A STUDY ON CONDUCTIVE POLYMER NANOCOMPOSITE OF POLYSTYRENE/POLYPYRROLE/MONTMORILLONITE

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A STUDY ON CONDUCTIVE POLYMER NANOCOMPOSITE OF POLYSTYRENE/POLYPYRROLE/MONTMORILLONITE

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Special dedication to my beloved mom, dad, brother and friends.
Thanks for the love, support and memories.

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ABSTARCT

Conductive nanocomposite of polystyrene/polypyrole/montmorillonite was prepared by melt-mixing method. Polystyrene properties improved by adding conductive filler (PPy) and also clay (MMT). This nanocomposite is conductive and the electrical, thermal and mechanical properties also improved. Firstly, the conductive polypyrrole (PPy) was synthesized via the chemical polymerization method. Fourier transform infrared spectrometry (FTIR) and scanning electron microscopy (SEM) were used to determine the functional group and the particle size of PPy. Later, the PPy at different weight ratios namely 5, 10, 15 and 20 wt. % were mixed with polystyrene (PS) and montmorillonite (MMT) to produce conductive nanocomposite. Finally, the nanocomposite was compression moulded into a thin sheet for further characterizations and testing. X-ray diffraction (XRD) results showed that the polymer chains were intercalated between the MMT galleries while the thermal gravimetric analysis (TGA) had proven that the incorporation of PPy into nanocomposite improved the thermal stability of sample. The tensile test results revealed that by increasing the amount of PPy would enhance the strength and the stiffness of the nanocomposite. Meanwhile, by increasing the weight percentage of PPy, the conductivity values of samples were also increased. The nanocomposite PS/PPy/MMT which was prepared in this work has wide range of applications in solar cells, batteries, diodes, membranes and supercapacitors.

ABSTRAK

Nanokomposit berkonduktif polistirena/polipirola/montmorilonite telah disediakan menggunakan kaedah campuran lebur. Pertamanya, polipirola berkonduktif (PPy) telah disintesiskan menggunakan kaedah pempolimeran kimia. Spektrometer inframerah (FTIR) dan mikroskopi imbasan elektron (SEM) telah digunakan untuk menentukan kumpulan berfungsi dan saiz partikel PPy. Kemudiannya, PPy pada nisbah berat yang berbeza iaitu 5, 10, 15, dan 20 wt% telah dicampurkan dengan polistirena(PS) dan montmorilonit (MMT) untuk menghasilkan nanokomposit berkonduktif. Akhirnya, nanokomposit telah diacu mampatkan kapada kepingan nipis untuk pencirian dan ujian selanjutnya. Keputusan pembelauan sinar-X telah menunjukkan rantai polimer terinterkalasi diantara galeri MMT, manakala analisis gravimetrik haba (TGA) telah membuktikan penggabungan PPy ke dalam nanokomposit telah memperbaiki kestabilan terma sampel. Keputusan ujian tegangan telah mendedahkan dengan meningkat kan amaun PPy akan menambahkan kekuatan dan kekakuan nanokomposit. Sementara itu, dengan meningkat kan peratusan berat PPy, nilai kekonduksian sampel juga meningkat. Nanokomposit PS/PPy/MMT yang telah disediakan dalam kerja ini mempunyai kegunaan yang luas dalam sel solar, bateri, diod, membran dan superkapasitor.

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LIST OF ABBREVIATIONS

PPy	-	Polypyrrole
PLS	-	Polymer layered silicate
MMT	-	Montmorillonite
PS	-	Polystyrene
SEM	-	Scanning Electron Microscopy
FTIR	-	Fourier Transform Infrared Spectroscopy
XRD	-	X-ray Diffraction
TGA	-	Thermogravimetric analysis
CP	-	Conducting Polymer
PANI	-	Polyaniline
MFI	-	Melt flow index
MW	-	Molecular weight
$HPLCO_2$	-	High-pressure liquid carbon dioxide
$SCCO_2$	-	Supercritical carbon dioxide
Tg	-	Glass transition temperature
LDPE	-	Low density polyethylene
PLSN	-	Polymer/layered silicate nanocomposites
Py	-	Pyrrole
$FeCl_3.6H_2O$	-	Iron (III) Chloride Hexahydrate
DBSNa	-	Sodium dodecylbenzene sulfonate
KBr	-	Potassium bromide
ASTM	-	American Society for Testing and Materials
wt %	-	Weight percentage
Phr	-	Part per hundred

