ISSN 2320-9984

Volume 1, Issue 1, April 2013

ISSN: 2320-9984 (Online)

International Journal of Modern Engineering & Management Research

Website: www.ijmemr.org

An Article on Evaluation Study of the Properties of PMMA Based Materials: Extension of their Applications in Different Fields

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Abstract**—***Poly (methyl methacrylate) (PMMA) is one of the widely used polymers in many electronic applications where optical-grade materials are needed because of its excellent balanced properties paired with a reasonable price. PMMA nano particles are being utilized in many medical applications also as efficient drug carrier tool. PMMA has excellent clarity with high rigidity and toughness as a homopolymer, though deficient characteristics of PMMA such as low impact strength, poor radiation, thermal stability, and solvent resistance deter its application in some areas. There has been great interest in polymer blends for quite some time, as polymer blending is a fast and economical way of improving the properties of commercially available polymers without the laborious development of new polymers. However, the physical properties of the newly developed polymer blends are strongly dependent upon the phase miscibility. Because of this, the study of the miscibility and phase behavior of polymers has attracted intense investigation in both the industrial and academic domains.*

1. INTRODUCTION

Polymethyl Methacrylate (PMMA) is a transparent thermoplastic and impact resistant substitute of glass. It has good impact resistant, weather resistant and chemical resistant properties. It is light in weight, rigid and has color versatility. The polymerization reaction of PMMA has been shown in following Figure 1.

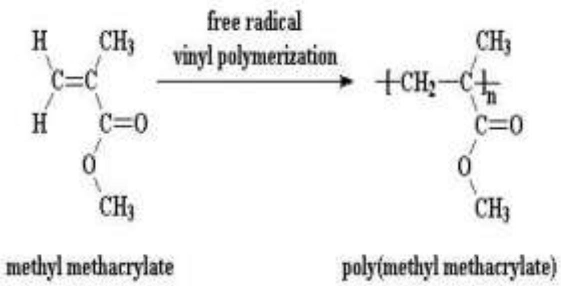

Figure 1: polymerization reaction of Polymethyl Methacrylate (PMMA)

PMMA is used in various applications across automotive, electronics, construction, signs and displays, sanitary ware, lighting fixtures and other industries. Signs and display is a major market with largest consumption of PMMA followed by construction industry. Asia-Pacific is the largest geographic market and accounts for more than half of PMMA consumption. It is also the largest producer of PMMA. During global economic crisis PMMA market faced a decline in demand. In 2010 and 2011, the industry recovered from recession and registered significant growth. The estimated consumption of PMMA reached 1.67 million tones in 2011 globally. A boom light guided panel (LGP) based LCD screen market is one of the major drivers for this material.

PMMA is a versatile material and has been used in a wide range of fields and applications. The German chemist Fittig and Paul discovered in 1877 the polymerization process that turns Methyl Methacrylate into poly Methyl Methacrylate (Lovell 1997). PMMA is routinely produced by emulsion polymerization. Water born polymerization such as emulsion polymerization are of great importance in industry application as they provide environmental friendly process, remove the reaction heat easily during polymerization and assume the feasible handling of the final product having a low viscosity. Research in controlled/free radical polymerization has been increased significantly during the past two decades. [1]

PMMA is often used as a light or shatter-resistant alternative to glass. It is an economical alternative to polycarbonate (PC) when extreme strength is not necessary. It is often preferred because of its moderate properties, easy handling and processing, and low cost. PMMA is a versatile material and has been used in a wide range of fields and applications as a substituent of glass, medical technologies and implants and aesthetic use as well. This properties and uses of PMMA motivated us to work on [2]

Applications:

Major Applications of PMMA include: Automotive industry - rear lamps, light fixtures Acrylic sheet - bathtubs Glazing – signs Composites - sinks, basins and bathroom fixtures Contact lenses, bone cements Membrane for dialysis Dental restorations Road Lines. Some important applications have been discussed below.

