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LPDE/Alumina Based Bio-Nano Composite Materials for Food Packaging Applications

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Abstract: Bio nano-materials are playing an important part in a number of applications due to their inherent eco-friendly advantages since the last few decades. Most of the materials used in food packaging are not degradable material, which do not meet increasing demands in society for sustainability and environmental safety. Thus, numerous polymers have been applied to develop biodegradable food packaging materials. However, the use of polymers has been limited due to the poor mechanical and barrier properties. These properties can be enhanced by adding reinforcing nano-sized compounds or fillers to form composites. The current research work is based on LDPE (Low Density Polyethylene) reinforced with nano alumina particles. The bio-nano composite material has been prepared by melt intercalation method. The microstructure is obtained by SEM analysis and tensile test are carried out to check with their tensile property. The results showed that by adding 1% of alumina nano particles in LDPE there is an increase in tensile strength and elongation of bio-nano composite materials.

Keywords: Biodegradable, low density polyethylene, nano-alumina, scanning electron microscope, tensile strength

I. INTRODUCTION

The utmost important behavior of food packaging is to protect the food products during transportation, storage and also to extend the shelf-life of food products by preventing unfavorable factors or conditions such as spoilage microorganisms, heat sources, light sources, chemical contaminants, oxidation, moisture formation, external force, etc. Regrettably, the use of polymers as a food packaging materials has many drawbacks like poorer mechanical, thermal, and barrier properties as compared to the conventional non-biodegradable materials made from petroleum by products [1]. In order to perform such functions, packaging materials provide physical protection and create proper physicochemical conditions for products that are essential for obtaining a satisfactory shelf life of food and maintaining quality and safety [2]. The food package should loss of moisture, prevent microbial contamination and act as a barrier against pervasion of water vapour, oxygen, CO_2 and other volatile substances such as flavours and taints in addition to the basic essential properties of packaging materials such as better mechanical, optical, and thermal properties [3][5]. Food packaging is not only used as a container but also acts as a defensive barrier with some advanced innovative functions [4][5]. In that sense, food packaging is quite different from other durable goods such as electronic items, home appliances, and furniture's, etc. because of its safety aspects and relatively very short shelf life.

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II. LITERATURE REVIEW

A. Nano composites

The field of nano composites, or nanotechnology is a promising and advancing field because it has found application in advancing technology. A wide range of clays and polymers have been used successfully to synthesis a polymer nano composite [6]. This review will be entered in the specific field under study LDPE/clay nano composites with emphasis on the general mode of preparation, characterization of nano composite materials and relevant areas of application as employed by other researchers[7].

B. Nano Composites Synthesis

To prepare any nano composites, many methods have been employed previously. One successful method to prepare polymer/layered silicate nano composites is to intercalate polymers into silicate galleries [8][9].

C. Scanning Electron Microscopy

Scanning electron microscopy (SEM) is usually used to examine the texture/surface of the sample (topography), particle size, shape and distribution (morphology), element composition, crystalline structure and also to examine fracture surfaces. The samples must be small enough to fit in sample chamber and it must be electrically conductive. Polymer sample typically need to be sputter coated to make sample conductive. Coating helps to improve image resolution

III. MATERIALS USED

A. Low-Density Polyethylene (LDPE)

Low-density polyethylene (LDPE) is a thermoplastic made from the monomer ethylene. It's composed of 4000-40000 carbon atoms [10]. It has many applications in packaging and pipes and fittings. LPDE doesn't break easily, water proof, can stand up to many hazardous materials. Despite competition from more modern polymers, LDPE continues to be an important plastic grade because it's a low cost polymer with good processability.

B. Nano Alumina

Nanosize aluminium oxide (nano-sized alumina) occurs in the form of spherical or nearly spherical nanoparticles, and in the form of oriented or undirected fibres.

IV. METHOD OF PREPARATION OF BIO-NANO COMPOSITES

A. Melt Intercalation

Melt intercalation technique has become the standard method for the preparation of polymer based bio-nano composites are many advantages as compared with solution intercalation and in situ intercalative polymerization. In this process, the polymer is heated at a specific temperature to get a molten mass and mixed with nano particles.

B. Preparation of Nano Composites

The nano composites were synthesized by the direct melting process method using an internal mixer. The mixing speed was set at 1000 RPM. After mixing the filler with LPDE. Compounding process was carried out.

C. Injection Casting

Injection moulding is a manufacturing process in which molten polymer is forced under high pressure into a mould through an opening. The polymer is held in the mould until solidification and then the mould opens and the part is removed from the mould by ejector pins.

V. MEASURING TECHNIQUES

A. Tensile testing

Tensile tests measure the force required to break a LPDE/Alumina nano-composite sample specimen and the extent to which the specimen stretches or elongates to that breaking point. It will produce stress-strain graphs used to determine tensile modulus. These tests for bio-nano composites provide tensile strength, tensile modulus, tensile strain, elongation and percent elongation at yield and elongation and percent elongation at break. In general, tensile strength increases with the polymer chain length and cross linking of polymer chains.

