UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT AND CHARACTERIZATION OF FLAME RETARDANT OIL PALM FILLER/KENAF REINFORCED HYBRID COMPOSITES

NAHEED SABA

IPTPH 2016 6

DEVELOPMENT AND CHARACTERIZATION OF FLAME RETARDANT OIL PALM FILLER/KENAF REINFORCED HYBRID COMPOSITES

By

NAHEED SABA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

November 2016

© COPYRIGHT UPM

COPYRIGHT

All material contained within the thesis, including without limitation text, logos, icons, photographs and all other artwork, is copyright material of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright © Universiti Putra Malaysia

DEDICATION

This thesis is exclusively dedicated to:

My beloved parents for their extreme love, sacrifices, encouragements, inspirations, compassion and moral support throughout my life

&

My endearing husband and my cute daughter for their support, patience and great understanding on me

© COPYRIGHT UPM

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT AND CHARACTERIZATION OF FLAME RETARDANT OIL PALM FILLER/KENAF REINFORCED HYBRID COMPOSITES

By

NAHEED SABA

November 2016

Chairman: Professor Paridah Md. Tahir, PhD
Institute : Tropical Forestry and Forest Products

Epoxy is among the most extensively used thermoset polymer in the composite industry, particularly for high performance and advanced applications. However, most cured epoxy systems are extremely brittle, poor resistance to crack initiation, possess lower impact strength and characteristics poor flame retardancy during fire threats, which limits its extensive applications. These weaknesses are more acute when used with natural fibers. To minimize these shortcomings flame retardant (FR) nano filler are incorporated as additive to improve its strength besides its flame retardancy. This study used oil palm empty fruit bunch (OPEFB) fibers obtained from palm oil processing mill for producing FR nano OPEFB. The FR nano sized OPEFB filler was produced through chemical (bromine water and tin chloride) treatment and cryogenic crushing followed by high energy ball milling process. Evaluation under SEM depicts that the surface morphology of the FR nano OPEFB possess amorphous and irregular shape. Thermal analysis revealed that the treated FR nano OPEFB is thermally stable compared to untreated OPEFB fibers. Residual char obtained is 29% for nano OPEFB, 10.85% for untreated (R-OPEFB) and 14.17% for B-OPEFB fibers. Epoxy nanocomposites were fabricated using different nano OPEFB filler loading (1, 3, 5 % by weight) through hand lay-up technique. A marked increase in mechanical properties and flame retardancy were observed for all filler filled epoxy nanocomposites, in particular at 3% loading. Tensile strength of 1% is 21.43MPa, 3% is 29.01 MPa and 5% is 22.61 MPa, while impact strength of 1% is 68.13% J/m, 3% is 98.71 J/m and 5% is 70.62 J/m are observed. LOI value for pure epoxy is 23%, 1% is 25 %, 3% is 29% and for 5% is 28% while, UL-94V ratings for pure epoxy is V-2, 1% is V-1, 3% and 5% is V-0. Mechanical in terms of tensile, impact and elongation at break, morphological, physical, structural, thermal in terms of decomposition temperature and char yield, dynamic mechanical in terms of storage modulus (E') and loss modulus (E''), Tg and damping factor, thermomechanical in terms of coefficient of thermal expansion (CTE) and flame retardancy analysis were conducted by fabricating kenaf/epoxy composites and kenaf/epoxy hybrid nanocomposites each at 40% by weight of kenaf fiber loading. Three types of hybrid nanocomposites namely, nano OPEFB/kenaf/epoxy, montmorillonite

© COPYRIGHT UPM

(MMT)/kenaf/epoxy and organically modified montmorillonite (OMMT)/kenaf/epoxy hybrid nanocomposites were fabricated. Considerable improvement in mechanical strength in terms of tensile, impact strength and elongation at break were realized by adding nano OPEFB filler in kenaf/epoxy composites. Tensile strength of kenaf/epoxy composites increases by 24.9% by adding nano OPEFB filler, while 56% increment was recorded by adding OMMT with respect to nano OPEFB/kenaf/epoxy hybrid nanocomposites. Impact strength of kenaf/epoxy increases considerably from 19.13J/m to 24.54 J/m by adding nano OPEFB filler, to 31.32 J/m by adding MMT and to 39.46 J/m by adding OMMT. The profound effects of the nano OPEFB filler addition in reducing void contents and number of fiber pull out from the fractured surface signifies the enhanced adhesion and interfacial bonding between kenaf fibers and matrix. Remarkable improvements in *E'*, *E''* and *Tg*, while reduction in CTE as function of temperature by adding nano OPEFB filler were also noticed. *Tg* value for kenaf/epoxy was increased from 70.1 ºC to 80.6 ºC by adding nano OPEFB filler. LOI and UL-94V ratings of kenaf/epoxy are 24% and V-2 respectively but the addition of nano OPEFB filler to it increases to 30% and V-0 respectively, for MMT to 28% and V-1 whereas for OMMT to 30% and V-0 rating. Results of the analysis revealed that there are improvements in the properties of the nano OPEFB/kenaf/epoxy nanocomposites which are quite comparable with those of MMT/kenaf/epoxy nanocomposites but lesser than the OMMT/kenaf/epoxy hybrid nanocomposites, except for flame retardancy. In conclusion, the proposed method to develop FR nano OPEFB filler from waste OPEFB fibers represents simple and convenient way in terms of time and energy required for utilizing OPEFB fibers waste efficiently.

© COPYRIGHT UPM

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor of Falsafah

PEMBANGUNAN DAN PENCIRIAN KOMPOSIT HIBRID TAHAN API DIPERKUKUH DENGAN PENGISI SAWIT/KENAF

Oleh

NAHEED SABA

November 2016

Pengerusi: Professor Paridah Md. Tahir, PhD
Institut : Perhutanan Tropika Dan Produk Hutan

Epoksi adalah antara polimer termoset yang paling banyak digunakan dalam industri komposit, terutamanya untuk aplikasi bahan prestasi tinggi dan termaju. Walau bagaimanapun, kebanyakan sistem epoksi adalah amat rapuh, rintangan yang lemah terhadap permulaan retakan, kekuatan impak yang rendah, dan ciri-ciri rencat nyala yang lemah semasa ancaman nyala, yang mana menghadkan aplikasinya yang lebih meluas. Kelemahan-kelemahan ini menjadi lebih berat apabila digunakan bersama gentian semula jadi. Untuk mengurangkan kekurangan ini, pengisi nano kalis nyala diletakkan sebagai bahan tambahan untuk meningkatkan kekuatan selain rencat nyalanya. Kajian ini menggunakan gentian tandan kosong kelapa sawit (OPEFB) yang diperolehi daripada kilang pemprosesan minyak sawit untuk menghasilkan FR nano OPEFB. FR nano OPEFB bersaiz nano telah dihasilkan melalui rawatan kimia (air bromin dan klorida timah) dan penghancuran kriogenik diikuti oleh proses kisar bola tenaga tinggi. Penilaian di bawah SEM menggambarkan bahawa morfologi permukaan OPEFB FR nano yang dihasilkan mempunyai bentuk amorfus yang tidak teratur. Analisis terma mendedahkan bahawa OPEFB FR nano yang dirawat adalah stabil dari segi haba berbanding gentian OPEFB yang tidak dirawat. Sisa menghanguskan diperolehi ialah 29% untuk nano OPEFB, 10.85% untuk tanpa dirawatan (R-OPEFB) dan 14.17% untuk serat B-OPEFB. Nanokomposit epoksi telah dihasilkan menggunakan kandungan pengisi OPEFB nano yang berbeza (1, 3, 5% mengikut berat) secara manual. Satu peningkatan ketara dalam sifat mekanik dan rencatan api diperhatikan dalam semua nanokomposit epoksi berisi, khususnya bagi 3% pengisian. Kekuatan tegangan bagi perisian 1% ialah 21.43MPa, 3% ialah 29.01 MPa dan 5% ialah 22.61 MPa. Manakala diperhatikan bahawa kekuatan hentaman perisian 1% ialah 68.13% J/m, 3% ialah 98.71 J/m dan 5% ialah 70.62 J/m. Nilai LOI untuk epoksi tulen ialah 23%, perisian 1% ialah 25 %, 3% ialah 29% dan untuk 5% ialah 28% manakala, pengkadaran UL-94V untuk epoksi tulen ialah V-2, perisian 1% ialah V-1, manakala kedua-dua 3% dan 5% ialah V-0. Peningkatan ketara dalam sifat-sifat mekanikal dan rencat nyala dapat diperhatikan dalam semua nanokomposit epoksi, khususnya pada perisian 3%. Mekanikal dari segi tegangan, kesan dan pemanjangan pada takat putus, morfologi, fizikal, struktur, haba dari segi suhu penguraian dan hasil char, dinamik mekanikal dari segi penyimpanan modulus (E') dan kehilangan modulus (E''), *Tg* dan redaman faktor, termomekanikal dari segi pekali pengembangan haba (CTE) dan analisis nyala retardancy telah dijalankan oleh mereka-reka komposit kenaf/epoksi dan nanokomposit kenaf/epoksi hibrid setiap satu pada 40% berdasarkan berat beban serat kenaf. Tiga jenis nanokomposit hibrid telah dihasikan iaitu nano OPEFB/kenaf/epoksi, montmorilonit (MMT)/kenaf/epoksi dan montmorilonit organik yang diubahsuai (OMMT)/kenaf/epoksi. Peningkatan yang besar dalam kekuatan mekanikal dari segi kekuatan tegangan, kekuatan impak dan pemanjangan pada takat putus dapat dilihat dengan menambah pengisi OPEFB nano dalam komposit kenaf/epoksi. Kekuatan tegangan bagi kenaf/komposit epoksi meningkat sebanyak 24.9% dengan menambahkan pengisi OPEFB nano, manakala 56% dengan menambahkan OMMT. Kekuatan hentaman komposit kenaf/ epoksi meningkatkan daripada 19.13 J/m kepada 24.54J/m dengan menambah pengisi OPEFB nano, kepada 31.32 J/m dengan menambahkan MMT dan kepada 39.46 J/m dengan menambahkan OMMT. Kesan mendalam penambahan pengisi OPEFB nano bagi mengurangkan kandungan liang udara dan bilangan serat yang tertarik keluar dari permukaan patah, melambangkan peningkatan pada rekatan dan ikatan antara muka di antara gentian kenaf dan matriks. Peningkatan yang luar biasa dalam E' , E'' dan *Tg*, manakala pengurangan CTE sebagai fungsi suhu juga dapat diperhatikan. Nilai *Tg* untuk kenaf/epoksi meningkatkan dari 70.1ºC ke 80.6ºC dengan menambahkan pengisi OPEFB nano. LOI and UL-94V pengkadaran kenaf/epoksi ialah 24% dan V-2 masing-masing tetapi tambahan pengisi OPEFB nano bagi ia meningkatkan kepada 30% dan V-0 masing-masing, untuk MMT kepada 28% dan V-1 manakala untuk OMMT kepada 30% dan V-0 kadar. Keputusan analisis menunjukkan bahawa terdapat penambahbaikan terhadap ciri-ciri nanokomposit hibrid OPEFB nano/kenaf/epoksi yang setanding dengan sifat-sifat MMT/kenaf/epoksi tetapi lebih rendah nanokomposit hibrid OMMT/kenaf/epoksi kecuali bagi rencat nyala. Kesimpulannya, kaedah yang dibangunkan bagi menghasilkan pengisi FR OPEFB nano dengan menggunakan sisa gentian OPEFB merupakan kaedah ringkas dan mudah dari segi masa dan tenaga yang diperlukan bagi penggunaan sisa OPEFB yang efisien.

ACKNOWLEDEGEMENTS

IN THE NAME OF "ALLAH, MOST GRACIOUS, MOST MERCIFUL"

Allahumdullilah, all praise to Almighty Allah *Subhanutallah* for strength, mercy and for his blessings in completing my PhD thesis. I would like to gratefully express my appreciation to Institute of Tropical Forestry and Forest Products (INTROP), to pursue my PhD study. I wish to express my profound gratitude, indebtedness and deep appreciation to my main supervisor Prof. Dr. Paridah Md. Tahir for her valuable support, guidance throughout the completion of this research study. I am also highly thankful to the members of the supervisory committee; Assoc. Prof. Dr. Khalina Abdan and Assoc. Prof. Dr. Nor Azowa Ibrahim for their valuable motivation and assistance in this research.

I am extremely thankful to the International Graduate Research Fellowship (IGRF), Malaysia for supporting me in pursuing this study.

I sincerely owe a great and invaluable appreciation and gratitude to my dear husband for his immense love and personal attention during my extremely tough time. I also extend my special thanks to my sweet daughter (Ayesha Jawaid), for her valuable smile, sacrifice and for providing fun filled atmosphere all the time. Most important I owe my sincere gratitude to my mother (Farhat Saba) and my father (S. Qutubuddin Ahmed) for their enormous love, upright upbringing and honest supplications towards my duty from childhood till now. Besides this, thanks to my beloved younger brother (Dr. Asif Saba), for his endless emotional support and moral encouragements during moments of prosperity and adversity.

Last but not least, I wish to convey acknowledge to entire family members including my in-laws, dearest friends and well-wishers for their precious encouragement given throughout the entire PhD journey. Finally, my thanks go to all people who knowingly and unknowingly helped me for the successful completion of this work.

Jazak Allahu Khairun!