LIST OF SYMBOLS

$^{\circ}C$	-	Centigrade
λ	-	Wave length
d	-	The spacing between diffractional lattice planes
θ	-	The angle of diffraction
ρ	-	Electrical resistivity
Ω	-	Ohm

CHAPTER 1

INTRODUCTION

1.1 Background of study

The discovery in 1977 of the high conductivity of doped polyacetylene motivated studies on the synthesis and study of various conjugated polymers. As a result, an entire class of polymeric conductors was developed. Typical representatives of this class are poly(p-phenylene), polypyrrole, polythiophene and its 3-methoxy-derivative, polyaniline. The common feature of the structure of conducting polymers is polyconjugation in the π-system of their backbone.

The conducting polymers (also called synthetic metals) are polyconjugated, which possess electronic (conductive, magnetic) characteristic of metals, while preserving the processibility and mechanical properties of polymers. They acquire high conductivity due to incorporation of a small concentration of dopants into the matrix of the initial polyconjugated polymers having conductivity varying from 10^{-10} to 10^{-5} S/cm. The resulting materials have conductivities typical of metals or semiconductors, 1 to 10^{5} S/cm (see Figure 1.1) (Vernitskaya and Efimov, 1997).

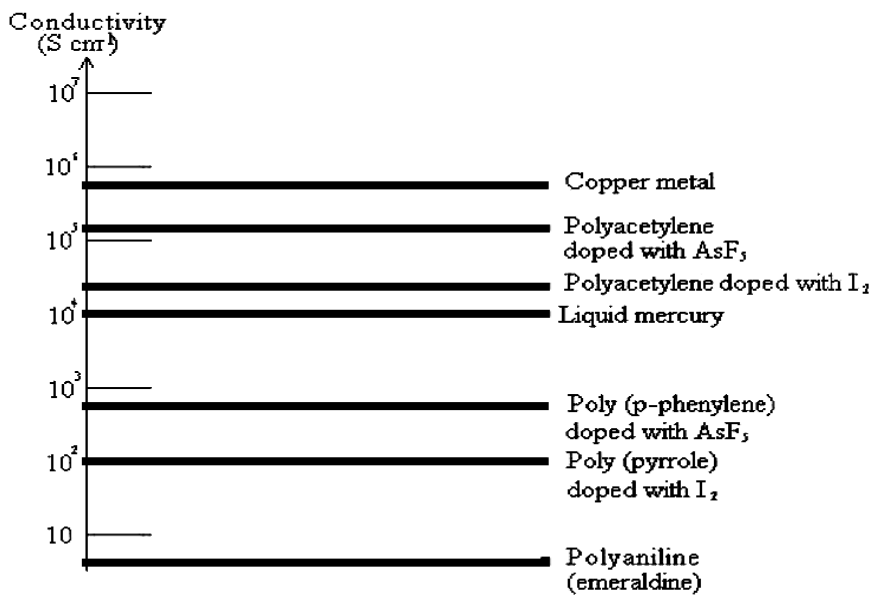

Figure 1.1: Logarithmic conductivity ladder of some polymers (Pratt, 2004).

In the early stage, the electrically conducting polymers in the industry were obtained by adding high loadings of metal powders such as silver and gold (sometime up to 75% by weight) with the polymer medium. Some disadvantages of this method are expensive manufacturing and worsening the other properties of polymer. Last few decades, conducting polymers like polyaniline, polypyrrole (PPy) and polythiophene have been used extensively to replace the old method. Apart from their comparable electrical properties and light weight materials with respect to metals, there are few drawbacks such as low processibility, low solubility and brittleness. Therefore, many studies had been conducted to solve the problems by forming the composites or blending with other polymers such polypropylene, ultrahigh-molecular-weight polyethylene, ethylene vinyl alcohol, polyethylene, polymethyl methacrylate, polyurethane and also natural rubber (Chen *et al.,* 1997; Hosseini and Entezami, 2003; Mavinakuli *et al.,* 2010, Peighambardoust and Pourabbas, 2007).