B. Tensile elongation

The ultimate tensile elongation of an engineering material is the percentage increase in length that occurs before it breaks under tension. The ultimate elongation values of several hundred percent are common for most elastomers and film/packaging polyolefin. Rigid plastics, particularly fibre reinforced ones, often exhibit that value under 5%. The combination of high ultimate tensile strength and high elongation leads to materials of high toughness.

VI. BIODEGRADATION TEST

The studies showed that upon adding the nano filler the thermal degradation of LDPE was reduced to 45°C. Thus, by comparative study the degradation rate of LDPE is studied. The initial weight of the each specimen was taken before the degradation study start. After 10 days of bio-degradation, again the weight of each specimen was taken after drying at 100°C for 5h in oven. The percentage recovery of total solids for each specimen as calculated using the following equation

Weight loss(%) = (W0-W1)/W0*100

= (3.069-3.067)/3.069*100 = 0.068 %

W_1= The total solid weight of each specimen recovered after biodegradation study

W_0= The initial total weight of the corresponding specimen before bio degradation study.

A. Figures and Tables

Table- I: Results of Material Tested

Particulars	LPDE	LPDE with Alumina
Tensile (Mpa)	8 - 10	15.17
Elongation at break (%)	170	409

The above table shows the tensile strength of LPDE is 8 to 10 MPa. With the addition of alumina particles into the LPDE the tensile strength of the materials was increased to 15.57 MPa. This is due to the hard particles present in the materials which will enhance the tensile strength of LPDE. MPa. This is due to the hard particles present in the materials which will enhance the tensile strength of LPDE.

At the same time the elongation break was increased from 170% to 409%. Which is due to the addition of alumina particles.

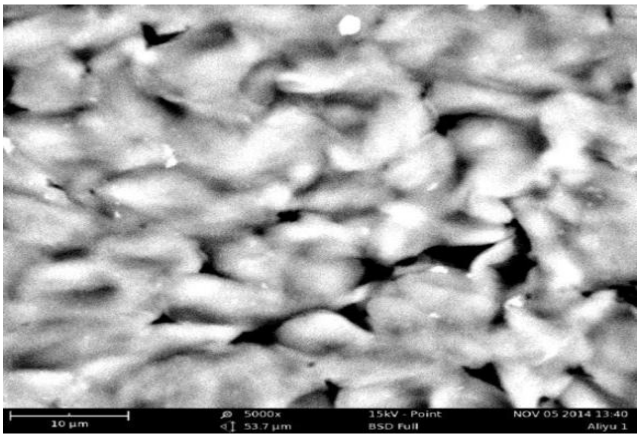


Fig. 1.Backscattered SEM image of LDPE with 0.5% alumina

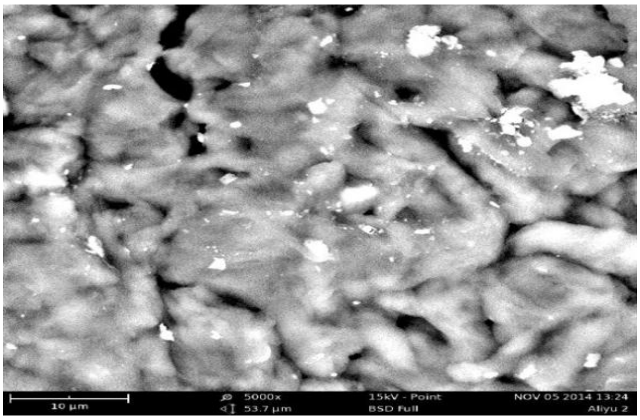
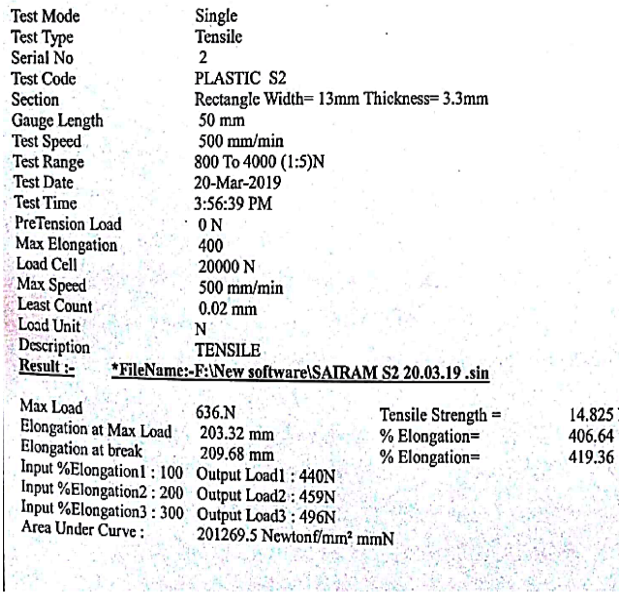


Fig. 2.Backscattered SEM image of LDPE with 1% alumina

The below figure shows the tensile testing paramentes of LPDE with alumina nano composite material.