Optical Applications:

Aromatic polyimides are promising candidates for engineering plastics because of their excellent thermal and physical properties. However, in most of the cases, their poor optical property limits their application in optical usage. Recently, special types of optical grade polyimides, for example, a polyimide synthesized from 2,2'-bis(3,4 dicarboxyphenyl) hexafluoropropane dianhydride (6FDA), with excellent optical, thermal, and mechanical properties have been investigated. [3, 4]

Since practical products are made though a polymer-polymer blending process, many have attractive physical properties but their corresponding lack of solubility and miscibility has limited their usefulness for electronic applications needing optical-grade materials. The current focus of attention in this field has been directed to finding homogeneous mixtures and exploring the beneficial properties that may be gained by blending. [5, 6]

Early investigations related to blending PMMA with polyimides showed that PMMA did not form miscible blends with any of the polyimides it was paired with. Fluorine-containing polyimides, especially those based on 6FDA, have been of interest because of their excellent physical and optical properties and their solubility in common solvents, enabling their utilization in polymer-polymer blending solu-tions. However, the extremely high glass transition temperature of 6FDA-based polyimides has deterred their widespread application. Blending PMMA with fluorine-containing polyimides offers an attractive opportunity for the development of novel materials exhibiting useful combina-tions of the two materials' respective properties. Compared to PMMA, the 6FDA-based polyimide provides enhanced chemical resistance and mechanical strength in blends. PMMA, on the other hand, permits lower processing temperatures than pure 6FDA-based polyimides. [7]

Use as Drug carrier for Gastro intestinal tract:

Polymethyl (2-^{14}C) methacrylate nanoparticles of a diameter of 130±30 nm were administered to Wistar rats as a single dose by oral gavage either in form of a suspension in saline, in saline with an additional content of 5% of polysorbate 80 or poloxamine 908, or suspended in peanut oil without or with addition of 5% oleic acid. The animals were sacrificed after 30 min, 1, 2, 4, 8 h, 1, and 4 days, the blood was collected, and different organs and tissues were removed. The gastrointestinal (GI)-tract was separated into stomach, small intestine, and colon. The contents of those parts were collected and the remaining GI-tract sections thoroughly rinsed. The radioactivity in the above organs, tissues, and GI-tract contents were determined using a scintillation counter. The radioactivity concentrations were highest in the GI-tract content and decreased rather rapidly (between 2 h and 1 day). Rather high concentrations (up to 10% of the administered dose at a given time point) also were seen in the GI-tract walls. These concentration did not correlate totally to those in the GI-tract contents. The concentration in the residual body reached 1–3% of the administered dose at a given time point. The highest concentrations in the body were observed between 15 and 60 min but remained at considerable levels for 4 days. By far the highest uptake (about 200–300% of the other preparations) was seen with the saline preparation containing 5% polysorbate 80. No significant difference appeared between saline without surfactants and peanut oil. The addition of oleic acid to the peanut oil increased the uptake of the nanoparticles by about 50%. [8]

Use As Colloidal Carriers:

Enalaprilat is a typical angiotensin-converting enzyme inhibitor and is very poorly absorbed from the gastrointestinal tract. The poly-(lactide-co-glycolide) (PLGA) and polymethylmethacrylate (PMMA) nanoparticles containing enalaprilat used as colloidal carriers for the transport of drugs through the intestinal mucosa. [9]

Use As pH Responsive material:

Biopolymers composed of a pH-responsive, hydrophilic poly(methacrylic acid-grafted-ethylene glycol) network polymerized in the presence of poly(methyl methacrylate) nanoparticles were designed for the oral delivery of chemotherapeutics for the treatment of colon cancer. An inulin–doxorubicin conjugate, designed to target the colon and improve doxorubicin efficacy, was loaded into these polymer carriers at an efficiency of 54%. Release studies indicated these polymer carriers minimized conjugate release in low pH conditions and released the conjugate at neutral pH conditions using a two-step pH experiment modeling the stomach and the small intestine. [10]

