PREPARATION OF NANOCOMPOSITE DIELECTRIC MATERIAL FROM METRO SOLID WASTE

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Abstract

Plastics are seemingly everywhere in the world today. In this plastics age, plastics are replacing metal, wood, paper and ceramic products in most industries today. These industries include transportation, medical, retail and electronics. The key feature of thermoplastics is the fact that the material can be heated and formed multiple times. Recycling is one of the advantages of thermoplastics[1]. Commodity thermoplastics include Polyethylene Terepthalate (PET), High Density Polyethylene (HDPE) ,Polyvinyl Chloride (PVC) , Low Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and Other Plastics. Metro Solid Waste (MSW) contains around 40% of post consumer plastics, among which 30% of recyclable thermoplastics[2]. Since, the removal of MSW is one of the major issues of this century, this kind of research is necessary, to convert the thermoplastic solid wastes as a useful electronic material. In this study, new nanocomposite dielectric materials were produced from the components of recycled thermoplastic as the matrix and montmorillonite as the filler by using a co- rotating twin screw extruder[3]. During the study, recycled Poly(Ethylene Terephthalate), R-PET, was mixed with organically modified quaternary alkyl ammonium montmorillonite in the contents of 1, 2, and 5 weight %. Three types of clays were evaluated during the studies. For comparison, 2 weight % clay containing samples were prepared with three different clay types, Cloisite 15A, 25A, 30B and the electrical properties of the resultant nanocomposites were experimentally tested.

Keywords: Metro Solid Waste (MSW), Nanocomposites, Polymer Electronics, Recycled PET, Dielectric material.

I. INTRODUCTION

Nanocomposites based on polymer-clay mixtures are a growing area of interest due to their potential in flexible applications. Improved mechanical, barrier properties and heat distortion temperature have been obtained. Most of these improvements have been attributed to the dispersion of the clay in the polymer[3],[4]. Polymers are often modified by fillers to increase the modulus and decrease thermal expansivity. Particle modified polymers have been compounded with inorganic fillers like glass fibers, talc, calcium carbonate etc where the filler percentages can be as large as 60% of filler[5]. The resulting composite has disadvantages such as an increase in specific gravity. Debonding between filler-polymer matrix surface due to lack of adhesion is also another problem. From an industrial approach, owing to high costs of development, synthesis and commercialization of new polymers, most researchers look for new materials by reinforcing or blending existing polymers, so the tailor made properties of the materials can be achieved, [6]. Poly(ethylene terepthalate) (PET) is a low-cost, and high performance thermoplastic that finds use areas in a variety of applications, such as in fabrics and soft drink bottles, reinforcement of tires and rubbery goods, food and beverage packaging. PET has excellent surface characteristics, and high heat deflection temperature. PET regrinds from post consumer soft drink bottles have slightly reduced molecular weight and structure related properties as compared to pure polymer[7].

In this study, the aim is to produce nanocomposite materials from recycled PET regrinds as the matrix with the addition of organically modified montmorillonite (mmt) clays as the filler, and observe the effects of clay content in the electrical properties of the resultant nanocomposite.

II. RECYCLING PROCESS

The growth in the plastics industry has led to a corresponding growth in the plastics recycling business. Legislation mandating recycling has assisted the growth of this business. When virgin plastic prices are high, the prices for recycled plastics are elevated and vice versa. During the last several years, the prices of virgin and recycled plastics have fluctuated wildly. The price of virgin PET in 1995 was $0.85 per pound and dropped to $0.46 per pound in 1999 [8],[9],[10]. The average price of recycled PET was $0.65 in 1996 and dropped to $0.23 by the end of 1996. The 1-billion pound increase in production of virgin plastic packaging overshadowed the 69-million-pound increase in tonnage of plastic packaging recycled between 1995 and 1996.The recycling process is shown in the following fig.1.

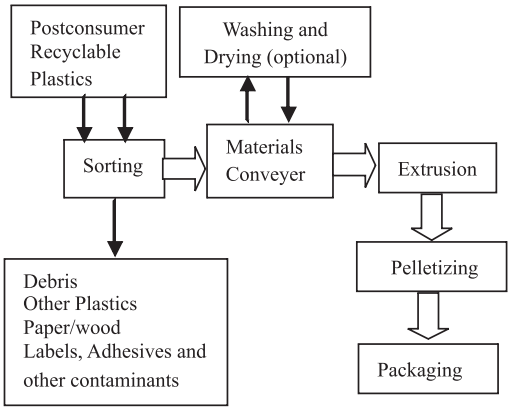

Fig. 1. Block diagram of Recycling Process

In 2000, plastic pellet production in the United States exceeded 100 billion pounds. Many companies were established to provide recycled materials from postindustrial and postconsumer sources[10]. The manufacturing process of converting recycled plastic into a new plastic product is daunting. Converting recycled plastics to plastic pellets involves sorting, washing, drying, and pelletizing. The most common processing steps include granulation, air classification, washing, separation, rinsing, and drying. The plastics are sorted by either manual or automated identification methods[10],[11].The manual method is labor-intensive and requires operators to monitor an assembly line and sort out clear plastic bottles (PET) from the milk containers (HDPE) and colored plastic containers (LDPE, PP, PVC). The automated method can employ one of several analytical techniques, including x-ray fluorescence, mass spectroscopy, Fourier Transform Near Infra-red (FT-NIR) spectroscopy, Fourier Transform medium Infra-red (FTIR) spectroscopy, or tribo-electric analysis, on the recycled plastic materials.