© COPYRIGHT UPM

I certify that a Thesis Examination Committee has met on 9 November 2016 to conduct the final examination of Naheed Saba on her thesis entitled "Development and Characterization of Flame Retardant Oil Palm Filler/Kenaf Reinforced Hybrid Composites" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Edi Suhaimi Bakar, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Mohd Sapuan bin Salit @ Sinon, PhD
Professor Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Edi Syams bin Zainudin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Faiz Mohammad, PhD
Professor
Aligarh Muslim University
India
(External Examiner)

NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 December 2016

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy**.** The members of the Supervisory Committee were as follows:

Paridah Md. Tahir, PhD
Professor
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia
(Chairman)

Khalina Abdan, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Nor Azowa Ibrahim, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date

© COPYRIGHT UPM

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been fully referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permissions must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ______________________________ Date: _________________________

Name and Matric No: Naheed Saba,GS38067

© UPM

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ---

Name of Chairman of Supervisory Committee: Prof. Dr. Paridah Md. Tahir

Signature: ---

Name of Member of Supervisory Committee: Assoc. Prof. Khalina Abdan

Signature: ---

Name of Member of Supervisory Committee: Assoc. Prof. Nor Azowa Ibrahim

© COPYRIGHT UPM

TABLE OF CONTENTS

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF TABLES

© COPYRIGHT UPM

LIST OF FIGURES

© COPYRIGHT UPM

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF ABBREVIATIONS

ASTM	American society for testing and materials
ABS	Acrylonitrile butadiene styrene
AC	Activated carbon
Al_2O_3	Aluminium oxide
AZD	Azodicarbonamide
Br	Bromine
B-OPEFB	Brominated OPEFB fibers
BS	Bamboo stem
C	Carbon
CB	Carbon black
CFA	Chemical foaming agent
Cl	Chlorine
CTE	Coefficient of thermal expansion
CNS	Coconut shells
CNSL	Cashew nut shell liquid matrix
CNTs	Carbon nanotubes
DeBDE	Decabromodiphenyl ether
DGEBA	Diglycidyl ether of bisphenol A
DMA	Dynamic mechanical analysis
DSC	Differential scanning calorimetry
DTG	Derivative thermogravimetry
E^*	Complex modulus
E'	Storage modulus
E''	Loss modulus
EDX	Elemental dispersive X-ray analysis
EMC	Equivalent moisture content
EP	Ethylene–propylene
ER	Epoxy resin
Fe_2O_3	Iron oxide
FRs	Flame retardants
FTIR	Fourier transform infrared spectroscopy
GNI	Gross national income
GO	Graphene oxide
HBr	Hydrogen bromide
HCl	Hydrochloric acid
HDP	Hexadecylpyridinium
HDTMA	Hexadecytrimethylammonium
HEBM	High energy ball milling
H_2O	Water
IR	Infrared
$LiAlH_4$	Lithium aluminum hydride
LOI	Limiting oxygen index
MFC	Microfibrillated cellulose
MPOB	Malaysian palm oil board
MMT	Montmorillonite

© COPYRIGHT UPM

NR	Non-rated
OPEFB	Oil palm empty fruit bunch
OPFB	Oil palm fruit bunch
OMMT	Organically modified MMT
OSU	Ohio State University
PBO	Poly p-phenylenebenzobisoxazole
PC	Polycarbonate
PCFC	Pyrolysis combustion flow calorimetry
PEEK	Poly(ether ether ketone)
PHA	Polyhydroxyalkanoates
PI	Phenylethynyl-terminated imide
PLA	Poly lactic acid
PPc	Compatibilized polypropylene
PVC	Poly vinyl chloride
RH	Relative humidity
R-OPEFB	Raw/Untreated OPEFB fiber
Sn	Tin
$SnBr_2$	Tin(II) bromide
$SnBr_4$	Tin(IV) bromide
SiC	Silicon carbide
$SnCl_2$	Tin chloride
$SnCl_4$	Tin(IV) chloride
SEM	Scanning electron microscopy
SiO_2	Silicon dioxide
Tg	Glass transition temperature
Tan δ	Tan delta
TBPA	Tetrabromophthalic anhydride
TEM	Transmission electron microscopy
TGA	Thermogravimetric analysis
TMA	Thermomechanical analysis
TMWF	Tea mill waste fibers
TiO_2	Titanium dioxide
TTS	Time-temperature superposition
UHMWPE	Ultra-high molecular weight poly(ethylene)
UL94	Underwriters laboratories 94
UP	Unsaturated polyester
UV	Ultra violet
XRD	X-ray diffraction

© COPYRIGHT UPM

LIST OF SYMBOLS

rpm	Rate per minute
hr	Hour
μm	Micrometer
MPa	Megapascal
GPa	Gigapascal
g/cm^3	Gram per cubic centimeter
nm	Nanometer
°C	Degree Celsius
K	Kelvin
J/m	Joule per mole
kJ	Kilojoules
mm	Millimeter
M	Mass
V	Volume
Hz	Hertz
cm^{-1}	Per centimeter
Min	Minute
mg	Milligram
mL/min	Milliliter per minute
Phr	Parts per hundred

© COPYRIGHT UPM

CHAPTER ONE

INTRODUCTION

1.1. Introduction and Background

1.1.1. Epoxy and polymer composites

Epoxy are one of the most important engineering polymeric materials among thermosets resin, which are commercially available and extensively applied in industrial paintings, coatings, general purpose adhesives, laminated circuit board, electrical and microelectronic materials, electronic insulation, military aircraft industries and in modern industries from past 50 years (Chruściel and Leśniak 2014, Yin et al. 2011). Biocomposites and composites has gained global attention due to increased pressure from environmental activists and growing awareness in society for the development of sustainable and biodegradable polymer composites (Satyanarayana et al. 2009). The term biocomposites and composites are quite interrelated and defined as composite materials in which at least one of the constituents is derived from natural resources. They show potential to replace the conventional traditional materials such as metals and wood for various specific applications, thereby saving weight and reducing energy requirements. Cellulosic fibers are one of most abundant and renewable bio-based materials in nature, grows in crops fields (Majeed et al. 2013) and are used as promising and effective alternate reinforcements or fillers in polymer composites fabrication to the expensive synthetic fibers such as glass, aramid or carbon fiber (Jawaid and Abdul Khalil 2011). Elaborative studies have been reported on variety of cellulosic fibers for the fabrication of polymer composites such as (Srisuwana et al. 2014) Jute (Boopalan et al. 2012) flax (Le Duigou et al. 2010, Modniks and Andersons 2013), hemp (Elkhaoulani et al. 2013) kenaf (Azwa and Yousif 2013) banana (Singh et al. 2012) oil palm empty fruit bunch fiber (OPEFB) (Kasolang et al. 2012) and pineapple fibers (Sapuan et al. 2011) for both thermoset and thermoplastic matrix. The advancement of engineering and nanotechnology based on polymeric materials science coupled with suitable nano filler results new formulation strategies with lighter, thinner, stronger and cheaper nanocomposites having promising applications in construction, buildings-bridges, packaging, aerospace and automotive industries. The term "nanocomposites" appeared in 1994 (Paul and Robeson 2008), and defined as composite materials in which at least one dimensions of the reinforcing filler is in the nano scale (<100 nm) (Biswas and Ray 2001). Currently nanocomposites and hybrid nanocomposites are the highly active area of research with different nano sized fillers for advance structural and non-structural applications (Khare et al. 2014).

Hybrid nanocomposites

In the composites science, hybrid composites are the systems in which one kind of reinforcing material is incorporated in a mixture of different matrices (poly blends) (Thwe and Liao 2003), or two or more reinforcing and filling materials are present in a

© COPYRIGHT UPM

single matrix (Jawaid et al. 2012) or both approaches are combined. Hybrid nanocomposites have shown great promising properties to overwhelm many limitations of traditional composites such as the poor interfacial attraction between the fiber and polymer, hydrophilic properties of cellulosic fibers consequently poor strength which hinder in their industrial applications.

Cellulosic fibers hybrid nanocomposites are quite less common, although they are potentially useful materials with respect to environmental concerns. Few research works has been reported for cellulosic fibers/nano filler hybrid nanocomposite, such as nanoclay/cellulose/ethylene–propylene copolymer (Singh and Pal 2007), nanoclay/rice husk/high density polyethylene HDPE (Kord 2011), nanoclay/foamed HDPE/wheat straw flour (Babaei et al. 2014), pine cone fiber/nanoclay (Arrakhiz et al. 2013), wood flour/polypropylene/glass fiber (Kord and Kiakojouri 2011), nanoclay/micro crystalline cellulose/ ethylene–propylene (EP) (Singh and Pal 2007). However, in contrast, a lot of research works has been conveyed involving nano filler reinforcement in synthetic fibers. Some of the important research works on hybrid nanocomposites are, carbon fiber/glass fiber/nano clay/polyamide (PA-6)(Wu et al. 2001), chopped glass fibers/hectorite-type clays (nano size)/polyamide (PA-6) (Akkapeddi 2000), glass fiber/layered silicate/polyamide (PA-6) (Vlasveld et al. 2005), nanoclay/glass fiber/polyester (Jawahar and Balasubramanian 2006), glass fiber/layered silicate/epoxy (Lin et al. 2006). All these hybrid composite revealed good mechanical and physical properties compared to un-hybridized composites.

1.2. Problem statements

Despite of several unique feature and applications of epoxies, the combustibility of epoxies still represents serious constrain in structural, high tech-electronic or automotive applications with high health risks as like other thermosets. As epoxies like other polymers on exposing to high temperatures (300–400ºC), decomposes releasing smoke, heat, toxic volatiles, and soot from the cured epoxy laminate which ultimately affecting its mechanical properties (Rakotomalala et al. 2010). In order to overcome this situation epoxies need to be modified. It has been established that nano filler even less than 5% by weight are sufficient to overcome in contrast to 40-60% fibers reinforcements for epoxy modifications. Currently, a lot of approach and research strategy has been counted/considered in order to enhance or modify epoxy properties to overcome its shortcomings through the incorporation of nano sized materials, even they are expensive (Saba et al. 2015a, Shukla et al. 2008), such as carbon nanotubes, carbon nanofibers, polyhedral silsesquioxanes (POSS); nanoclay, montmorillonite (MMT), organically modified MMT (OMMT), silane, boron carbide nano particles or graphene that are quite expensive (Saba et al. 2016a).

To the best of the author knowledge to date, no research work has been reported on the development of flame retardant (FR) nano filler from organic material such as oil palm empty fruit bunch fibers (OPEFB). OPEFB fibers composed of cellulose (~ 65%) hemicellulose (~ 40%) and lignin (~29%), hence bromine water used in this study can easily react with lignin and carbonyl of sugar unit, like coir fibers (Sen and Kumar 2010).

© COPYRIGHT UPM

In addition to this, the use of OPEFB fibers wastes as nano FR material will provide an ecofriendly and effective way to minimize the deposition, continuous explosive expansion and their wastes management. About 85 million dry tons of solid wastes biomass per annum including oil palm trunk, frond, fruit mesocarp and OPEFB are generated annually in Malaysia (Shinoj et al. 2011). Mature oil palm tree and OPEFB are displayed in **Figure 1.1.** This research study will fulfil the research gap in the context of potential FR materials from organic source by utilizing abundant huge wastes of OPEFB, for the modification of epoxy resin.

Figure 1.1: (a) Oil palm tree and (b) Oil palm empty fruit bunch (OPEFB)
[Courtesy: Prof. Dr. Ir. Sapuan Mohd Salit]

This research work primarily focused to investigate the simple and convenient preparation method of nano filler FR materials through unique combination of chemical treatment followed by nano making process through cryogenizer and high energy ball milling (HEBM) technique. The developed nano filler are then used to fabricate epoxy nanocomposites and hybrid epoxy nanocomposites with combination of locally and easily available kenaf fibers as reinforcement for different applications.

In the present study 1%, 3%, and 5% by weight FR nano OPEFB filler are dispersed uniformly in epoxy matrix to fabricate epoxy nanocomposites through hand lay-up technique. The developed nanocomposites are then characterized to investigate the optimum nano filler loading in the epoxy. The filler loading which shows best in properties are then continued to fabricate hybrid nanocomposites. All kenaf hybrid nanocomposites are fabricated by keeping 40% kenaf fiber loading by weight. In the literature it has been reviewed that for both hybrid and un-hybrid cellulose fiber reinforced polymer composites, 40% fiber loading of cellulose fiber are optimum to improve the mechanical, thermal and physical properties with considerable better fiber/matrix bonding (Jawaid et al. 2013, El-Shekeil et al. 2014). The physical, mechanical, morphological, thermal, dynamic and flame retardancy analysis of nano OPEFB filler/epoxy composites and nano OPEFB filler/kenaf/epoxy hybrid nanocomposites are evaluated. The properties improvement in different parameter was compared to analyze the effectiveness of hybrid nano composites.

There is a growing demand for an innovative research trend to utilize the waste bio-resources as a cheaper and easily available FR material to convey opportunities for effective waste management issues for extremely lively, safe-secured and exciting upcoming future. However, challenges still involve in achieving multifunctional composites with high-performance mechanical properties and effective flame retardancy at the same time to broaden the range of engineering and domestic goods applications (Saba et al. 2016a).

1.3. Research objectives

The primary aim of this current study is to develop FR nano OPEFB filler by treatment followed by cryogenizer and high energy ball milling techniques, to fabricate and characterize epoxy composites, epoxy nanocomposites and kenaf/epoxy hybrid nanocomposites by incorporating FR nano OPEFB filler. The specific research objectives are as follows:

1. To characterize FR nano OPEFB filler prepared from wastes OPEFB fibers.
2. To evaluate the mechanical, morphological and flame retardancy properties of epoxy nanocomposites.
3. To determine physical, mechanical and morphological properties of nano OPEFB filler/kenaf/epoxy hybrid nanocomposites.
4. To analyse the thermal and flame retardancy properties of nano OPEFB filler/kenaf/epoxy hybrid nanocomposites.
5. To evaluate the effectiveness of nano OPEFB filler/kenaf/epoxy hybrid nanocomposites with MMT/kenaf/epoxy hybrid nanocomposites and OMMT/kenaf/epoxy hybrid nanocomposites in terms of physical, mechanical, morphological, structural, thermal and flame retardancy properties.

1.4. Significance of study

a. The findings from the current study are expected to enhance the knowledge in developing flame retardant nano material derived from wastes oil palm empty fruit bunch fibers through simple chemical treatment.
b. It is also expected that the development of nano materials from oil palm empty fruit bunch fibers may help to address environmental problems of disposing the huge amounts of wastes derived from oil palm mill. Hence, they could serve as good alternative to commercially available expensive nano sized fillers.
c. Time problems associated with the process of developing nano filler only through high energy ball milling can be overcome through unique combination of cryogenizer and high energy ball milling.
d. In term of waste disposal and its management issue, this research finding delivers a new platform for proper utilizing the huge underutilized

© COPYRIGHT UPM

lignocellulosic wastes derived from agricultural products into valuable flame retardant nano filler and its polymer composites.

e. The fruitful development of such nano filler from waste of oil palm trees would provide opportunities in fulfilling the growing global need for green and nano products and together contribute towards Malaysia's gross national income (GNI) and will improve the living standard by generating high value jobs for the benefit of Malaysians.
f. This study may also add to the effort to unveil the potential application of flame retardant nano filler in modifying the properties of conventional polymer such as epoxy, by fabricating epoxy nanocomposites.
g. This study also directs the successful development and fabrication of the epoxy based hybrid nanocomposites with locally, cheaper and abundantly available kenaf fibers, in order to improved physical, mechanical, thermal, thermomechanical along with flame retardancy.