Use as Filler:

Polypropylene (PP) is a commercially important polymer, which is of practical use in a wide range of applications. mechanical properties of a polymer can be improved by the addition of filler materials. In general, inorganic fillers are applied to improve the stiffness The principal factors which affect mechanical, stru-ctural, thermal, electrical and physical properties of polymeric materials, are matrix structure, processing and use of fillers or reinforcements. The filler contents, sur-face treatment and adhesion between filler and polymer matrix affect the macroscopic and mechanical characte-ristics of composite materials. Lipatov et al(1976) observed broadening of relaxation time spectra in surface layer of particulate filled PMMA which has been attributed to decrease in number of chain conformations at the interface and to energetic interaction of chains with surface. Flexibility of chains in surface layers could be lowered by conformational restrictions imposed by filler. [11]

Use in Gas-Sensing applications:

Gas detection instruments are increasingly needed for industrial health and safety, environmental monitoring and process control. To meet this demand, considerable research into new type of sensors is underway to enhance the performance of traditional devices. The polymer–ceramic composites have superior characteristics and play vital role in gas sensing applications. The gas sensors based on Carbon nano tube/polymer, ceramic and metal oxide composites such as epoxy, polyimide, PMMA/ BaTiO3 and SnO2 have also been developed.

The emission of gaseous pollutants such as sulphur oxide, nitrogen oxide and toxic gases from related industries has become a serious environmental concern. Thus sensing devices need to be installed in such places. These devices should be cheap, reagentless and able to quantify the levels of gases in a rapid manner, at room temperature with low power consumption. The room temperature gas sensing property is very attractive for many applications. A novel fluorescent polymer PMMA-PM for optical sensing prepared using electrospinning technique has been reported. A new multilayer integrated optical sensor (MIOS) for ammonia detection at room temperature using PMMA and PANI has also been reported. PMMA-Polypyrrole composite films were prepared electrochemically and used as gas sensors by observing the change in the current when exposed to ammonia gas and the film gives a fast and reproducible response towards ammonia gas. [12]

A nanofibrous sensor for ammonia gas fabricated by using polydiphenylamine (PDPA) with PMMA onto patterned interdigit electrode has been reported. The functional groups in PDPA and the high active surface area of the fibrous membrane combine together and thus enable the device to detect a lower concentration of ammonia with good reproducibility. Composite of MWCNT and PMMA has been prepared for gaseous toluene detection

The polymer composite developed through dissolution of styrene and polyaniline in PMMA is used as polymer gas sensor arrays for electronic nose. Chemical sensors have been used in industrial processing, environmental monitoring and inflammable environments for human safety. Colorimetric gas sensors, selective and low-cost colorimetric gas sensors have been reported. Humidity sensing properties of PMMA were enhanced by doping with two alkali salts (KOH and K2CO3) has also been reported.Pulsed high magnetic field sensor using PMMA has been reported18. A compact wireless gas sensor using a CNT and PMMA thin film resistor shows fast response and change in resistance from 102 to 103 due to surface modification. In fact, analytical gas sensors offer a promising and inexpensive solution to problems related to hazardous gases in the environment. Amperometric sensors consisting of an electrochemical cell in a gas flow which respond to electrochemically active gases and vapours have been used to detect hazardous gases and vapours [13]. The design and development of a compact wireless gas sensor with a surface modified multiwalled carbon nanotube (*f*-CNT) chemiresistor as the sensing element is presented in this paper. *f*-CNT/polymer composite sensing film is patterned on a printed circuit board and is integrated to the wireless system. The change in resistance of the CNT/polymer composite film due to exposure of different gases is utilized as the principle of this gas sensor. The response for different organic vapors are evaluated and it is observed that the *f*-CNT/ PMMA composite film shows fast response and change in resistance of the order of 10^2–10^3 due to its surface modification. [14]

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