The automated sorting method efficiently and quickly sorts the plastic. One researcher listed the advantages and disadvantages of each and recommended two techniques for use at a large automotive company for plastic bumper materials. Other researchers reported the speed at which spectroscopic techniques can identify plastics with the use of a computer and tabulated spectra. Hundreds of identifications per second can help sort plastics with more than 99 percent accuracy. One researcher reported a throughput rate of 2,000 kg per hour[12]. The sorting efficiency was improved with the development of an automated sensor cleaning system. The washing methods vary from one reclamation facility to another. In past years several washing facilities were built at great expense. Washing is the most expensive activity of the postconsumer plastic recycling process. The last step in the postconsumer recycling process is melt processing, where the clean plastic material is pelletized and placed in containers for shipments. The quality of recycled materials that are collected from consumers can be poor. The poor quality is attributed to dirt, contaminants, labels, and other plastics that are mixed with the recycled plastics as listed in the Table1. Thus, the plastic is not separated into its category but is part of a mixture of many types of plastics and other polymers from adhesives on labels. This leads to PCR plastic materials that can have lower mechanical properties than virgin materials.

Table 1. Contaminants in Recycled Pet Resin

CONTAMINANTS	VALUE (PPM)
PVC	60
Polyethylene	5
Metal pieces	0
Adhesive	10
Paper pieces	1

III. EXPERIMENTAL

The objective of this experiment is to produce a new nanocomposite, using recycled PET as the polymer matrix and nanoclay as the filler. This new material is intended to be used as the dielectric material in capacitors. Nanocomposites with three different types of montmorillonite organoclay, Cloisite 15A, 25A, and 30B, based on the matrix of recycled PET were prepared using a co-rotating twin screw extruder. It is observed that the effects of clay type and clay content on structures and properties. Optimum clay content was selected as 2 weight %. Using this clay content, various clay types, Cloisite 15A, 25A and 30B were studied. The electrical properties volume resistivity, surface resistivity, dielectric constant, dielectric strength and arc resistance were experimentally derived using test samples, which were prepared based on ASTM standards. Table 2. shows the different ASTM standard specimen used in the testing.

Apart from the electrical studies, thermal behaviour of the material is investigated using Thermal Gravimetric Analysis (TGA) and Differential Scanning Calorimetric (DSC) analysis.

Table 2. Test Specimen Standards

Sl.No	TEST	STANDARD	SHAPE & SIZE
1	Volume resistivity	ASTMD257	Round Disc 110mm diameter 3mm thickness
2	Surface resistivity		
3	Dielectric Constant	ASTMD150	Round Disc 50mm diameter 3mm thickness
4	Dielectric Strength	ASTMD149	Round Disc 110mm diameter 3mm thickness
5	Arc Resistant	ASTMD495	Round Disc 110mm diameter 3mm thickness

RESULTS AND DISCUSSION

A. Thermal Studies

Differential scanning calorimetric analysis was performed in order to evaluate the changes in Glass Transition temperature (Tg) with increasing clay content. Glass transition temperature is largely related to the molecular mobility of polymer chains shown in Fig. 2.

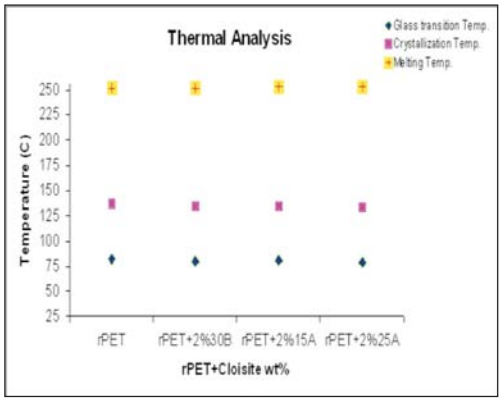

Fig. 2. Thermal Analysis of Resultant Nanocomposites

The crystallization (Tc) and melting temperatures (Tm) do not change as much with the clay type and clay content, indicating that the rearrangement capability of the chains into crystals are not much affected.

