In the ex-situ, the inorganic nanoparticles are first synthesized and then introduced in the polymer solution or melt. This is based on physical entrapment of the metal or metal oxide nanoparticles into the polymer network, but homogenous dispersion are difficult to obtain. To overcome this difficulty, the in-situ approach can be used. Here, the metal or metal oxide particles are generated inside the polymer phase using a metal precursor, which is converted in the desirable nanoparticles. The in-situ method allows control over the particle size and the morphology.

1} ***Sol-Gel Process*****:**

The term sol-gel is associated to two reaction steps, sol and gel. Sol is a colloidal suspension of solid particles in a liquid phase and gel the interconnected network formed between phases.



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The sol-gel process consists in two main reactions: hydrolysis (Equation 1a) and condensation (Equation 1b). Both are multi-steps processes and occur sequentially.

Hydrolysis is a cleaving of organic chain bonding to metal and subsequent replacement with -OH groups through nucleophilic addition. The protonated species leaves the hydrolysed metal as an alcohol (alcoxolation). Condensation is based on oxygen, metal,oxygen bond formation(-O-M-O-). By definition, condensation reaction releases small molecules, such as, water or alcohol.

Equation 1a) $M(OR)4 + H2O \rightarrow HO\text{-}M(OR)3 + ROH$

Equation 1b) $(OR)3M\text{-}OH + HO\text{-}M(OR)3 \rightarrow (OR)3M\text{-}O\text{-}M(OR)3 + H2O$

$(OR)3M\text{-}OH + RO\text{-}M(OR)3 \rightarrow (OR)3M\text{-}O\text{-}M(OR)3 + ROH$

The metal reactivity, amount of water, solvent, temperature and the use of complexing agents or catalysts are the reaction main parameters. To use or not a catalyst depends on the chemical nature of the metal atom and steric hindrance of the alkoxide group. Electrophilic character of the metal atom and its ability to increase the coordination number, seems to be the main parameters.

2} *Intercalation Polymer-Layered Materials*:

The four main processes to prepare nanocomposites of polymer-layered :

- exfoliation-adsorption,
- in situ intercalative polymerization,
- melt intercalation and
- template synthesis

Exfoliation-Adsorption:-This process involves the use of solvent, in which polymer or prepolymer is soluble, to promote the exfoliation of layered silicate into single layers. When the appropriated solvent is used, it is possible to break the weak forces that stack the layers together. Then, the polymer is easily absorbed onto the laminated sheets. After solvent evaporation, a sandwich of polymer is obtained by sheets reassemble. Emulsion polymerization, where reinforcement layers are dispersed in the aqueous solution, is also included in this process.

In Situ Intercalative Polymerization:

In this process monomer is in solution where silicate layers are swollen within. The polymerization is initiated between layers, expanding and dispersing the fillers into the polymer. An advantage of this method is the tethering effect, which allows nanomaterial with chemical active surface to link polymer chain during polymerization.

Melt Intercalation:

Melt mixing is the most promising and practical method to be used in industry. Since solvents are not required, this can be applied to polymer processing industry to produce nanocomposites based on usual compounding devices, such as, extruders or mixers. Direct mixing due to simplest, economical, and environmentally friendly technic, is the mainstream for the fabrication of polymer nanocomposite. Usually during extrusion the filler is mixed with the molten polymer, whose chains penetrate inside the galleries of reinforcement layers inducing its intercalation. compatibility between layers surface and polymer, either intercalated or exfoliated nanocomposites can be obtained, depending the degree of layers separation. This method, commonly requires "trial-and-error-based" experiments to test different process conditions to optimize dispersion. Processing equipment and processing conditions have important role since the combination of shear stresses, residence time and temperature improve clay dispersion. Other important parameter for effective reinforcement dispersion is the polymer molecular weight. Polymers with high molecular weight enhance filler dispersion since these can transfer shear stress to the clay. Nevertheless, normally lower levels of exfoliation are achieved when compared with in situ polymerization. Polymers that are not suitable for adsorption or in situ polymerization methods, nanocomposites can be prepared by melting intercalation process. Thermoplastics with strong polar groups, as polyamide-6, ethylene vinyl acetate and polystyrene have been intercalated/exfoliated. However, polyolefins, the main volume of produced polymers, only in specific cases intercalation was successfully achieved.

