Pmma Nano-Composites: A Review

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ABSTRACT

In recent years, polymer nano composites in which reinforcing additives with nanoscale dimensions have attracted researchers interest since improved properties and challenging applications are found with those composites. Among the wide variety of available polymers, polymethyl methacrylate (PMMA) represents a particular suitable matrix for embedding nanoscopic inorganic fillers due to its outstanding mechanical, chemical, optical and physical properties. The paper provides a comprehensive review of the recent studies conducted on PMMA nano composites, various properties of resulting composites, as well as their processing with some novel techniques to improve upon existing method and their applications have been discussed.

Advances in the use of PMMA have opened up a wide range of applications in the field of Nano technology. The various nano sized filler materials like carbon nanotubes,Tio2,Calcium aluminate ,CaCO3 ,Mgcl2 , Yttrium aluminium garnet have improved various desired mechanical ,electrical ,thermal ,optical properties of PMMA. However there is a need to condense these developments in the form of an article for batter understanding and easy access. This review highlights the fundamental, physical properties of PMMA coupled with experimental evidence of its essential chemistry such as solubiliy, hydrolysis, polymerization reaction, reaction with amines and various compounds and thermal decomposition.

This review focus on the scientific principles and mechanism of producing PMMA nano-composites on the basis of various methods of producing and manufacturing with a discussion on commercial applications and helth/safety concerns for PMMA polymer nano-composites

Keywords*: PMMA, Nano-Composites, .*

INTRODUCTION

The advancements in the field of technology are constantly taking pace with the help of innovation in several areas. To help support this trend we should consider not only providing effective ways to minimize the cost of the overall production but also having the desired output. During the last few years, it has been seen that researchers are not only focusing to provide new and alternative ways to meet the demand of the consumer but also developing effective substitutes for the survival of the economy. Keeping this in mind the main problem that is faced in most of the development projects is to curb the cost of the production in possible ways such as providing alternative material sources in some areas where work can be carried out without affecting much to the results at the end of the production. The main focus of this review paper is to drive attention towards various other materials that exist and can prove to be much useful in the future generation. Acrylic is often used as a glass substitute but with consideration of its other properties it can be used in a variety of different areas. The most important characteristics of acrylic (PMMA) are its optical clarity, low UV sensitivity and overall weather resistance. Apart from this, the availability of this material makes it even more productive. [1]

1.PMMA Nanocomposites

1.1. PMMA

Poly(methyl methacrylate) (PMMA), also known as acrylic or acrylic glass as well as by the trade names Plexiglas, Acrylite, Lucite, and Perspex among several others names too. Chemically, it is the synthetic polymer of methyl methacrylate. The material was developed in 1928 in several different laboratories by many chemists, Methacrylate acid,, derived from acrylic acid was formulated in 1865. The reaction between methacrylic acid and methnol results in the ester methyl methacrylate. The full chemical name is poly(methyl 2-methylpropenoate)Acrylic or Poly (methyl methacrylate) PMMA also known as acrylic is a transparent thermoplastic.

1.2. Charecterisation

PMMA or acrylic is a strong and lightweight material. The density of acrylic ranged between 1.17-1.20 g/cm 3 which is half less than that of glass. The impact strength of PMMA is greater than that of glass and polysterene. Acrylic can transmit upto 92% of visible light with just 3mm of thickness. With refractive index of 1.4905 at 589.3 nm it can reflect upto 4% light from its surface.

It does not contain any traces of bisphenol-A which is potentially harmful compound found in polycarbonate. It is often used in sheet form due to its properties such as lightweight and shatter resistance as an alternative to glass. It often serves as an economical alternative to polycarbonate whenever extreme strength is not desired. It is often recognized by trade names such as Plexiglass.

Due to advancements in technology efforts have been made to increase the impact resistance and scratch resistance and high hardness of this material.

Due to the environmental stability of acrylic is better as compared to polystyrene and polyethylene it is considered for most of the outdoor applications in the plastics industry.

Manufacturing methods of PMMA

1. Emulsion polymerization 2.Solution polymerization
3. Bulk polymerization 4.Suspension polymerization

1.3. Nanocomposites

A Nanocomposite is a matrix to which nanoparticles have been added to improve a particular property of material. They have multiple phase domains and atleast one of these domains has a nanoscale structure. The mechanical, electrical, thermal, optical, electrochemical properties of the nanocomposites will differ markedly from that of the component materials.