1.5. Scope of the study

The aim of present research work is to fabricate and characterize the feasibility of using FR nano OPEFB filler and kenaf fibers as reinforcement in epoxy matrix. Present study deals with the development of epoxy nanocomposites as well as their hybrid epoxy nanocomposites. The literature survey on hybrid composites and nanocomposites based on epoxy resins indicates that until now, no work has been reported on FR nano OPEFB filler/kenaf/epoxy hybrid nanocomposites. Presently, OPEFB fibers and kenaf bast fibers which is easily available in Malaysia, can be utilized as a reinforcing material along with epoxy resin, as they are still underutilized, thus the concerns about the raw material application problems of this by-product can be solved. Moreover the advantages that shows eminent significance in composite fabrication and applications are offered by both OPEFB fibers and kenaf fibers, comprises cheaper, renewable, biodegradable, easier processing and disposal properties. The novel preparation method of nano filler from OPEFB fibers through distinctive combination of cryogenizer and HEBM method will reduced the cost and save time. As the nano filler until now developed from only high energy ball milling technique requires 32- 60hr at 400-600 rate per minute (rpm). The new combination of nano filler derived from agricultural wastes and cellulosic fiber composite materials frequently exhibit remarkable improvements of physical, mechanical, thermal and flame retardancy compared with conventional composites OPEFB and kenaf fibers reinforced polymer composites.

1.6. Thesis organization

The layout of this thesis is in accordance with Universiti Putra Malaysia alternative thesis format based on publications, in which each research chapter **(3 – 10)** represent a separate study that has its own: 'Introduction', 'Materials and methods', 'Results and discussion' and 'Conclusions'. Thus, it is important to note that there is no separate chapter dedicated to the materials and methodology. The details of the thesis structure are presented beneath.

© COPYRIGHT UPM

Chapter 1

The problems that necessitate this research as well as the research objectives were clearly highlighted in this chapter. In addition, the significant contribution, major challenges/gaps and scope of this study were also explicated within the chapter.

Chapter 2

A comprehensive literature review or scientific information on essential areas connected to the topic (such as, biomass, cellulosic fibers, polymer matrix, nano filler, composites, manufacturing techniques, nanocomposites, natural fiber reinforced polymer nanocomposites, hybrid composites, natural fiber/nano filler hybrid nanocomposites, nanotechnologies application and challenges) of this thesis was presented in this chapter.

Chapter 3

This chapter presents the first article entitled "**Preparation and characterization of fire retardant nano filler from oil palm empty fruit bunch fibers".** In this article, the preparation of oil palm nano filler from oil palm empty fruit bunch fibers through cryogenizer and high energy ball milling techniques and the different characterization of developed oil palm nano filler was investigated.

Chapter 4

This chapter entails the second article entitled "**Fabrication of epoxy nanocomposites from oil palm nano filler: mechanical and morphological properties".** The effect of incorporating different loading percentage by weight (1%, 3%, 5%) of oil palm nano filler on tensile, impact properties and on the morphologies of epoxy composites were evaluated in this chapter.

Chapter 5

This chapter presents the third article entitled "**Flame retardancy behavior of oil palm nano filler based epoxy nanocomposites".** In this article the improvement in fire retardant properties of epoxy composites offered by the incorporation of different loading percentage by weight (1%, 3%, 5%) of oil palm nano filler are analysed. The best loading percentage of oil palm nano filler are intended to be utilized for improving the properties of kenaf fibers reinforced epoxy composites.

© COPYRIGHT UPM

Chapter 6

This chapter presents the fourth article entitled "**Effect of oil palm nano filler on mechanical and morphological properties of kenaf reinforced epoxy composites''.** This article deals with the fabrication of oil palm nano filler filled kenaf/epoxy hybrid nanocomposites and its characterization to analyze the effect of nano filler on tensile, impact and morphological properties of kenaf fibers reinforced epoxy composites. Moreover comparative study of nano OPEFB filler/kenaf/epoxy hybrid composites with the MMT/kenaf/epoxy and OMMT/kenaf/epoxy were also investigated in detail.

Chapter 7

This chapter shows the fifth research article entitled "**Thermal properties of oil palm nano filler/kenaf reinforced epoxy hybrid nanocomposites''.** This article deals the fabrication of hybrid nanocomposites and its characterization to analyze the effect of nano OPEFB filler on thermal properties of kenaf fibers reinforced epoxy composites. It also elaborates the comparative study of nano OPEFB filler/kenaf/epoxy hybrid composites with MMT/kenaf/epoxy and OMMT/kenaf/epoxy hybrid nanocomposites.

Chapter 8

This chapter shows the sixth research article entitled "**Dynamic mechanical properties of oil palm nano filler/kenaf/epoxy hybrid nanocomposites".** In this study the dynamic mechanical properties of nano OPEFB filler/kenaf/epoxy hybrid composites were analyzed and compared with kenaf fibers reinforced epoxy composites. This article also includes the comparative study of nano OPEFB filler/kenaf/epoxy hybrid composites with the MMT/kenaf/epoxy and OMMT/kenaf/epoxy hybrid nanocomposites.

Chapter 9

This chapter shows the seventh research article entitled "**Physical, structural and thermomechanical properties of oil palm nano filler/kenaf/epoxy hybrid nanocomposites".** In this study the physical, thermomechanical and structural properties of nano OPEFB filler/kenaf/epoxy hybrid composites were analyzed and compared with kenaf fibers reinforced epoxy composites. Moreover, this article also holds the comparative study in physical, thermomechanical and structural properties improvement with the MMT/kenaf/epoxy and OMMT/kenaf/epoxy hybrid nanocomposites.

© COPYRIGHT UPM

Chapter 10

The present chapter displays the eighth research article entitled "**Flame retardancy behavior of oil palm nano filler/kenaf/epoxy hybrid nanocomposites".** In this article the fire retarding properties of nano OPEFB filler/kenaf/epoxy hybrid composites were analyzed and compared with kenaf fibers reinforced epoxy composites. Furthermore, this article also embraces the comparative study in fire retarding properties improvement in nano OPEFB filler/kenaf/epoxy hybrid composites with the MMT/kenaf/epoxy and OMMT/kenaf/epoxy hybrid nanocomposites.

Chapter 11

Finally, the overall conclusions from the various research articles as well as relevant suggestions for future research were presented in this chapter.

1.7. Research methodology flow

Figure 1.2 shows the research methodology flow for this thesis. The methodology flow covers every single experiment conducted in this work; ranging from the preparation of flame retardant nano filler from OPEFB fibers to the fabrication of epoxy nanocomposites and kenaf hybrid nanocomposites and their characterization. The photographic images of all equipment used for characterizing the physical, mechanical, morphological and thermal properties of nano OPEFB filler, nanocomposites and hybrid nanocomposites are presented in **Appendix A.**

© COPYRIGHT UPM

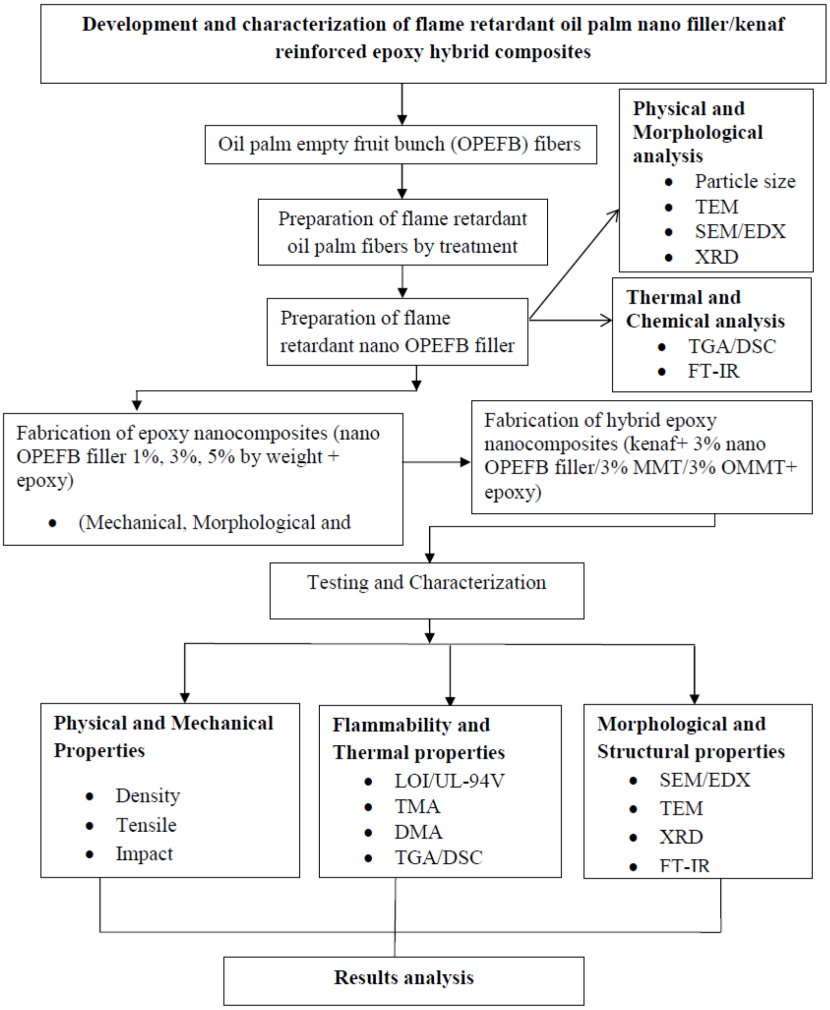

Figure 1.2: Research methodology flow chart

REFERENCES

Abdul Khalil HPS, Firoozian P, Bakare IO, Akil HM, Noor HM (2010) Exploring biomass based carbon black as filler in epoxy composites: Flexural and thermal properties. Mater Des 31:3419–3425

Abdul khalil HPS, Fizree HM, Jawaid M, Alattas OS (2011) Preparation and characterization of nano structured materials from oil palm ash-A bioagricultural waste from oil palm mill. Bioresour 6:4537–4546

Abdul Khalil HPS, Jawaid M, Hassan A, Firoozian P, Akil HM (2013) Preparation of activated carbon filled epoxy nanocomposites. Morphological and thermal properties. J Therm Anal Calorim 113:623–631

Abdul Khalil HPS, Fizree HM, Bhat A, Jwaid M, Abdullah CK (2013a) Development and characterization of epoxy nanocomposites based on nano-structured oil palm ash. Compos Part B Eng 53:324–333

Abe K, Iwamoto S, Yano H (2007) Obtaining cellulose nanofibers with a uniform width of 15 nm from wood. Biomacromol 8:3276–3278

Abe K, Yano H (2010) Comparison of the characteristics of cellulose microfibril aggregates isolated from fiber and parenchyma cells of Moso bamboo (Phyllostachys pubescens). Cellul 17:271–277

Abraham TN, George K (2009) Studies on recyclable nylon-reinforced PP composites: Effect of fiber diameter. J Thermoplast. Compos. Mater 22 (1):5-20

Adikary S, Wanasinghe D (2012) Characterization of Locally available Montmorillonite clay using FTIR technique. Annual Transactions of Institution of Engineers Sri Lanka 1 (part B):140-145

Adnan S, Ismail TNMT, Noor NM, Din NSMNM, Hanzah NA, Kian YS, Hassan HA (2016) Development of Flexible Polyurethane Nanostructured Biocomposite Foams Derived from Palm Olein-Based Polyol. Adv Mater Sci Eng Article ID 4316424

Agunsoye JO, Aigbodion VS (2013) Bagasse filled recycled polyethylene bio-composites: Morphological and mechanical properties study. Results Phys 3:187–194

Agunsoye JO, Isaac TS, Samuel SO (2012) Study of Mechanical Behaviour of Coconut Shell Reinforced Polymer Matrix Composite. J Miner Mater Charact Eng 11:774–779

Ahmad MB, Gharayebi Y, Sapuan MS, Hussein MZ, Shameli K (2011) Comparison of In Situ polymerization and solution-dispersion techniques in the preparation of Polyimide/Montmorillonite (MMT) Nanocomposites. Int J Mol Sci 12:6040–6050

Ahmed MA, Kandil UF, Shaker NO, Hashem AI (2015) The overall effect of reactive rubber nanoparticles and nano clay on the mechanical properties of epoxy resin. J Radiat Res Appl Sci 8:549–561

Ahmed KS, Vijayarangan S, Kumar A (2007) Low Velocity Impact Damage Characterization of Woven Jute—Glass Fabric Reinforced Isothalic Polyester Hybrid Composites. J Reinf Plast Compos 26 (10):959-976

Ahmetli G, Deveci H, Soydal U, Seker A, Kurbanli R (2012) Coating, mechanical and thermal properties of epoxy toluene oligomer modified epoxy resin/sepiolite composites. Prog Org Coat 75 (1):97-105

Ajayan PM, Schadler LS, Braun PV (2006) Nanocomposite science and technology. John Wiley & Sons-Verlag Germany

© COPYRIGHT UPM

Aji IS, Sapuan MS, Zainudin ES, Abdan K (2009) Kenaf fibres as reinforcement for polymeric composites: A review. Int J Mech Mater Eng 4:239–248

Akil HM, Omar MF, Mazuki AAM, Safiee S, Ishak ZAM, Abu Bakar A (2011) Kenaf fiber reinforced composites: A review. Mater Des 32:4107–4121

Akkapeddi M (2000) Glass fiber reinforced polyamide-6 nanocomposites. Polym Compos 21 (4):576-585

Alaee M, Arias P, Sjödin A, Bergman Å (2003) An overview of commercially used brominated flame retardants, their applications, their use patterns in different countries/regions and possible modes of release. Environ Int 29 (6):683-689

Alamgir Kabir M, Monimul Huque M, Rabiul Islam M, Bledzki AK (2010) Mechanical properties of jute fiber reinforced polypropylene composite: Effect of chemical treatment by benzenediazonium salt in alkaline medium. Bioresour 5:1618–1625