Template Synthesis:

Template synthesis technic, a method completely different from other described above, is based on sol-gel technic. Using an aqueous solution (or gel) containing the silicate building blocks and polymer, filler is synthesized within the polymer matrix. During the process, polymers act as template helping the nucleation and growth of crystals, being trapped inside the layers as they grow Theoretically, template synthesis should promote the dispersion of the silicate layers in a one-step process, but some serious drawbacks have been observed.

- However, exfoliation-adsorption process reveals commercial handling problems due to the solvents high costs and phase separation of the synthesized product from the solvent.

- Intercalation method is practical and promising method to be used in industry hence large scale production is carried out.

- The most intresting advanges of the use of sol-gel method is its method is its compatibility with polymers and polymerization processes, which allows the formation of nano paricles in the presence of organic molecules.

Therefore to prepare nanocomposite by extrusion, mainly synthesis of nanoparticles by sol-gel reaction and dispersion of fillers in polymer matrices.

TESTING METHODS:

THERMAL ANALYSIS

- Glass transition temperature, Tg, by DSC
- Dynamic Mechanical Thermal Analysis,DMTA
- Decomposition temperature, volatile content, filler content by TGA

CHEMICAL ANALYSIS

- Material identifications and qualification
- Reaction monitoring to understand cure chemistry
- Curing with, IR.
- Morphology, chemical composition crystalline structure and orientation by SEM.
- Structural characterization and chemical analysis by TEM.

MECHANICAL TESTING

- Tesile testing
- Flexural testing

5. IMPLICATION

The development of synthetic polymers from petroleum-based products has benefited humankind for decades but has also led to severe problems including overexploitation of fossil resources and environmental pollution. Therefore, there is a great interest in the development of alternatives and biodegradable polymers. Several bio-based polymers such as poly(lactic acid) (PLA), polyhydroxyalkanoates, and functionalized vegetable/plant starch and protein-based resins have been created from renewable resources Poly(lactic acid) is a biodegradable polymer derived from sugar-based materials. It exhibits mechanical properties similar to those of synthetic polymers such as polyethylene, polypropylene, polystyrene, and polyethylene terephthalate.

These results will provide new insights into fundamentals and structure-property relationships of polymer nanocomposites and composites with the different reinforcement such as organic & inorganic fillers. These novel PLA thermoplastic nanocomposites and composites with enhanced properties have potential applications in packaging materials. Commercialization of such products in the future would accelerate the use of biopolymers (starch, cellulose, hemicelluloses, etc.) and reduce our reliance on fossil resources.

In the first step of this study incorporation of various reinforcements into PLA will strongly influence in its properties for packaging materials such as thermal stability, decrease in crystallinity etc. Incorporation of fillers into PLA nanocomposites on promoting the degree of filler dispersion, rheological, mechanical and barrier properties. PLA/nanomaterial will be prepared.

Substituting PET with PLA in food packages, which require high-barrier properties, is not feasible unless some modifications are applied to develop its permeability. Also, the brittleness of PLA may also limit its applications where toughness and impact resistance are critical. However, with the help of nanotechnology and providing safe PLA nanocomposites, many of its weakness compared to petrochemical-based polymer will be resolved.

In the second step of this study the morphological observations, using TGA, DSC , SEM and TEM, and quantification of filler dispersion revealed that an increased and homogeneous dispersion of filler will achieved in nanocomposites prepared.

The mechanical properties of the neat PLA, the PLA nanocomposites will also be considered.

Semi-crystalline PLA exhibited a high tensile modulus and strength while it had a very low elongation at break and toughness. However, a good dispersion and distribution of nanofillers and an increased molecular weight in nanocomposites will led to a significant increase in the mechanical properties of the PLA nanocomposites in comparison with the neat PLA.

According to its safety, biodegradability,the substituting of many petrochemical-based polymers by PLA for almost all pharmaceutical and direct food contact packaging materials in the near future.

Special emphasis is given to the advantages of nanotechnology application in order to improve mechanical and oxidation stability, the barrier properties for food packaging application

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