In mechanical terms, nanocomposites differ from the conventional composite materials due to the exceptionally high surface to volume ratio and aspect ratio. The large amount of reinforcement surface area means that a relatively small amount of nanoscale reinforcement can have an observable effect on the macroscale properties of the composites[1]

2. Review on experimental Analysis of PMMA Nanocomposites

2.1 Calcium Aluminate - PMMA

PMMA based cement was 1st introduced by Dr. John Charnley and has been clinically used for the construction of prosthetic appliances and the fixation of all joint prosthese. The objective of this study is to assess the influence of lithium fluoride on in vitro bio compactibility and bioactivity of calcium aluminate (CA) – PMMA composite cement exhibiting quick setting time (<15 min) low exothermic temperature (<47^{0}c) and high compressive strength (>100 MPA).

Weak mechanical properties of PMMA arises from cyclic loading and over stress beyond endurance which can result in fracture in the cement structure and the production of wear debris flow at interface between PMMA based cement and implant. Addition of Calcium Aluminate to PMMA based cement is considered one of the possible way to improve mechanical and biological properties of PMMA based cements. Adding ceramic filler is made to decrease the relative amount of MMA in the composition, which would decrease the exothermic, polymerization shrinkage and the release of toxic MMA into the tissue, thus improving the biocompactibility and bioactivity of PMMA based cement. Bone cement have been used in artificial joints (hip joints, knee joints, shoulders and elbow joints).[2]

2.2 Ceraium doped Yttrium Aluminium Garnate (Ce:YAG)

The yttrium–alumina (Y2O3–AI2O3) system has three compounds that are stable at room temperature and are classified according to their molar ratio and thermodynamic condition. These are yttrium aluminium garnet (YAG), yttrium aluminium perovskite (YAP), and the symmetric yttrium aluminium monoclinic structures (YAM).YAG is having optical mechanical and high temperature creep resistance. The objective of adding YAG in PMMA is to improve thermal stability .

A Ce:YAG –PMMA composite was prepared using in situ polymerization by embedding the Ce:YAG nanopowder in a blend of methyl methacrylate (MMA) and 2-methacrylic acid (MMA)monomer and activating the photopolymerization using a radical initiator. Thermal stability of PMMA increased with an increase in the nano-phosphorescent content. It also increases the glass transition temperature. Increase in thermal stability at higher filler loading for PMMA composite because of stronger interaction between Ce:YAG and PMMA and it's degradation volatiles. Increase in Ce:YAG content as a result of the increased stiffness of the composites and immobilization of the polymer chain.[3]

2.3 Titanium Dioxide

A translucent UV protecting poly (methyl methacrylate) (PMMA)/TiO2 nanocomposite has been fabricated using anatase TiO2 nanoparticles by solution method. simple and effective method to prepare transparent PMMA/TiO2 nanocomposites by employing myristic acid modified TiO2 NPs. Based on the synthesis of soluble anatase titania nanoparticles with controlled size, TiO2/PMMA nanocomposite thin film was fabricated by solution casting method where the polymer was initially dissolved in toluene and was mixed with anatase titania nanoparticles dispersed in the same solution. The transparent TiO2/PMMA nanocomposite thin film showed promising thermal stability and high UV-C absorption efficiency at very low TiO2 concentrations (0.1 wt % and 1 wt%). This work describes fabrication of transparent organic/inorganic nanocomposite polymeric material possessing scope for UV shielding application by virtue of its optical properties. The inorganic nano particle having capability of cutting the UV absorption. The thermal stability and UV-C absorption efficiency is greater of TiO_2 .This are used in making UV protection shield.[4]

2.4 CNTS

SWCNT

PMMA/SWCNT composites were prepared via in Situ polymerization induced either by heat, ultraviolet (UV) light or ionizing (gamma) radiation. The properties of CNTS are high aspect ratio, high mechanical strength, novel electrical properties. The polymer matrix for all of the produced nanocomposites interact with dispersed CNTs as demonstrated by the presence of gamma transition in the dielectric loss data and an increased dielectric constant.
The fabrication of transparent polymer nanotube composites may prove to be a useful tool in developing transparent composites with enhanced optical and electrical properties .[5]

2.5 Zn_2SiO_4=Eu^{3+}(Mn^{2+})

Luminescent composites of poly(methylmethacrylate) (PMMA) and nanophosphors (Zn2SiO4:Mn2+, Zn2SiO4:Eu3+) were prepared by dispersion casting method. Nanoparticles embedded in PMMA matrix preserve their typical phosphorescence emission. A shift towards higher glass transition temperatures and slight improvements in thermal stability of the nanocomposites compared to pure PMMA. Zinc silicate
(Zn2SiO4) has been identified as a suitable host matrix for many transition metal and rare earth (RE) dopant ions, providing excellent luminescent properties in the blue, green, and red spectral zones. Manganese-doped zinc silicate, Zn2SiO4:Mn2+, has been used extensively as a green luminescent phosphor in cathode ray tubes, lamps, and plasma display panels for a number of reasons, including its high saturated color, strong luminescence, long life span, lack of moisture sensitivity, and chemical stability. Addition of this filler gives the higher glass transition temperature and improved thermal stability. Material obtained also display combined feature of both composite component inorganic and organic hence have useful application.[6]