Alamri H, Low IM (2012) Effect of water absorption on the mechanical properties of nano-filler reinforced epoxy nanocomposites. Mater Des 42:214–222

Alcock B, Cabrera N, Barkoula NM, Loos J, Peijs T (2006) The mechanical properties of unidirectional all-polypropylene composites. Compos Part A Appl Sci Manuf 37 (5):716-726

Alavudeen A, Rajini N, Karthikeyan S, Thiruchitrambalam M, Venkateshwaren N (2015) Mechanical properties of banana/kenaf fiber-reinforced hybrid polyester composites: Effect of woven fabric and random orientation. Mater Des 66:246–257

Alexandre M, Dubois P (2000) Polymer-layered silicate nanocomposites: preparation, properties and uses of a new class of materials. Mater Sci Eng R 28 (1):1-63

Ali ES, Ahmad S (2012) Bionanocomposite hybrid polyurethane foam reinforced with empty fruit bunch and nanoclay. Compos Part B Eng 53:2813–2816

Andideh M, Naderi G, Ghoreishy MHR, Soltani S (2014) Effects of nanoclay and short nylon fiber on morphology and mechanical properties of nanocomposites based on NR/SBR. Fiber Polym 15:814–822

Anuar H, Ahmad SH, Rasid R , Ahmad A, Busu WNW (2008) Mechanical Properties and Dynamic Mechanical Analysis of Thermoplastic-Natural-Rubber-Reinforced Short Carbon Fiber and Kenaf Fiber Hybrid Composites. J Appl Polym Sci 107:4043–4052

Arbelaiz A, Fernández B, Cantero G, Llano-Ponte R, Valea A, Mondragon I (2005) Mechanical properties of flax fibre/polypropylene composites. Influence of fibre/matrix modification and glass fibre hybridization. Compos Part A Appl Sci Manuf 36 (12):1637-1644

Ardanuy M, Claramunt J, Filho RDT (2015) Cellulosic fiber reinforced cement-based composites: A review of recent research. Constr Build Mater 79:115–128

Arrakhiz F, Benmoussa K, Bouhfid R, Qaiss A (2013) Pine cone fiber/clay hybrid composite: mechanical and thermal properties. Mater Des 50:376-381

Assaedi H, Shaikh FUA, Low IM (2016) Effect of nano-clay on mechanical and thermal properties of geopolymer. J Asian Ceram Soc 4:19–28

Asiri AM, Hussein MA, Abu-Zied BM, Hermas AEA (2013) Effect of NiLaxFe2-xO4 nanoparticles on the thermal and coating properties of epoxy resin composites. Compos Part B Eng 51:11–18

Atkinson P, Haines P, Skinner G (2001) The mechanism of action of tin compounds as flame retardants and smoke suppressants for polyester thermosets. Polym Degrad Stab 71 (3):351-360

© COPYRIGHT UPM

Avila HA, Rodríguez-Páez JE (2009) Solvents effects in the synthesis process of tin oxide. J Non Cryst Solids 355:885–90
Ayrilmis N, Kaymakci A, Akbulut T, Elmas GM (2013) Mechanical performance of composites based on wastes of polyethylene aluminum and lignocellulosics. Compos Part B Eng 47:150–154
Azeez AA, Rhee KY, Park SJ, Hui D (2013) Epoxy clay nanocomposites - Processing, properties and applications: A review. Compos Part B Eng 45:308–320
Aziz SH, Ansell MP (2004) The effect of alkalization and fibre alignment on the mechanical and thermal properties of kenaf and hemp bast fibre composites: Part 1 - polyester resin matrix. Compos Sci Technol 64:1219–1230
Azwa Z, Yousif B, Manalo A, Karunasena W (2013) A review on the degradability of polymeric composites based on natural fibres. Mater Des 47:424-442
Azwa ZN, Yousif BF (2013) Characteristics of kenaf fibre/epoxy composites subjected to thermal degradation. Polym Degrad Stab 98:2752–2759
Babaei I, Madanipour M, Farsi M, Farajpoor A (2014) Physical and mechanical properties of foamed HDPE/wheat straw flour/nanoclay hybrid composite. Compos Part B Eng 56:163-170
Bakar AA, Keat TB, Hassan A (2010) Tensile properties of a poly(vinyl chloride) composite filled with poly(methyl methacrylate) grafted to oil palm empty fruit bunches. J Appl Polym Sci 115:91–98
Balakrishnan H, Hassan A, Wahit MU, Yussuf AA, Razak SBA (2010) Novel toughened polylactic acid nanocomposite: Mechanical, thermal and morphological properties. Mater Des 31:3289–3298
Batouli SM, Zhu Y, Nar M, D'Souza NA (2014) Environmental performance of kenaf-fiber reinforced polyurethane: a life cycle assessment approach. J Clean Prod 66:164-173
Berardi U, Iannace G (2015) Acoustic characterization of natural fibers for sound absorption applications. Build Environ 94:840-852
Beukers A, Van Hinte E (2005) Lightness: The inevitable renaissance of minimum energy structures. 010 Publishers, Amazon, Rotterdam
Bhat AH, Abdul Khalil HPS (2011) Exploring 'nano filler' based on oil palm ash in polypropylene composites. Bioresour 6(2): 1288-1297
Bhattacharya S, Aadhar M (2014) Studies on preparation and analysis of organoclay nano particles. Res J Eng Sci 3 (3):10
Bhoopathi R, Ramesh M, Deepa C (2014) Fabrication and Property Evaluation of Banana-Hemp-Glass Fiber Reinforced Composites. Procedia Eng 97:2032–2041
Bilbao-Sainz C, Bras J, Williams T, Sénechal T, Orts W (2011) HPMC reinforced with different cellulose nano-particles. Carbohyd Polym 86(4): 1549-1557
Bissoli-Dalvi M, Nico-Rodrigues EA, Alvarez CED, Fuica GES, Montarroyos DCG (2016) The sustainability of the materials under the approach of ISMAS. 106:357–363
Biswas M, Ray SS (2001) Recent progress in synthesis and evaluation of polymer-montmorillonite nanocomposites. In: New polymerization techniques and synthetic methodologies. (Edi.) Abe A, Albertsson AC, Coates GW, Genzer J, Kobayashi S, Lee KS, Leibler L, Long TE, Möller M, Okay O, Percec V, Tang BZ, Terentjev EM, Theato P, Vicent MJ, Voit B, Wiesner U, Zhang X, Springer Verlag, Berlin Heidelberg167-221
Biswas S, Shahinur S, Hasan M, Ahsan Q (2015) Physical , Mechanical and Thermal Properties of Jute and Bamboo Fiber Reinforced Unidirectional Epoxy Composites. Procedia Eng 105:933–939

© COPYRIGHT UPM

Brostow W, Datashvili T, Jiang P, Miller H (2016) Recycled HDPE reinforced with sol-gel silica modified wood sawdust. Eur Polym J 76:28–39

Braga RA, Magalhaes Jr PAA(2015) Analysis of the mechanical and thermal properties of jute and glass fiber as reinforcement epoxy hybrid composites. Mater Sci Eng C 56:269–273

Brechet Y, Cavaille JY, Chabert E, Chazeau L, Dendievel R, Flandin L, Gauthier C (2001). Polymer Based Nanocomposites: Effect of Filler-Filler and Filler-Matrix Interactions. Adv Eng Mater 3(8): 1438-1656

Boccarusso L, Carrino L, Durante M, Formisano A, Langella A, Minutolo FMC (2016) Hemp fabric/epoxy composites manufactured by infusion process: Improvement of fire properties promoted by ammonium polyphosphate. Compos Part B Eng 89:117-126

Bondeson D, Oksman K (2007) Polylactic acid/cellulose whisker nanocomposites modified by polyvinyl alcohol. Compos Part A Appl Sci Manuf 38:2486–2492

Boopalan M, Umapathy MJ, Jenyfer P (2012) A Comparative Study on the Mechanical Properties of Jute and Sisal Fiber Reinforced Polymer Composites. Silicon 4:145–149

Borba PM, Tedesco A, Lenz DM (2014) Effect of reinforcement nanoparticles addition on mechanical properties of SBS/Curauá fiber composites. Mater Res 17 (2):412-419

Busu W, Nazri W, Anuar H, Ahmad S, Rasid R, Jamal NA (2010) The mechanical and physical properties of thermoplastic natural rubber hybrid composites reinforced with Hibiscus cannabinus, L and short glass fiber. Polym Plast Technol Eng 49 (13):1315-1322

Chakraborty A, Sain M, Kortschot M (2005) Cellulose microfibrils: A novel method of preparation using high shear refining and cryocrushing. Holzforschung 59:102–107

Camargo PHC, Satyanarayana KG, Wypych F (2009) Nanocomposites: synthesis, structure, properties and new application opportunities. Mater Res 12 (1):1-39

Carpentier F, Bourbigot S, Le Bras M, Delobel R, Foulon M (2000) Charring of fire retarded ethylene vinyl acetate copolymer—magnesium hydroxide/zinc borate formulations. Polym Degrad Stab 69 (1):83-92

Cassagnau P (2013) Linear viscoelasticity and dynamics of suspensions and molten polymers filled with nanoparticles of different aspect ratios. Polym 54(18): 4762-4775

Castrillo PD, Olmos D, Amador DR, González-Benito J (2007) Real dispersion of isolated fumed silica nanoparticles in highly filled PMMA prepared by high energy ball milling. J Colloid Interf Sci 308:318–324

Çavdar AD, Kalaycioğlu H, Mengeloglu F (2011) Tea mill waste fibers filled thermoplastic composites: The effects of plastic type and fiber loading. J Reinf Plast Compos 30:833–844

Cecen V, Seki Y, Sarikanat M, Tavman IH (2008) FTIR and SEM analysis of polyester- and epoxy-based composites manufactured by VARTM process. J Appl Polym Sci 108 (4):2163-2170

Cervantes-Uc JM, Espinosa JIM, Cauich-Rodríguez JV, Ávila-Ortega A, Vázquez-Torres H, Marcos-Fernández A, San Román J (2009) TGA/FTIR studies of segmented aliphatic polyurethanes and their nanocomposites prepared with commercial montmorillonites. Polym Degrad Stab 94:1666–1677

Cicala G, Cristaldi G, Recca G, Ziegmann G, El-Sabbagh A, Dickert M (2009) Properties and performances of various hybrid glass/natural fibre composites for curved pipes. Mater Des 30 (7):2538-2542

© COPYRIGHT UPM

Chandradass J, Kumar MR, Velmurugan R (2007) Effect of nanoclay addition on vibration properties of glass fibre reinforced vinyl ester composites. Mater Lett 61 (22):4385-4388

Chan ML, Lau KT, Wong TT, Cardona F (2011) Interfacial bonding characteristic of nanoclay/polymer composites. Appl Surf Sci 258 (2):860-864

Chang Y, Huang P, Wu B, Chang S (2015) A study on the color change benefits of sustainable green building materials. Constr Build Mater 83:1–6

Chaturvedi S, Dave PN (2013) Design process for nanomaterials. J Mater Sci 48 (10):3605-3622

Chen C, Morgan AB (2009) Mild processing and characterization of silica epoxy hybrid nanocomposite. Polym 50 (26):6265-6273

Chen C, Wang H, Xue Y, Xue H, Liu X (2016) Structure, rheological, thermal conductive and electrical insulating properties of high-performance hybrid epoxy/nanosilica/AgNWs nanocomposites. Compos Sci Technol 128:207–214

Chen W, Tao X, Liu Y (2006) Carbon nanotube-reinforced polyurethane composite fibers. Compos Sci Technol 66 (15):3029-3034

Chieng BW, Ibrahim NA, Wan Yunus WMZ (2010) Effect of organo-modified montmorillonite on poly(butylene succinate)/poly(butylene adipate-co-terephthalate) nanocomposites. Express Polym Lett 4:404–414

Chirayil CJ, Joy J, Mathew L, Mozetic M, Koetz J, Thomas S (2014) Isolation and characterization of cellulose nanofibrils from Helicteres isora plant. Ind Crops Prod 59:27–34

Chruściel JJ, Leśniak E (2014) Modification of epoxy resins with functional silanes, polysiloxanes, silsesquioxanes, silica and silicates. Prog Polym Sci 41:67–121

Costantino U, Bugatti V, Gorrasi G, Montanari F, Nocchetti M, Tammaro L, Vittoria V (2009) New polymeric composites based on poly(ε-caprolactone) and layered double hydroxides containing antimicrobial species. ACS Appl Mater Interfaces 1:668–677

Dadfar MR, Ghadami F (2013) Effect of rubber modification on fracture toughness properties of glass reinforced hot cured epoxy composites. Mater Des 47:16-20

Dahlke B, Larbig H, Scherzer H, Poltrock R (1998) Natural fiber reinforced foams based on renewable resources for automotive interior applications. J Cell Plast 34 (4):361-379

Darder M, Aranda P, Ruiz-Hitzky E (2007) Bionanocomposites: a new concept of ecological, bioinspired, and functional hybrid materials. Adv Mater19 (10):1309-1319

Davoodi M, Sapuan MS, Ahmad D, Ali A, Khalina A, Jonoobi M (2010) Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam. Mater Des 31 (10):4927-4932

De Azeredo HM (2009) Nanocomposites for food packaging applications. Food Res Int 42 (9):1240-1253

De B, Gupta K, Mandal M, Karak N (2015) Biocide immobilized OMMT-carbon dot reduced Cu_2O nanohybrid/hyperbranched epoxy nanocomposites: Mechanical, thermal, antimicrobial and optical properties. Mater Sci Eng C Mater Biol Appl 56:74–83

De Medeiros ES, Agnelli JA, Joseph K, De Carvalho LH, Mattoso LH (2005) Mechanical properties of phenolic composites reinforced with jute/cotton hybrid fabrics. Polym compos 26 (1):1-11

De Velde KV, Kiekens P (2001) Thermoplastic pultrusion of natural fibre reinforced composites. Compos struct 54 (2):355-360