Among of the conducting polymers, PPy has been the one of the most investigated polymer due to its good electrical conductivity and easiness to synthesis (Ansari, 2006). However, PPy is brittle, infusible and inprocessable (Baytekin, 2009).

Blending of PPy with the commercial polymers such as PS, PP and so on can enhance the properties of composite and can be use to overcome the problems and at the same time polymer blend and conductive polymer nanocomposite. (Alexandre and Dubois, 2000).

The development of nanocomposite materials, i.e. compounds in which an inorganic solid is associated with organic entities interacting at a molecular level, open the way to the preparation of new materials with predetermined characteristics. One of the most promising ways of synthesizing polymer nanocomposites is by intercalating a polymer into a layered inorganic host. Previous efforts have focused on the intercalation of a suitable monomer followed by polymerization or polymer intercalation from solution. The direct melt intercalation has recently been reported as a desired versatile and environmentally benign approach (Chen *et al,* 2001).

In this research, PPy have been mixed with a commodity polymer i.e. polystyrene (PS) was chosen as a matrix because of its processesability and readily availability. Nair et al. (2008) reported that the distributed PPy over an amorphous PS layer would not give any regularly faceted shape. In addition, a higher electrical conductivity would be obtained if PPy formed a denser coating with a higher purity on the PS fiber surface. MMT was chosen as nanofiller in the nanocomposite for versatile properties.

1.2 Problem Statement

Among the polyolefins, polystyrene has many applications in daily life. It is a thermoplastic with noticeable mechanical properties and reasonable market price. However, its poor conductivity and thermal stability have become major drawbacks. Research showed that the addition of MMT to PS could improve the thermal stability and the mechanical properties but has no avail to the conductivity. PPy as a conducting polymer has become a great choice due to easy synthesis, good environmental and thermal stability and also highly conductivity. However PPy is brittle, infusible and inprocessable which lead to poor mechanical properties. Furthermore, it is expensive if compared with other conductive polymers such as PANi. However, with proper design, these disadvantages can be manipulated this in research.

In this study, PPy which was synthesized via chemical polymerization route has been blended with PS/MMT in order to induce the conductivity to the PS/MMT blend. The nanocomposite was prepared by melt-mixing PS as a host, MMT as filler and PPy with different ratios of. It was expected that PPy could make the blend more conductive with the aid from MMT which could improve the blend conductivity.

1.3 Objective of the Study

The aim of this research is to produce a nanocomposite with acceptable conductivity and thermal and mechanical properties. Thus the main objective of this study is to use polypyrrole as conductive filler in PS/PPy/MMT nanocomposites. The specific objectives of this study are:

i. To prepare blend of PS/PPy /MMT in different ratios of PPy.
ii. To study the effect of PPy on thermal stability, mechanical and electrical properties of the blend.

1.4 Scope of Research

The scopes of the study are as follows:

1. Literature review

   Literature, search on the development of the conductive polymer blend in the area of PPy and PS blend.

2. Sample preparation
   a) Synthesis the PPy using the chemical method.
   b) Blending the PS/MMT with varies amount of PPy.

3. Sample characterization and morphological study
   a) Scanning electron microscopy (SEM) was carried out to determine the surface of the blend sample and also PPy powder.

b) Fourier transform infrared spectroscopy (FTIR) was done to confirm the PPy structure and also evaluate the blend samples.

c) X-ray diffraction (XRD) was carried out to evaluate the intercalation of polymer chains in MMT galleries.

4. Thermal properties analysis

Thermogravimetric analysis (TGA) was done to determine the thermal stability of the blend samples.

5. Conductivity test

Resistivity analysis was carried out to determine the conductivity of the blend samples.

6. Mechanical properties study

Tensile test was done to evaluate the tensile strength, elongation at break and young modulus of blend samples.

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