2.6. $CaCO_3$

PMMA based nanocomposite filled with calcium carbonate nanoparticle ($CaCO_3$) have been prepared by Situ polymerization. $CaCO_3$ increases Young's modulus. PBA grouped nanoparticle allow to keep unchanged impact strength. The presence of $CaCO_3$ in PMMA matrix improves abrasion resistance and also modify wear mechanism. It also improves stiffness. The addition of $CaCO_3$ in PMMA matrix improves all these properties hence it is very useful filler. Tensile strength will increase as compared to only PMMA.It is used as amineral filler because it is easily available around the world .it reduces the specific size and economical.[7]

2.7. $MgCl_2$

PMMA based nanocomposites with MgCl2 as filler enhances glass transition and mechanical properties of PMMA composite nanofibre. Pure PMMA and various compositions of MgCl2/PMMA nanofibres were successfully fabricated by Electro-spinning process. Young's modulus and tensile stress would be increased with 1% wt incorporation of MgCl2 leads to decrease in mechanical properties. The MgCl2/PMMA nanocomposites samples produced under 25% wt PMMA and 1% wt MgCl2 can be described as the optimized sample because of best thermal and mechanical properties amongst all samples. Applications of this composite are optical sensors.[8]

2.8. SiO_2

Nanosilica/PMMA composites improve the mechanical properties and also enhances the storage modulus of PMMA matrix by about 54.3 & 46.5 at 40^{o}C. Nanosilica/PMMA composite containing nanoparticles obtained by supercritical processing of nanosilica solution ,showed an increase in hardness by 44.6% and elastic modulus by
25.7% relative to neat PMMA. A silane coupling agent , as a conventional surface agent , has been considered as popular chemical agent to chemically or physically modify nano Sio_2 particles to achieve better filler dispersion and to promote compatibility with matrices. [9]

2.9. CuO

Homogeneous nanocomposites of PMMA-CuO films are prepared by using casting method. The copper oxide nanoparticles are added to PMMA with different concentration (0,2,4,8)wt% and mixed for several minutes for complete homogenization. The absorbance of (PMMA-CuO) nanocomposites with wavelength increased with increase in concentrations of nanoparticles.The optical constant (absorption coefficient , extinction coefficient),refractive index and imaginary dielectric constants affected. Energy band gap of (PMMA-CuO) nanocomposites decreases with increase in concentration. Applications of CuO/PMMA nanocomposites are contact breaker, UV shielding ,windows, contact lenses, PNC glasses[10]

Analysis

Sr. no.	Base material	Filler material	Manufacturing process	Properties improved	Application
1	PMMA	CA		High compressive strength, quick setting time, improves mechanical and biological properties, decrease exothermic polymerization shrinkage.	Artificial joint like knee joint, elbow joint.
2	PMMA	Ce:YAG	In Situ polymerization	Improve optical mechanical properties, high temperature creep resistance.	
3	PMMA	TiO_2	Solution method	Thermal stability, UV absorption.	UV protection shield
4	PMMA	CNTs	In Situ	High aspect	
			polymerization	ratio, high mechanical strength, increased die electric constant.	
5	PMMA	Zn_2SiO_4	Dispersion casting method	Improves thermal stability, improves glass transition temperature.	

6	PMMA	$CaCO_3$	Situ polymerization	Increases Young's modulus improves abrasion resistance and wear mechanism.	
7	PMMA	$MgCl_2$	Electro spinning process	Young's modulus, tesile strength increases, enhances glass transition and mechanical properties improved.	Optical sensor
8	PMMA	SiO_2	Supercritical processing of nanosilica solution.	Increases elastic modulus, improve mechanical properties.	
9	PMMA	CuO	Casting	Wavelength increased, increase in concentration of nanoparticles	UV shielding, windows, PNC glasses, contact breaker.

3. CONCLUSION

In conclusion, new technologies require materials showing novel properties and/or improved performance compared to conventionally processed components. In this context, PMMA nanocomposites are suitable materials to meet the emerging demands arising from scientific and technologic advances. Processing methods for different types of PMMA nanocomposites (CMNC, MMNC and PMNC) are available, but some of these pose challenges thus giving opportunities for researchers to overcome the problems being encluntered with nanosize materials. They offer improved performance over monolithic and microcomposite counterparts and are consequently suitable candidates to overcome the limitations of many currently existing materials and devices. A number of applications already exists, while many potentials are possible for these materials, which open new vistas for the future. In view of their unique properties such as very high mechanical properties even at low loading of reinforcements, gas barrier and flame related properties, many potential applications and hence the market for these materials have been projected in various sectors. Thus all the three types of PMMA nanocomposites provide opportunities and rewards creating new world wide interest in these new materials.

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