© COPYRIGHT UPM

Deng C, Zhao J, Deng CL, LV Q, Chen L, Wang YZ (2014) Effect of two types of iron MMTs on the flame retardation of LDPE composite. Polym Degrad Stab 103:1-10
Devi LU, Bhagawan SS, Thomas S (2009) Dynamic mechanical analysis of pineapple leaf/glass hybrid fiber reinforced polyester composites. Polym Compos 31:956–965
Dewan MW, Hossain MK, Hosur M, Jeelani S (2013) Thermomechanical properties of alkali treated jute-polyester/nanoclay biocomposites fabricated by VARTM process. J Appl Polym Sci 128:4110–4123
Dhakal HN, Sarasini F, Santulli C, Tirillo J, Zhang Z, Arumugam V (2015) Effect of basalt fibre hybridisation on post-impact mechanical behaviour of hemp fibre reinforced composites. Compos Part A Appl Sci Manuf 75:54–67
Dittenber DB, GangaRao HV (2012) Critical review of recent publications on use of natural composites in infrastructure. Compos Part A Appl Sci Manuf 43 (8):1419-1429
Dong Y, Umer R, Lau AKT (2015) Fillers and Reinforcements for Advanced Nanocomposites. Elsevier-Woodhead Publishing, Cambridge-England
Dorigato A, Dzenis Y, Pegoretti A (2013) Filler aggregation as a reinforcement mechanism in polymer nanocomposites. Mech Mater 61: 79-90
Dueramae I, Jubsilp C, Takeichi T, Rimdusit S (2014) High thermal and mechanical properties enhancement obtained in highly filled polybenzoxazine nanocomposites with fumed silica. Compos Part B Eng 56:197–206
Duncan TV (2011) Applications of nanotechnology in food packaging and food safety: barrier materials, antimicrobials and sensors. J Colloid Interface Sci 363 (1):1-24
Durin-France A, Ferry L, Lopez Cuesta JM, Crespy A (2000) Magnesium hydroxide/zinc borate/talc compositions as flame-retardants in EVA copolymer. Polym Int 49 (10):1101-1105
Eesaee M, Shojaei A (2014) Effect of nanoclays on the mechanical properties and durability of novolac phenolic resin/woven glass fiber composite at various chemical environments. Compos Part A Appl Sci Manuf 63:149–158
Eichhorn S, Baillie C, Zafeiropoulos N, Mwaikambo L, Ansell M, Dufresne A, Entwistle K, Herrera-Franco P, Escamilla G, Groom L (2001) Review: Current international research into cellulosic fibres and composites. J Mater Sci 36 (9):2107-2131
Eng CC, Ibrahim NA, Zainuddin N, Ariffin H, Yunus WMZW, Then YY (2014) Enhancement of Mechanical and Dynamic Mechanical Properties of Hydrophilic Nanoclay Reinforced Polylactic Acid/Polycaprolactone/Oil Palm Mesocarp Fiber Hybrid Composites. Int J Polym Sci Article ID 715801
Elkhaoulani A, Arrakhiz FZ, Benmoussa K, Bouhfid R, Qaiss A (2013) Mechanical and thermal properties of polymer composite based on natural fibers: Moroccan hemp fibers/polypropylene. Mater Des 49:203–208
El-Shekeil YA, Sapuan MS, Jawaid M, Al-Shujaa OM (2014) Influence of fiber content on mechanical, morphological and thermal properties of kenaf fibers reinforced poly(vinyl chloride)/thermoplastic polyurethane poly-blend composites. Mater Des 58:130–135
Ellis TS, D'Angelo JS (2003) Thermal and mechanical properties of a polypropylene nanocomposite. J Appl Polym Sci 90 (6):1639-1647
Esfandiari A (2007) Mechanical properties of PP/Jute and glass fiberscomposites: The statistical investigation. J Appl Sci 7:3943-3950

Essabir H, Boujmal R, Bensalah MO, Rodrigue D, Bouhfid R, Qaiss AEK (2016) Mechanical and thermal properties of hybrid composites: Oil-palm fiber/clay reinforced high density polyethylene. Mech Mater 98:36–43

Fahma F, Iwamoto S, Hori N, Iwata T, Takemura A (2010) Isolation, preparation, and characterization of nanofibers from oil palm empty-fruit-bunch (OPEFB). Cellul 17:977–985

Fahmy TYA, Mobarak F (2008) Nanocomposites from natural cellulose fibers filled with kaolin in presence of sucrose. Carbohyd Polym 72:751–755

Faruk O, Bledzki AK, Fink HP, Sain M (2012) Biocomposites reinforced with natural fibers: 2000–2010. Prog Polym Sci 37 (11):1552-1596

Ferrante L, Tirillo J, Sarasini F, Touchard F, Ecault R, Urriza MV, Chocinski-Arnault L, Mellier D (2015) Behaviour of woven hybrid basalt-carbon/epoxy composites subjected to laser shock wave testing: Preliminary results. Compos Part B Eng 78:162-173

Ferrer A, Filpponen I, Rodriguez A, Laine J, Rojas OJ(2012) Valorization of residual Empty Palm Fruit Bunch Fibers (EPFBF) by microfluidization: Production of nanofibrillated cellulose and EPFBF nanopaper. Bioresour Technol 125:249–255

Feih S, Mouritz AP, Mathys Z, Gibson AG (2010) Fire structural modelling of polymer composites with passive thermal barrier. J Fire Sci 28 (2): 141-160

Frenot A, Henriksson MW, Walkenström P (2007) Electrospinning of cellulose-based nanofibers. J Appl Polym Sci 103:1473–1482

Fong H, Liu W, Wang CS, Vaia RA (2002) Generation of electrospun fibers of nylon 6 and nylon 6-montmorillonite nanocomposite. Polym 43 (3):775-780

Fu H, Huang Y, Liu L (2004) Influence of fibre surface oxidation treatment on mechanical interfacial properties of carbon fibre/polyarylacetylene composites. Mater Sci Technol 20 (12):1655-1660

Fu SY, Xu G, Mai YW (2002) On the elastic modulus of hybrid particle/short-fiber/polymer composites. Compos Part B Eng 33 (4):291-299

Gabr MH, Okumura W, Ueda H, Kuriyama W, Uzawa K, Kimpara I (2015) Mechanical and thermal properties of carbon fiber/polypropylene composite filled with nano-clay. Compos Part B Eng 69:94–100

Gaan S, Sun G, Hutches K, Engelhard M (2008) Flame Retardancy of Cellulosic Fabrics: Interactions between Nitrogen Additives and Phosphorus-Containing Flame Retardants. In: Fire Retardancy of Polymers 294-306

Gacitua W, Ballerini A, Zhang J (2005) Polymer nanocomposites: synthetic and natural fillers a review. Maderas Ciencia y tecnología 7 (3):159-178

Ghosh PK, Kumar K, Chaudhary N (2015) Influence of ultrasonic dual mixing on thermal and tensile properties of MWCNTs-epoxy composite. Compos Part B Eng 77:139–144

González MG, Baselga J, Cabanelas JC (2012) Applications of FTIR on epoxy resins-identification, monitoring the curing process, phase separation and water uptake. INTECH Open Access Publisher, 261-284

Grause G, Furusawa M, Okuwaki A, Yoshioka T (2008) Pyrolysis of tetrabromobisphenol-A containing paper laminated printed circuit boards. Chemosphere 71:872–878

Greene ME, Kinser CR, Kramer DE, Pingree LS, Hersam MC (2004) Application of scanning probe microscopy to the characterization and fabrication of hybrid nanomaterials. Microsc Res Tech 64 (5-6):415-434

Grexa O, Poutch F, Manikova D, Martvonova H, Bartekova A (2003) Intumescence in fire retardancy of lignocellulosic panels. Polym Degrad Stab82 (2):373-377

© COPYRIGHT UPM

Guilherme MR, Mattoso LHC, Gontard N, Guilbert S, Gastaldi E (2010) Synthesis of nanocomposite films from wheat gluten matrix and MMT intercalated with different quaternary ammonium salts by way of hydroalcoholic solvent casting. Compos Part A Appl Sci Manuf 41:375–382

Haafiz MMK, Eichhorn SJ, Hassan A, Jawaid M (2013) Isolation and characterization of microcrystalline cellulose from oil palm biomass residue. Carbohyd Polym 93:628–634

Hakamy A, Shaikh FUA, Low IM (2014) Thermal and mechanical properties of hemp fabric-reinforced nanoclay–cement nanocomposites. J Mater Sci 49:1684-1694

Hari J, Pukanzsky B (2011) Nanocomposites: Preparation, structure, properties. In: Applied Plastics Engineering Handbook: Processing and Materials (Edi.) Kutz M Elsevier, USA

Hao J, Xiong Y, Wu N (2008) Phosphorus-Based Epoxy Resin–Nanoclay Composites. In: Fire Retardancy of Polym160-167

Hao X, Gai G, Liu J, Yang Y, Zhang Y, Nan CW (2006) Flame retardancy and antidripping effect of OMT/PA nanocomposites. Mater Chem Phys 96 (1):34-41

Hassan A, Salema AA, Ani FN, Abu Bakar A (2010) A review on oil palm empty fruit bunch fiber-reinforced polymer composite materials. Polym Compos 31 (12):2079-2101

Hassan M, Nour M, Abdelmonem Y, Makhlouf G, Abdelkhalik A (2016) Synergistic effect of chitosan-based flame retardant and modified clay on the flammability properties of LLDPE. Polym Degrad Stab 133:8-15

Han Z, Fina A (2011) Thermal conductivity of carbon nanotubes and their polymer nanocomposites: A review. Prog Polym Sci 36: 914-944

Hanemann T, Szabó DV (2010) Polymer-nanoparticle composites: From synthesis to modern applications. Mater (Basel) 3:3468–3517

Hansen C, Björkman A (1998) The ultrastructure of wood from a solubility parameter point of view. Holzforschung-Int J Biol Chem Phys Technol Wood 52 (4):335-344

Han Z, Wang Y, Dong W, Wang P (2014) Enhanced fire retardancy of polyethylene/alumina trihydrate composites by graphene nanoplatelets. Mater Lett 128:275-278

Hazarika A, Mandal M, Maji TK (2014) Dynamic mechanical analysis, biodegradability and thermal stability of wood polymer nanocomposites. Compos Part B Eng 60:568–576

Hemmasi AH, Ghasemi I, Bazyar B, Samariha A (2013) Studying the Effect of Size of Bagasse and Nanoclay Particles on Mechanical Properties and Morphology of Bagasse Flour/Recycled Polyethylene Composites. Bioresour 8:3791–3801

Hirvikorpi T, Vähä-Nissi M, Nikkola J, Harlin A, Karppinen M (2011) Thin Al 2 O 3 barrier coatings onto temperature-sensitive packaging materials by atomic layer deposition. Surf Coat Tech 205 (21):5088-5092

Horrocks AR, Smart G, Price D, Kandola B (2009) Zinc stannates as alternative synergists in selected flame retardant systems. J Fire Sci 27: 495-521

Horrocks AR, Kandola BK, Davies PJ, Zhang S, Padbury SA (2005) Developments in flame retardant textiles–a review. Polym Degrad Stab 88 (1):3-12

Horrocks AR, Smart G, Kandola B, Price D (2012) Zinc stannate interactions with flame retardants in polyamides; Part 2: Potential synergies with non-halogen-containing flame retardants in polyamide 6 (PA6). Polym Degrad Stab97 (4):645-652

Hostler S, Abramson A, Gawryla M, Bandi S, Schiraldi D (2009) Thermal conductivity of a clay-based aerogel. Int J Heat Mass Tran 52 (3):665-669

Huang R, Xu X, Lee S, Zhang Y, Kim BJ, Wu Q (2013) High Density Polyethylene Composites Reinforced with Hybrid Inorganic Fillers: Morphology, Mechanical and Thermal Expansion Performance. Mater (Basel) 6:4122–4138

Huang ZM, Zhang YZ, Kotaki M, Ramakrishna S (2003) A review on polymer nanofibers by electrospinning and their applications in nanocomposites. Compos Sci Technol 63 (15):2223-2253

Hubbe MA, Rojas OJ, Lucia LA, Sain M (2008) Cellulosic nanocomposites: A review. Bioresour 3(3): 929-980

Ibrahim MM, Dufresne A, El-Zawawy WK, Agblevor FA (2010) Banana fibers and microfibrils as lignocellulosic reinforcements in polymer composites. Carbohyd Polym 81:811–819

Idicula M, Malsotra SK, Joseph K, Thomas S (2005) Dynamic mechanical analysis of randomly oriented intimately mixed short banana/ sisal hybrid fiber reinforced polyester composites. Compos Sci Technol 65:1077–1087

Idicula M, Neelakantan NR, Oommen Z, Joseph K, Thomas S (2005) A study of the mechanical properties of randomly oriented short banana and sisal hybrid fiber reinforced polyester composites. J Appl Polym Sci 96:1699–1709

Idumah CI, Hassan A (2016) Characterization and preparation of conductive exfoliated graphene nanoplatelets kenaf fibre hybrid polypropylene composites. Synth Met 212:91–104

Ioannidou O, Zabaniotou A (2007) Agricultural residues as precursors for activated carbon production-A review. Renew Sustain Energ Rev 11:1966–2005

Im JS, Lee SK, In SJ, Lee S (2010) Improved flame retardant properties of epoxy resin by fluorinated MMT/MWCNT additives. J Anal Appl Pyrol 89 (2):225-232

Isitman NA, Kaynak C (2010) Nanoclay and carbon nanotubes as potential synergists of an organophosphorus flame-retardant in poly (methyl methacrylate). Polym Degrad Stab95 (9):1523-1532

Islam MS, Ahmad MB, Hasan M, Aziz SA, Jawaid M, Haafiz MKM, Zakaria SAH (2015) Natural Fiber-Reinforced Hybrid Polymer Nanocomposites: Effect of Fiber Mixing and Nanoclay on Physical, Mechanical, and Biodegradable Properties. Bioresour 10:1394–1407

Islam S, Hasbullah NAB, Hassan M, Talib ZA, Jawaid M, Haafiz MMK (2015) Physical , mechanical and biodegradable properties of kenaf/coir hybrid fiber reinforced polymer nanocomposites. Mater Today Commun 4:69–76

Ismail H, Shaari SM (2010) Curing characteristics, tensile properties and morphology of palm ash/halloysite nanotubes/ethylene-propylene-diene monomer (EPDM) hybrid composites. Polym Test 29:872–878

Jacob M, Thomas S, Varughese KT (2004) Mechanical properties of sisal/oil palm hybrid fiber reinforced natural rubber composites. Compos Sci Technol 64 (7):955-965