Test Mode	Single
Test Type	Tensile
Serial No	2
Test Code	PLASTIC S2
Section	Rectangle Width= 13mm Thickness= 3.3mm
Gauge Length	50 mm
Test Speed	500 mm/min
Test Range	800 To 4000 (1:5)N
Test Date	20-Mar-2019
Test Time	3:56:39 PM
PreTension Load	0 N
Max Elongation	400
Load Cell	20000 N
Max Speed	500 mm/min
Least Count	0.02 mm
Load Unit	N
Description	TENSILE

Result :- ***FileName:-F:\New software\SAIRAM S2 20.03.19 .sin**

Max Load	636.N	Tensile Strength =	14.825
Elongation at Max Load	203.32 mm	% Elongation=	406.64
Elongation at break	209.68 mm	% Elongation=	419.36
Input %Elongation1 : 100	Output Load1 : 440N		
Input %Elongation2 : 200	Output Load2 : 459N		
Input %Elongation3 : 300	Output Load3 : 496N		
Area Under Curve :	201269.5 Newtonf/mm² mmN		

Fig. 3.Parameter setting

B. Abbreviations and Acronyms

1. PVA - Polyvinyl Alcohol
2. LDPE - Low Density Polyethylene
3. SEM - Scanning Electron Microscope
4. PGA - Polyglycolic acid
5. PBS - Polybutylene Succinate

VII. RESULTS AND DISCUSSION

LDPE/alumina nanocomposites exhibit a wide range of stress-strain behaviours as shown in Figure 4 and 5. It's behaviour begins in the linear elastic region. The figure shows that the stress at break gradually increased with the increasing of alumina loading up to 1 weight%.

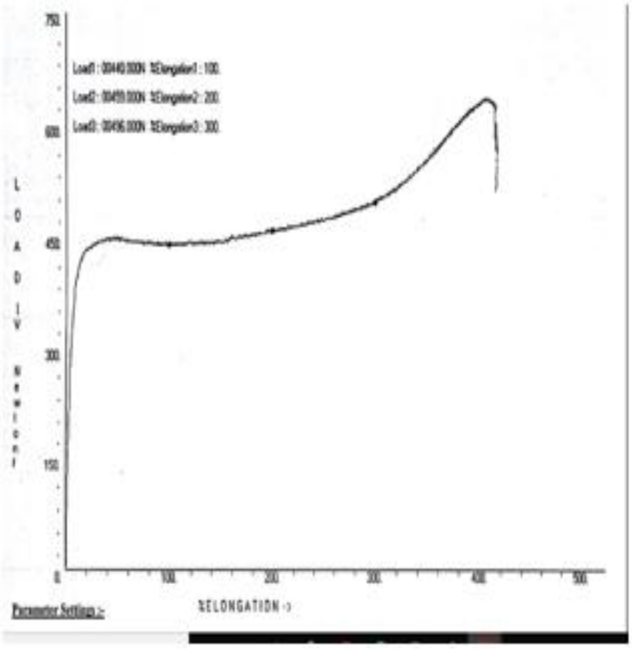


Fig. 4. Stress-strain graph for LDPE with 0.5weight % Nano alumina

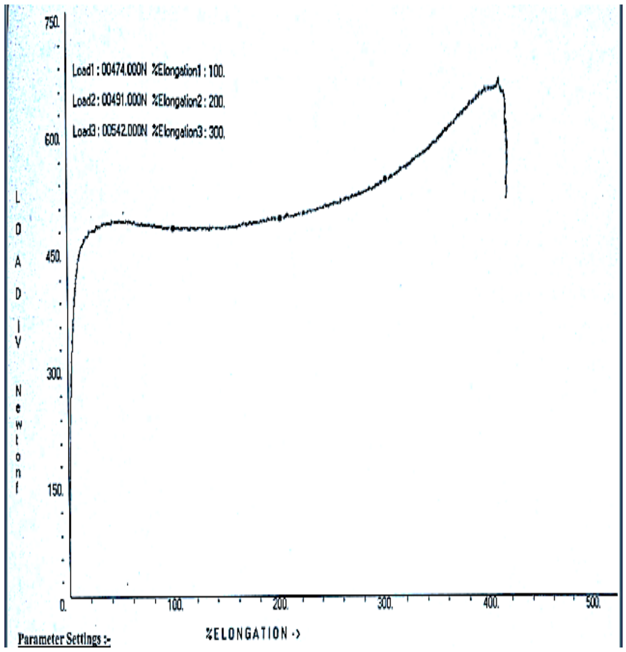


Fig. 5. Stress-strain graph for LDPE with 1weight % Nano alumina

This result suggests that the fine alumina particle would reinforce and orient along the direction of stress, and this has contributed to the increase of tensile strength of the nano composite with the addition of 0.5 and 1 weight% of alumina particles.

VIII. CONCLUSION

In recent years significant progress has been made in the synthesis, processing and performance of bio nano composite materials for food packaging applications. These LPDE /Al2O3 bio-nano composite materials offer improved performances over other polymers and hence can be used to overcome the limitations of many existing polymers. These bio-nano composite materials have unique behaviour such as good mechanical and barrier properties with the small addition of Alumina Nano fillers.

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