B. Resistivity Studies

Resistivity tests were conducted using ASTMD257 samples for both volume resistivity and surface resistivity. According to the results shown in Fig.3(a) and Fig.3(b), 2 weight % 30B yields better resistivity than other two 15A and 25A clay blends. This shows obviously the material structure plays a vital role in determining the resistivity of polymer nanocomposites. As a whole, intercalation or exfoliation of the nano-filler into the rPET matrix decides the resistivity.

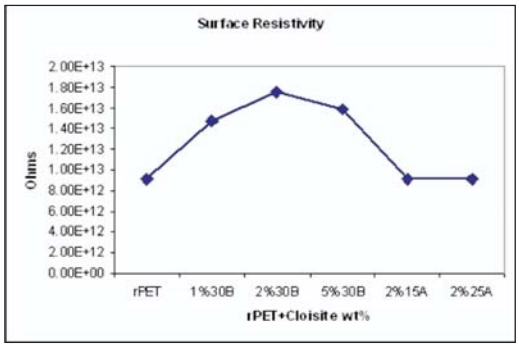

Fig. 3(a) Surface Resistivity

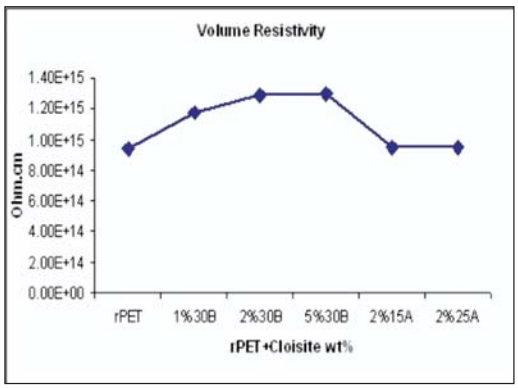

Fig. 3(b) Volume Resistivity

C. Dielectric Studies

ASTM D149, D150 and D495 specimen were prepared to verify the dielectric properties of the samples. The tests are conducted for dielectric strength, permittivity and arc resistance and results are shown in figure Fig.4(a), Fig.4(b) and Fig.4(c) respectively.

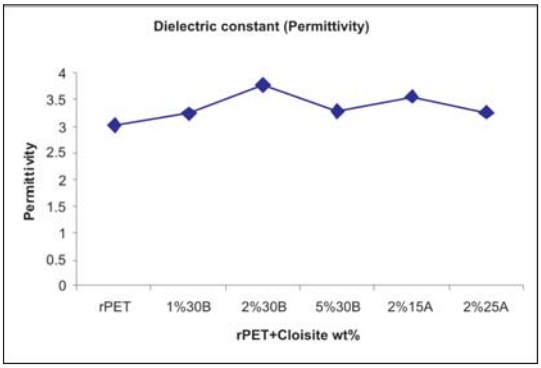

Fig. 4(a) Dielectric Constant

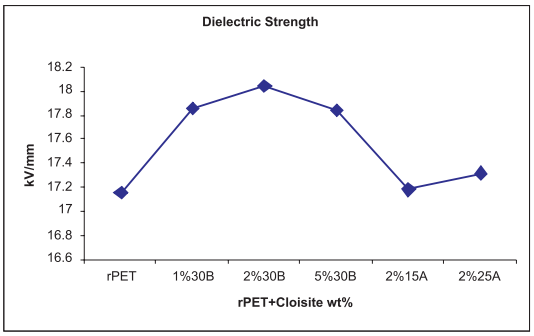

Fig. 4(b) Dielectric Strength

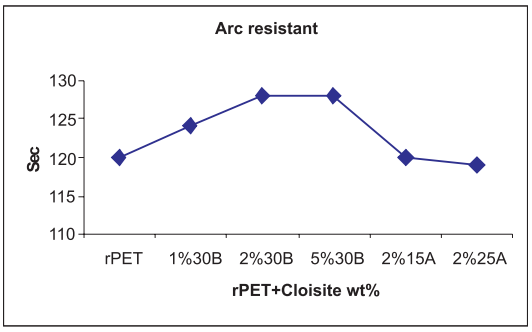

Fig. 4(c) Arc Resistance

These results show, 2 weight % 30B yields better in dielectric properties than other two 15A and 25A clay blends.

V. CONCLUSION

In this study, the recycled PET nanocomposites are fabricated with various weight percentages of Cloisite 30B, 25A and 15A and their thermal and electrical properties were studied. The electrical studies show the compositions rPET containing 2 weight % 30B organoclay has higher dielectric strength and permittivity values than remaining organoclay samples. Invariably, the sample rPET+ 2 wt % Cloisite30B yields good dielectric property and can be a right candidate as a nano dielectric material. DSC analysis showed that the incorporation of clay particles into the base polymer caused changes in Tg values. The maximum increase in Tg values was observed in the sample containing 2 weight % of 25A clay type. The Tg increased from 81.8oC (value of r-PET) to 83.2oC. Thus, a new nano dielectric material is proposed, which can be used in capacitors.

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