Jahanmardi R, Kangarlou B, Dibazar A (2013) Effects of organically modified nanoclay on cellular morphology, tensile properties, and dimensional stability of flexible polyurethane foams. J Nanostructure Chem 3:82

Jarukumjorn K, Suppakarn N (2009) Effect of glass fiber hybridization on properties of sisal fiber-polypropylene composites. Compos Part B Eng 40:623–627

Jawaid M, Abdul Khalil HPS (2011) Effect of layering pattern on the dynamic mechanical properties and thermal degradation of oil palm-jute fibers reinforced epoxy hybrid composite. Bioresour 6:2309–2322

Jawaid M, Abdul Khalil HPS, Abu Bakar A (2011) Woven hybrid composites: Tensile

© COPYRIGHT UPM

and flexural properties of oil palm-woven jute fibres based epoxy composites. Mater Sci Eng A 528:5190–5195
Jawaid M, Alothman OY, Saba N, Paridah MT, Abdul Khalil HPS (2014) Effect of Fibers Treatment on Dynamic Mechanical and Thermal Properties of Epoxy Hybrid Composites. Polym Compos 36(9): 1669–1674
Jawaid M, Abdul Khalil HPS, Alattas OS (2012) Woven hybrid biocomposites: Dynamic mechanical and thermal properties. Compos Part A Appl Sci Manuf 43:288–293
Jawaid M, Abdul Khalil HPS (2011) Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. Carbohyd Polym 86 (1):1-18
Jawaid M, Abdul Khalil HPS, Abu Bakar A (2010) Mechanical performance of oil palm empty fruit bunches/jute fibres reinforced epoxy hybrid composites. Mater Sci Eng A 527 (29):7944-7949
Jawaid M, Abdul Khalil HPS, Hassan A, Dungani R, Hadiyane A (2013) Effect of jute fibre loading on tensile and dynamic mechanical properties of oil palm epoxy composites. Compos Part B Eng 45:619–624
Jawaid M, Abdul Khalil HPS, Abu Bakar A, Hassan A, Dungani R (2013) Effect of jute fibre loading on the mechanical and thermal properties of oil palm-epoxy composites. J Compos Mater 47(13): 1633-1641
Jawahar P, Balasubramanian M (2006) Influence of nanosize clay platelets on the mechanical properties of glass fiber reinforced polyester composites. J Nanosci Nanotechnol 6:3973–3976
Jen MHR, Tseng YC, Wu CH (2005) Manufacturing and mechanical response of nanocomposite laminates. Compos Sci Technol 65 (5):775-779
Jeencham R, Suppakarn N, Jarukumjorn K (2014) Effect of flame retardants on flame retardant, mechanical, and thermal properties of sisal fiber/polypropylene composites. Compos Part B Eng 56:249-253
Jiang H, Pascal Kamdem D, Bezubic B, Ruede P (2003) Mechanical properties of poly (vinyl chloride)/wood flour/glass fiber hybrid composites. J Vinyl and Addit Techn 9 (3):138-145
Jiang Y, Li J, Li B, Liu H, Li Z, Li L (2015) Study on a novel multifunctional nanocomposite as flame retardant of leather. Polym Degrad Stab115:110-116
Jiang W, Jin FL, Park SJ (2012) Thermo-mechanical behaviors of epoxy resins reinforced with nano-Al_2O_3 particles. J Ind Eng Chem 18:594–596
Ji Y, Li B, Ge S, Sokolov JC, Rafailovich MH (2006) Structure and nanomechanical characterization of electrospun PS/clay nanocomposite fibers. Langmuir 22 (3):1321-1328
John MJ, Thomas S (2008) Biofibres and biocomposites. Carbohyd polym 71 (3):343-364
Johnston CT, Khan B, Barth EF, Chattopadhyay S, Boyd SA (2012) Nature of the interlayer environment in an organoclay optimized for the sequestration of Dibenzo-p -dioxin. Environ Sci Technol 46:9584–9591
Jonoobi M, Khazaeian A, Paridah MT, Azry SS, Oksman K (2011) Characteristics of cellulose nanofibers isolated from rubberwood and empty fruit bunches of oil palm using chemo-mechanical process. Cellul 18:1085–1095
Joshi M, Butola BS, Simon G, Kukaleva N (2006) Rheological and viscoelastic behavior of HDPE/octamethyl-POSS nanocomposites. Macromol 39:1839–1849
Kalia S, Kaith B, Kaur I (2009) Pretreatments of natural fibers and their application as reinforcing material in polymer composites—A review. Polym Eng Sci 49 (7):1253-1272

© COPYRIGHT UPM

Kamel S (2007) Nanotechnology and its applications in lignocellulosic composites, a mini review. Express Polym Lett 1 (9):546-575
Kandare E, Kandola BK, Myler P (2013) Evaluating the influence of varied fire-retardant surface coatings on post-heat flexural properties of glass/epoxy composites. Fire Safety J 58:112-120
Kandola B, Horrocks A, Myler P, Blair D (2003) Mechanical performance of heat/fire damaged novel flame retardant glass-reinforced epoxy composites. Compos Part A Appl Sci Manuf 34 (9):863-873
Karger-Kocsis J (2000) Reinforced polymer blends. Polymer blends 2:395
Karger-Kocsis J, Mahmood H, Pegoretti A (2015) Recent advances in fiber/matrix interphase engineering for polymer composites. Prog Mater Sci 73:1-43
Kasolang S, Ahmad MA, Bakar MAA, Hamid AHA (2012) Specific wear rate of kenaf epoxy composite and oil palm empty fruit bunch (OPEFB) epoxy composite in dry sliding. J Teknol Sciences Eng 58:85–88
Katsoulis C, Kandola BK, Myler P, Kandare E (2012) Post-fire flexural performance of epoxy-nanocomposite matrix glass fibre composites containing conventional flame retardants. Compos Part A Appl Sci Manuf 43 (8):1389-1399
Khare KS, Khabaz F, Khare R (2014) Effect of carbon nanotube functionalization on mechanical and thermal properties of cross-linked epoxy-carbon nanotube nanocomposites: Role of strengthening the interfacial interactions. ACS Appl Mater and Interface. 6(9): 6098–6110
Khobragade PS, Hansora D, Naik JB, Chatterjee A (2016) Flame retarding performance of elastomeric nanocomposites: A review. Polym Degrad Stab
Khondker O, Fukui T, Inoda M, Nakai A, Hamada H (2004) Fabrication and mechanical properties of aramid/nylon plain knitted composites. Compos Part A Appl Sci Manuf 35 (10):1195-1205
Kong K, Hejda M, Young RJ, Eichhorn SJ (2009) Deformation micromechanics of a model cellulose/glass fibre hybrid composite. Compos Sci Technol 69 (13):2218-2224
Kong LB, Zhang TS, Ma J, Boey F (2008) Progress in synthesis of ferroelectric ceramic materials via high-energy mechanochemical technique. Prog Mater Sci 53:207–322
Kord B (2011) Nanofiller reinforcement effects on the thermal, dynamic mechanical, and morphological behavior of HDPE/rice husk flour composites. Bioresour 6 (2):1351-1358
Kord B (2012) Effect of nanoparticles loading on properties of polymeric composite based on hemp fiber/polypropylene. J. Thermoplast. Compos. Mater 25 (7):793-806
Kord B, Kiakojouri SMH (2011) Effect of nanoclay dispersion on physical and mechanical properties of wood flour/polypropylene/glass fiber hybrid composites. Bioresour 6 (2):1741-1751
Kotal M, Bhowmick AK (2015) Polymer nanocomposites from modified clays : Recent advances and challenges. Prog Polym Sci 51:127–187
Kovacevic Z, Bischof S, Fan M (2015) The influence of Spartium junceum L. fibres modified with montmorrilonite nanoclay on the thermal properties of PLA biocomposites. Compos Part B Eng 78:122-130
Kozłowski R, Władyka-Przybylak M (2008) Flammability and fire resistance of composites reinforced by natural fibers. Polym Adv Technol 19 (6):446-453
Kreyling WG, Semmler-Behnke M, Chaudhry Q (2010) A complementary definition of nanomaterial. Nano Today 5 (3):165-168

© COPYRIGHT UPM

Kumar AP, Singh RP (2007) Novel hybrid of clay, cellulose, and thermoplastics. I. Preparation and characterization of composites of ethylene–propylene copolymer. J Appl Polym Sci 104 (4):2672-2682

Kumar AP, Depan D, Tomer NS, Singh RP (2009) Nanoscale particles for polymer degradation and stabilization—trends and future perspectives. Prog Polym Sci 34 (6):479-515

Kumar NM, Reddy GV, Naidu SV, Rani TS, Subha M (2008) Mechanical properties of coir/glass fiber phenolic resin based composites. J Reinf Plast Compos 28(21): 2605-2613

Kumar S, Dang TD, Arnold FE, Bhattacharyya AR, Min BG, Zhang X, Vaia RA, Park C, Adams WW, Hauge RH (2002) Synthesis, Structure, and Properties of PBO/SWNT Compos Macromol 35 (24):9039-9043

Kwon HJ, Sunthornvarabhas J, Park JW, Lee JH, Kim HJ, Piyachomkwan K, Sriroth K, Cho D (2014) Tensile properties of kenaf fiber and corn husk flour reinforced poly(lactic acid) hybrid bio-composites: Role of aspect ratio of natural fibers. Compos Part B Eng 56:232–237

Landro LD, Lorenzi W (2009) Mechanical Properties and Dynamic Mechanical Analysis of Thermoplastic-Natural Fiber/Glass Reinforced Composites. Macromol Symp 286:145–155

Laoutid F, Bonnaud L, Alexandre M, Lopez-Cuesta JM, Dubois P (2009) New prospects in flame retardant polymer materials: from fundamentals to nanocomposites. Mater Sci Eng R 63 (3):100-125

Lazko J, Landercy N, Laoutid F, Dangreau L, Huguet M, Talon O (2013) Flame retardant treatments of insulating agro-materials from flax short fibres. Polym Degrad Stab98 (5):1043-1051

Leao AL, Rowell R, Tavares N (1998) Applications of natural fibers in automotive industry in Brazil—thermoforming process. In: Science and technology of polymers and advanced materials. (Eds.) PN Prasad, JE Mark, SH Kandil, ZH Kafafi, Springer US Business Media New York 755-761

Le Duigou A, Davies P, Baley C (2010) Macroscopic analysis of interfacial properties of flax/PLLA biocomposites. Compos Sci Technol 70:1612–1620

Lee CH, Sapuan MS, Hassan MR (2014) A review of the flammability factors of kenaf and allied fibre reinforced polymer composites. Adv Mater Sci Eng Article ID 514036

Lee JH, Rhee KY, Park SJ (2010) The tensile and thermal properties of modified CNT-reinforced basalt/epoxy composites. Mater Sci Eng A 527 (26): 6838-6843

Lee SE, Cho S, Lee YS (2014) Mechanical and thermal properties of MWCNT-reinforced epoxy nanocomposites by vacuum assisted resin transfer molding. Carbon Lett 15:32–37

Lenża J, Merkel K, Rydarowski H (2012) Comparison of the effect of montmorillonite, magnesium hydroxide and a mixture of both on the flammability properties and mechanism of char formation of HDPE composites. Polym Degrad Stab97 (12):2581-2593

Lewin M (2011) Flame retarding polymer nanocomposites: Synergism, cooperation, antagonism. Polym Degrad Stab96 (3):256-269

Li P, Zheng Y, Li M, Shi T, Li D, Zhang A (2016) Enhanced toughness and glass transition temperature of epoxy nanocomposites filled with solvent-free liquid-like nanocrystal-functionalized graphene oxide. Mater Des 89:653–659

Liang R, Hota G (2009) Fiber reinforced polymer composites for civil infrastructures. In: Proceedings of the International Conference on FRP Composites for Infrastructure Applications, San Francisco, CA, USA 4-6

© COPYRIGHT UPM

Liang Y, Xia X, Luo Y, Jia Z (2007) Synthesis and performances of Fe_2O_3/PA-6 nanocomposite fiber. Mater Lett 61 (14):3269-3272

Liany Y, Tabei A, Farsi M, Madanipour M (2013) Effect of nanoclay and magnesium hydroxide on some properties of HDPE/wheat straw composites. Fiber Polym14 (2):304-310

Liu H, Chaudhary D, Yusa SI, Tade MO (2011) Glycerol/starch/Na+-montmorillonite nanocomposites: A XRD, FTIR, DSC and 1H NMR study. Carbohyd Polym 83:1591–1597

Liu SP (2014) Flame retardant and mechanical properties of polyethylene/magnesium hydroxide/montmorillonite nanocomposites. J Ind Eng Chem 20 (4):2401-2408

Lin LY, Lee JH, Hong CE, Yoo GH, Advani SG (2006) Preparation and characterization of layered silicate/glass fiber/epoxy hybrid nanocomposites via vacuum-assisted resin transfer molding (VARTM). Compos Sci Technol 66:2116–2125

Liu QQ, Song L, Lu H, Hu Y, Wang Z, Zhou S (2009) Study on combustion property and synergistic effect of intumescent flame retardant styrene butadiene rubber with metallic oxides. Polym Adv Technol 20 (12):1091-1095

Lin Z, Ye W, Du K, Zeng H (2001) Homogenization of functional groups on surface of carbon fiber and its surface energy. J Huaqiao Univ 22 (3):261-263

Lincoln D, Vaia R, Wang ZG, Hsiao B (2001) Secondary structure and elevated temperature crystallite morphology of nylon-6/layered silicate nanocomposites. Polym 42 (4):1621-1631

Liu H, Liu D, Yao F, Wu Q (2010) Fabrication and properties of transparent polymethylmethacrylate/cellulose nanocrystals composites. Bioresour Technol 101:5685–5692

Liu HY, Wang GT, Mai YW, Zeng Y (2011) On fracture toughness of nano-particle modified epoxy. Compos Part B Eng 42: 2170-2175

Liu T, Lim KP, Tjiu WC, Pramoda K, Chen ZK (2003) Preparation and characterization of nylon 11/organoclay nanocomposites. Polym 44 (12):3529-3535

Li Y, Ding X, Guo Y, Rong C, Wang L, Qu Y, Ma X, Wang Z (2011) A new method of comprehensive utilization of rice husk. J Hazard Mater 186:2151–2156

Lou SJ, Szarko JM, Xu T, Yu L, Marks TJ, Chen LX (2011) Effects of additives on the morphology of solution phase aggregates formed by active layer components of high-efficiency organic solar cells. J Am Chem Soc 133 (51):20661-20663

Loveless TA (2015) Mechanical Properties of Kenaf Composites Using Dynamic Mechanical Analysis. Thesis (MSc) Utah state university Logan, Utah

Lu N, Swan RH, Ferguson I (2011) Composition, structure, and mechanical properties of hemp fiber reinforced composite with recycled high-density polyethylene matrix. J Compos Mater 46:1915–1924

Machrafi, H., Lebon, G., Iorio, C. S. (2016) Effect of volume-fraction dependent agglomeration of nanoparticles on the thermal conductivity of nanocomposites: Applications to epoxy resins, filled by SiO_2, AlN and MgO nanoparticles. Compos Sci Technol 130: 78-87

Mahjoub R, Yatim JM, Mohd Sam AR, Hashemi SH (2014) Tensile properties of kenaf fiber due to various conditions of chemical fiber surface modifications. Constr Build Mater 55:103–113

Majeed K, Jawaid M, Hassan A, Abu Bakar A, Abdul Khalil HPS, Salema AA, Inuwa I (2013) Potential materials for food packaging from nanoclay/natural fibres filled hybrid composites. Mater Des 46:391-410

Maldas D, Kokta B (1993) Performance of hybrid reinforcements in PVC composites. II: Use of surface-modified mica and different cellulosic materials as reinforcements. J Vinyl Technol 15 (1):38-44

© COPYRIGHT UPM

Mandal S, Alam S, Varma I, Maiti S (2008) Studies on bamboo/glass fiber reinforced USP and VE resin. J Reinf Plast Compos
Manoharan S, Suresha B, Ramadoss G, Bharath B (2014) Effect of Short Fiber Reinforcement on Mechanical Properties of Hybrid Phenolic Composites. J Mater Article ID 478549
Marques PA, Trindade T, Neto CP (2006) Titanium dioxide/cellulose nanocomposites prepared by a controlled hydrolysis method. Compos Sci Technol 66 (7):1038-1044
Marquis DM, And EG, Chivas-Joly C (2011) Properties of Nanofillers in Polymer. In: Nanocomposites and Polymers with Analytical Methods (ed.) Cuppoletti J, Ist. Intech Publishing, Croatia 261–284
Matabola K, De Vries A, Moolman F, Luyt A (2009) Single polymer composites: a review. J Mater Sci 44 (23):6213-6222
Mattos BD, Misso AL, De Cademartori PHG, De Lima EA, Magalhães WLE, Gatto DA (2014) Properties of polypropylene composites filled with a mixture of household waste of mate-tea and wood particles. Constr Build Mater 61:60–68
Mazuki AAM, Akil HM, Safiee S, Ishak ZAM, Abu Bakar A (2011) Degradation of dynamic mechanical properties of pultruded kenaf fiber reinforced composites after immersion in various solutions. Compos Part B Eng 42:71–76
Mehta N, Parsania P (2006) Fabrication and evaluation of some mechanical and electrical properties of jute-biomass based hybrid composites. J Appl Polym Sci 100 (3):1754-1758
Meng T, Gao X, Zhang J, Yuan J, Zhang Y, He J (2009) Graft copolymers prepared by atom transfer radical polymerization (ATRP) from cellulose. Polym 50 (2):447-454
Mihranyan A, Ferraz N, Strømme M (2012) Current status and future prospects of nanotechnology in cosmetics. Prog Mater Sci 57 (5):875-910
Mishra S, Mohanty A, Drzal L, Misra M, Parija S, Nayak S, Tripathy S (2003) Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites. Compos Sci Technol 63 (10):1377-1385
Mngomezulu ME, John MJ, Jacobs V, Luyt AS (2014) Review on flammability of biofibres and biocomposites. Carbohyd polym 111:149-182
Mochalin VN, Neitzel I, Etzold BJM, Peterson A, Palmese G, Gogotsi Y (2011) Covalent incorporation of aminated nanodiamond into an epoxy polymer network. ACS Nano 5(9): 7494-7502
Modniks J, Andersons J (2013) Modeling the non-linear deformation of a short-flax-fiber-reinforced polymer composite by orientation averaging. Compos Part B Eng 54:188–193
Mohan P (2013) A critical review: The modification, properties, and applications of epoxy resins. Polym Plast Technol Eng 52: 107-125
Mohan TP, Kanny K (2011) Water barrier properties of nanoclay filled sisal fibre reinforced epoxy composites. Compos Part A Appl Sci Manuf 42:385–393
Mohan TP, Velmurugan R, Kanny K (2015) Damping characteristics of nanoclay fi lled hybrid laminates during medium velocity impact. Compos Part B Eng 82:178–189
Mohanty A, Misra M, Drzal L (2001) Surface modifications of natural fibers and performance of the resulting biocomposites: an overview. Compos Interface 8 (5):313-343
Mohanty A, Misra M, Drzal L (2002) Sustainable bio-composites from renewable resources: opportunities and challenges in the green materials world. J Polym Environ 10 (1-2):19-26

© COPYRIGHT UPM

Montazeri A, Chitsazzadeh M (2014) Effect of sonication parameters on the mechanical properties of multi-walled carbon nanotube/epoxy composites. Mater Des 56: 500-508

Monti M, Tsampas S, Fernberg S, Blomqvist P, Cuttica F, Fina A, Camino G (2015) Fire reaction of nanoclay-doped PA6 composites reinforced with continuous glass fibers and produced by commingling technique. Polym Degrad Stab121:1-10

Mohanty AK, Misra M, Drzal LT (2005) Natural fibers, biopolymers, and biocomposites. (Edi.) Mohanty AK, Misra M, Drzal LT, CRC Press, Boca Raton, USA

Mir A, Zitoune R, Collombet F, Bezzazi B (2009) Study of Mechanical and Thermomechanical Properties of Jute/Epoxy Composite Laminate. J Reinf Plast Compos 29:1669–1680

Mustapa IR, Shanks RA, Kong I (2013) Poly(lactic acid)-Hemp-Nanosilica Hybrid Composites: Thermomechanical, Thermal Behavior and Morphological Properties. Int J Adv Sci Eng Technol 3:192–199

Nagendra PS, Prasad VVS, Ramji K (2014) Synthesis of Bio-Degradable Banana Nanofibers. Int J Innov Technol Res 2:730 – 734

Najafi A, Kord B, Abdi A, Ranaee S (2012) The impact of the nature of nanoclay on physical and mechanical properties of polypropylene/reed flour nanocomposites. J Thermoplast Compos Mater 25 (6):717-727

Nakato T, Miyamoto N (2009) Liquid Crystalline Behavior and Related Properties of Colloidal Systems of Inorganic Oxide Nanosheets. Mater (Basel) 2:1734–1761

Nassar A, Nassar E (2014) Thermo and Mechanical Properties of Fine Silicon Carbide /Chopped Carbon Fiber Reinforced Epoxy Composites. Univers J Mech Eng 2:287–292

Nawani P, Desai P, Lundwall M, Gelfer MY, Hsiao BS, Rafailovich M, Frenkel A, Tsou AH, Gilman JW, Khalid S (2007) Polymer nanocomposites based on transition metal ion modified organoclays. Polym 48 (3):827-840

Neher B, Ahmed F (2016) Thermal properties of palm fiber and palm fiber reinforced ABS composite. J Therm Anal Calorim 124:1281–1289

Neitzel I, Mochalin V, Knoke I, Palmese GR, Gogotsi Y (2011) Mechanical properties of epoxy composites with high contents of nanodiamond. Compos Sci Technol 71(5): 710-716

Nie W, Liu J, Liu W, Wang J, Tang T (2015) Decomposition of waste carbon fiber reinforced epoxy resin composites in molten potassium hydroxide. Polym Degrad Stab111:247-256

Nguyen DM, Vu TT, Grillet AC, Thuc HA, Thuc CNH (2016) Effect of organoclay on morphology and properties of linear low density polyethylene and Vietnamese cassava starch biobased blend. Carbohyd Polym 136:163–170

Nguyen TMD, Chang SC, Condon B, Uchimiya M, Fortier C (2012) Development of an environmentally friendly halogen-free phosphorus–nitrogen bond flame retardant for cotton fabrics. Polym Adv Technol 23: 1555–1563

Njuguna J, Pielichowski K, Alcock JR (2007) Epoxy-Based Fibre Reinforced Nanocomposites. Adv Eng Mater 9 (10):835-847

Njuguna J, Pielichowski K, Desai S (2008) Nanofiller-reinforced polymer nanocomposites. Polym Adv Technol 19 (8):947-959

Nohales A, Muñoz-Espí R, Félix P, Gómez CM (2011) Sepiolite-reinforced epoxy nanocomposites: Thermal, mechanical, and morphological behavior. J Appl Polym Sci 119 (1):539-547

© COPYRIGHT UPM

Nourbakhsh A, Ashori A (2009) Influence of Nanoclay and Coupling Agent on the Physical and Mechanical Properties of Polypropylene/Bagasse Nanocomposite. Polym (Guildf) 112:1386–1390
Ogasawara T, Ishida Y, Ishikawa T, Yokota R (2004) Characterization of multi-walled carbon nanotube/phenylethynyl terminated polyimide composites. Compos Part A Appl Sci Manuf 35 (1):67-74
Ojha S, Raghavendra G, Acharya SK (2014) A comparative investigation of bio waste filler (wood apple-coconut) reinforced polymer composites. Polym Compos 35:180–185
Oksman K, Mathew A, Bondeson D, Kvien I (2006) Manufacturing process of cellulose whiskers/polylactic acid nanocomposites. Compos Sci Technol 66 (15):2776-2784
Oliwa R, Heneczkowski M, Oleksy M, Galina H (2016) Epoxy composites of reduced flammability. Compos Part B Eng 95:1-8
Omar MF, Akil HM, Ahmad ZA, Mazuki AAM, Yokoyama T (2010) Dynamic properties of pultruded natural fibre reinforced composites using Split Hopkinson Pressure Bar technique. Mater Des 31:4209–4218
Ooi ZX, Ismail H, Abu Bakar A (2014) Study on the ageing characteristics of oil palm ash reinforced natural rubber composites by introducing a liquid epoxidized natural rubber coating technique. Polym Test 37:156–162
Padal KTB, Ramji K, Prasad VVS (2014) Isolation and characterization of jute nano fibres. International J Mech Eng Robotic Res (IJMERR) 3:422–428
Panneerdhass R, Gnanavelbabu A, Rajkumar K (2014) Mechanical Properties of Luffa Fiber and Ground nut Reinforced Epoxy Polymer Hybrid Composites. Procedia Eng 97:2042 – 2051
Paul DR., Robeson LM (2008) Polymer nanotechnology: Nanocomposites. Polym (Guildf) 49:3187–3204
Paul KT, Satpathy SK, Manna I, Chakraborty KK, Nando GB (2007) Preparation and characterization of nano structured materials from fly ash: A waste from thermal power stations, by high energy ball milling. Nanoscale Res Lett 2:397–404
Pavlidou S, Papaspyrides CD (2008) A review on polymer-layered silicate nanocomposites. Prog Polym Sci 33:1119–1198
Payae Y, Lopattananon N (2009) Adhesion of pineapple-leaf fiber to epoxy matrix: The role of surface treatments. Songklanakarin J Sci Technol 31:189–194
Peng W, Riedl B (1995) Thermosetting resins. J Chem Educ 72 (7):587
Piekarska K, Sowinski P, Piorkowska E, Haque MMU, Pracella M (2016) Structure and properties of hybrid PLA nanocomposites with inorganic nanofillers and cellulose fibers. Compos Part A Appl Sci Manuf 82:34–41
Prabu VA, Uthayakumar M, Manikandan V, Rajini N, Jeyaraj P (2014) Influence of redmud on the mechanical, damping and chemical resistance properties of banana/polyester hybrid composites. Mater Des 64:270–279
Prasad AVR, Rao KB, Rao KM, Ramanaiah K, Gudapati SPK (2015) Influence of Nanoclay on the Mechanical Performance of Wild Cane Grass Fiber-Reinforced Polyester Nanocomposites Influence of Nanoclay on the Mechanical Performance of Wild Cane Grass Fiber-Reinforced Polyester. Int J Polym Anal Charact 20:541–556
Pickering K (2008) Properties and performance of natural-fibre composites. (Edi.) Pickering KL, CRC Press-WoodHead Publishing Limited, Cambridge-England
Pilloni M, Nicolas J, Marsaud V, Bouchemal K, Frongia F, Scano A, Ennas G, Dubernet C (2010) PEGylation and preliminary biocompatibility evaluation of magnetite-silica nanocomposites obtained by high energy ball milling. Int J Pharm

© COPYRIGHT UPM

401:103–112
Poletto M, Ornaghi Júnior HL, Zattera AJ (2014) Native cellulose: Structure, characterization and thermal properties. Mater (Basel) 7:6105–6119
Poulin P, Vigolo B, Launois P (2002) Films and fibers of oriented single wall nanotubes. Carbon 40 (10):1741-1749
Presting H, König U (2003) Future nanotechnology developments for automotive applications. Mater Sci Eng C 23 (6):737-741
Qian D, Dickey EC, Andrews R, Rantell T (2000) Load transfer and deformation mechanisms in carbon nanotube-polystyrene composites. Appl phys lett 76 (20):2868-2870
Qu H, Wu W, Zheng Y, Xie J, Xu J (2011a) Synergistic effects of inorganic tin compounds and Sb_2O_3 on thermal properties and flame retardancy of flexible poly (vinyl chloride). Fire Safety J 46 (7):462-467
Quan D, Ivankovic A (2015) Effect of core e shell rubber (CSR) nano-particles on mechanical properties and fracture toughness of an epoxy polymer. Polym 66: 16-28
Rajini N, Jappes JTW, Jeyaraj P, Rajakarunakaran S, Bennet C(2013) Effect of montmorillonite nanoclay on temperature dependence mechanical properties of naturally woven coconut sheath/polyester composite. J Reinf Plast Compos 32:811–822
Rakotomalala M, Wagner S, Döring M (2010) Recent developments in halogen free flame retardants for epoxy resins for electrical and electronic applications. Mater 3 (8):4300-4327
Rallini M, Natali M, Kenny JM, Torre L (2013) Effect of boron carbide nanoparticles on the fire reaction and fire resistance of carbon fiber/epoxy composites. Polym 54 (19):5154-5165
Ramesh M (2016) Kenaf (Hibiscus cannabinus L.) fibre based bio-materials: A review on processing and properties. Prog Mater Sci 78:1-92
Rana S, Alagirusamy R, Joshi M (2011) Effect of carbon nanofiber dispersion on the tensile properties of epoxy nanocomposites. J. Compos. Mater. 45:2247–2256
Ran Z, Yan Y, Li J, Qi Z, Yang L (2014) Determination of thermal expansion coefficients for unidirectional fiber-reinforced composites. Chin J Aeronaut 27:1180–1187
Rashdi AAA, Sapuan MS, Ahmad MMHM, Abdan K (2009) Review of kenaf fiber reinforced polymer composites. Polimery/Polym 54:777–780
Rattanasom N, Saowapark T, Deeprasertkul C (2007) Reinforcement of natural rubber with silica/carbon black hybrid filler. Polym Test 26 (3):369-377
Ray SS, Okamoto M (2003) Polymer/layered silicate nanocomposites: a review from preparation to processing. Prog Polym Sci 28 (11):1539-1641
Rayung M, Ibrahim NA, Zainuddin N, Saad WZ, Razak NIA, Chieng BW (2014) The effect of fiber bleaching treatment on the properties of poly (lactic acid)/oil palm empty fruit bunch fiber composites. Int J Mol Sci 15 (8):14728-14742
Razak NWA, Kalam A (2012) Effect of OPEFB Size on the Mechanical Properties and Water Absorption Behaviour of OPEFB/PPnanoclay/PP Hybrid Composites. Procedia Eng 41:1593–1599
Reddy GV, Rani TS, Rao KC, Naidu SV (2008) Flexural, compressive, and interlaminar shear strength properties of kapok/glass composites. J Reinf Plast Compos
Ren Y, Wang Y, Wang L, Liu T (2015) Evaluation of intumescent fire retardants and synergistic agents for use in wood flour/recycled polypropylene composites. Constr Build Mater 76:273-278

© COPYRIGHT UPM

Reti C, Casetta M, Duquesne S, Delobel R, Soulestin J, Bourbigot S (2009) Intumescent biobased-polylactide films to flame retard nonwovens. J Eng Fibers Fabr 4 (2):33-39

Ribeiro M, Sousa S, Nóvoa P (2015) An Investigation on Fire and Flexural Mechanical Behaviors of Nano and Micro Polyester Composites Filled with SiO_2 and Al_2O_3 Particles. Mater Today: Proc 2 (1):8-19

Ridzuan MJM, Majid MSA, Afendi M, Mazlee MN, Gibson AG (2016) Thermal behaviour and dynamic mechanical analysis of Pennisetum purpureum/glass reinforced epoxy hybrid composites. Compos Struct 152:850–859

Ridzuan MJM, Majid MSA, Afendi M, Azduwin K, Amin NAM, Zahri JM, Gibson AG (2016) Moisture absorption and mechanical degradation of hybrid Pennisetum purpureum/glass–epoxy composites. Compos Struct 141:110–116

Roco MC, Mirkin CA, Hersam MC (2011) Nanotechnology research directions for societal needs in 2020: summary of international study. J Nanopart Res 13 (3):897-919

Romanzini D, Lavoratti A, Ornaghi Jr HL, Amico SC, Zattera AJ (2013) Influence of fiber content on the mechanical and dynamic mechanical properties of glass/ramie polymer composites. Mater Des 47:9–15

Roohani M, Habibi Y, Belgacem NM, Ebrahim G, Karimi AN, Dufresne A (2008) Cellulose whiskers reinforced polyvinyl alcohol copolymers nanocomposites. Eur Polym J 44:2489–2498

Rosa SML, Rehman N, De Miranda MIG, Nachtigall SMB, Bica CID (2012) Chlorine-free extraction of cellulose from rice husk and whisker isolation. Carbohyd Polym 87:1131–1138

Rosamah E, Hossain MS, Abdul Khalil HPS, Nadirah WOW, Dungani R, Amiranajwa N, Suraya NLM, Fizree HM, Omar AKM (2016) Properties enhancement using oil palm shell nanoparticles of fibers reinforced polyester hybrid composites. Adv Compos Mater 3046:1–14

Roy S, Vengadassalam K, Hussain F, Lu H (2004) Compressive Strength Enhancement of Pultruded Thermoplastic Composites Using Nanoclay Reinforcement. In: 45th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics & Materials Conference 1778 Long Beach, US

Rowell RM (2008) Natural fibres: types and properties. In: Properties and performance of natural-fibre composites (Ed.) Pickering K, Woodhead Publishing, CRC press Cambridge-England 3-66

Rozenberg BA, Tenne R (2008) Polymer-assisted fabrication of nanoparticles and nanocomposites. Prog Polym Sci 33(1): 40-112

Ruan S, Gao P, Yang XG, Yu T (2003) Toughening high performance ultrahigh molecular weight polyethylene using multiwalled carbon nanotubes. Polym 44 (19):5643-5654

Ruan S, Gao P, Yu T (2006) Ultra-strong gel-spun UHMWPE fibers reinforced using multiwalled carbon nanotubes. Polym 47 (5):1604-1611

Rzayev ZMO, Burcu S, Soylemez EA (2011) Functional Copolymer/Organo-MMT Nanoarchitectures. VIII. Synthesis, morphology and thermal behavior of poly (maleic anhydride-alt-acrylamide)-organo-MMT clays nanohybrids. Eng 3(1): 73-82

Saba N, Paridah MT, Jawaid M (2014) A Review on Potentiality of Nano Filler/Natural Fiber Filled Polymer Hybrid Composites. Polym (Basel) 6:2247–2273

Saba N, Jawaid M, Alothman OY, Paridah MT, Hassan A (2015a) Recent advances in epoxy resin, natural fiber-reinforced epoxy composites and their applications. J Reinf Plast Compos:0731684415618459

© COPYRIGHT UPM

Saba N, Jawaid M, Hakeem KR Paridah MT, Khalina A, Alothman OY(2015b) Potential of bioenergy production from industrial kenaf (Hibiscus cannabinus L.) based on Malaysian perspective. Renew Sustain Energ Rev 42:446–459

Saba N, Paridah MT, Jawaid M (2015c) Mechanical Properties of Kenaf Fibre Reinforced Polymer Composite: A Review. Constr Build Mater 76:87–96

Saba N, Paridah MT, Abdan K, Ibrahim NA (2015d) Preparation and characterization of fire retardant nano-filler from oil palm empty fruit bunch fibers. Bioresour 10 (3):4530-4543

Saba N, Jawaid M, Paridah MT, Alothman OY (2016a) A review on flammability of epoxy polymer, cellulosic and non-cellulosic fiber reinforced epoxy composites. Polym Adv Technol 27(5):577–590

Saba N, Jawaid M, Alothman OY, Paridah MT (2016b) A review on dynamic mechanical properties of natural fibre reinforced polymer composites. Constr Build Mater 106:149–159

Saba N, Paridah MT, Abdan K, Ibrahim NA (2016c) Fabrication of Epoxy Nanocomposites from Oil Palm Nano Filler : Mechanical and Morphological Properties. Bioresour 11:7721–7736

Saba N, Paridah MT, Abdan K, Ibrahim NA (2016d) Effect of oil palm nano filler on mechanical and morphological properties of kenaf reinforced epoxy composites. Constr Build Mater 123:15-26

Saba N, Paridah MT, Abdan K, Ibrahim N (2016e) Dynamic mechanical properties of oil palm nano filler/kenaf/epoxy hybrid nanocomposites. Constr Build Mater 124:133-138

Saba N, Jawaid M, Asim M (2016f) Recent Advances in Nanoclay/Natural Fibers Hybrid Composites. In: Nanoclay Reinforced Polymer Composites. (Edi) Jawaid M, Qaiss AK, Bouhfid R, Springer-Singapore 1-28

Saheb DN, Jog J (1999) Natural fiber polymer composites: a review. Adv Polym Tech 18 (4):351-363

Sahoo SK, Mohanty S, Nayak SK (2015) Study of thermal stability and thermo-mechanical behavior of functionalized soybean oil modified toughened epoxy/organo clay nanocomposite. Prog Org Coat 88:263–271

Samariha A, Hemmasi AH, Ghasemi I, Bazyar B, Nemati M (2015) Effect of nanoclay contents on properties, of bagasse flour/reprocessed high density polyethylene/nanoclay composites. Maderas Cienc y Tecnol 17:637–646

Sanjay MR, Yogesha B (2016) Study on Water Absorption Behaviour of Jute and Kenaf Fabric Reinforced Epoxy Composites : Hybridization Effect of E-Glass Fabric. Int J Compos Mater 6:55–62

Sandler J, Pegel S, Cadek M, Gojny F, Van Es M, Lohmar J, Blau W, Schulte K, Windle A, Shaffer M (2004) A comparative study of melt spun polyamide-12 fibres reinforced with carbon nanotubes and nanofibres. Polym 45 (6):2001-2015

Sandler J, Werner P, Shaffer MS, Demchuk V, Altstädt V, Windle AH (2002) Carbon-nanofibre-reinforced poly (ether ether ketone) composites. Compos Part A Appl Sci Manuf 33 (8):1033-1039

Sapiai N, Jumahat A, Mahmud J (2015) Flexural and Tensile Properties Of K enaf / Glass Fibres Hybrid Composites. J Teknol 76:115–120

Sapuan MS, Mohamed AR, Siregar JP, Ishak MR (2011) Pineapple Leaf Fibers and PALF-Reinforced Polymer Composites. In: Cellulose fibers: bio- and nano-polymer composites (Edi.) Kalia S, Kaith BS, Kaur I, Springer Berlin Heidelberg 325–343

Sapuan MS, Leenie A, Harimi M, Beng YK (2006) Mechanical properties of woven banana fibre reinforced epoxy composites. Mater Des 27:689–693

© COPYRIGHT UPM

Sathishkumar T, Navaneethakrishnan P, Shankar S, Rajasekar R (2013) Characterization of new cellulose sansevieria ehrenbergii fibers for polymer composites. Compos Interface 20 (8):575-593
Sathishkumar T, Naveen J, Satheeshkumar S (2014) Hybrid fiber reinforced polymer composites–a review. J Reinf Plast Compos 33 (5):454-471
Satyanarayana K, Sukumaran K, Kulkarni A, Pillai S, Rohatgi P (1986) Fabrication and properties of natural fibre-reinforced polyester composites. Compos 17 (4):329-333
Schadler L, Brinson L, Sawyer W (2007) Polymer nanocomposites: a small part of the story. Jom 59 (3):53-60
Schaefer DW, Justice RS (2007). How nano are nanocomposites. Macromol 40(24): 8501-8517
Shalwan A, Yousif B (2014a) Influence of date palm fibre and graphite filler on mechanical and wear characteristics of epoxy composites. Mater Des 59:264-273
Shalwan A, Yousif B (2014b) Investigation on interfacial adhesion of date palm/epoxy using fragmentation technique. Mater Des 53:928-937
Schmidt H (1994) Multifunctional inorganic-organic composite sol-gel coatings for glass surfaces. J Non Cryst Solids 178:302-312
Sedaghat S (2013) Synthesis of clay-CNTs nanocomposite. J Nanostruct Chem 3:3–6.
Sen AK, Kumar S (2010) Coir-fiber-based fire retardant nano filler for epoxy composites. J Therm Anal Calorim 101:265–271
Shenvi SS, Isloor AM, Ahmad AL, Garudachari B, Ismail AF (2016) Influence of palm oil fuel ash, an agro-industry waste on the ultrafiltration performance of cellulose acetate butyrate membrane. Desalin Water Treat 3994:1–13
Shi G, Zhang MQ, Rong MZ, Wetzel B, Friedrich K (2004) Sliding wear behavior of epoxy containing nano-Al2O3 particles with different pretreatments. Wear 256:1072–1081
Shinoj S, Visvanathan R, Panigrahi S, Kochubabu M (2011) Oil palm fiber (OPF) and its composites: A review. Ind Crops Prod 33:7–22
Shinoj S, Visvanathan R, Panigrahi S, Varadharaju N (2011) Dynamic mechanical properties of oil palm fibre (OPF)-linear low density polyethylene (LLDPE) biocomposites and study of fibre matrix interactions. Biosyst Eng 109:99 –107
Shokrieh MM, Kefayati AR, Chitsazzadeh M (2012) Fabrication and mechanical properties of clay/epoxy nanocomposite and its polymer concrete. Mater Des 40:443–452
Shukla DK, Kasisomayajula SV, Parameswaran V (2008) Epoxy composites using functionalized alumina platelets as reinforcements. Compos Sci Technol 68:3055–3063
Siddika S, Mansura F, Hasan M (2013) Physico-Mechanical Properties of Jute-Coir Fiber Reinforced Hybrid Polypropylene Composites. Int J Chem Mater Sci Eng 7:41–45
Singh AP, Pal KR (2007) Novel hybrid of clay, cellulose, and thermoplastics. I. Preparation and characterization of composites of ethylene–propylene copolymer. J Appl Polym Sci 104:2672–2682
Singh VK, Gope PC, Sakshi C, Singh BD (2012) Mechanical behavior of banana fiber based hybrid bio composites. J Mater Environ Sci 3:185–194
Singla P (2012) Clay Modification by the Use of Organic Cations. Green Sustain Chem 02:21–25
Siyamak S, Ibrahim NA, Abdolmohammadi S, Yunus WM, Rahman MZ (2012) Enhancement of mechanical and thermal properties of oil palm empty fruit

© COPYRIGHT UPM

bunch fiber poly(butylene adipate-co-terephtalate) biocomposites by matrix esterification using succinic anhydride. Mol 17:1969–1991

Souza VS, Bianchi O, Lima MFS, Mauler RS (2014) Morphological, thermomechanical and thermal behavior of epoxy/MMT nanocomposites. J Non Cryst Solids 400:58–66

Sponton M, Mercado L, Ronda J, Galia M, Cadiz V (2008) Preparation, thermal properties and flame retardancy of phosphorus-and silicon-containing epoxy resins. Polym Degrad Stab 93 (11):2025-2031

Sreekala M, Kumaran M, Geethakumariamma M, Thomas S (2004) Environmental effects in oil palm fiber reinforced phenol formaldehyde composites: Studies on thermal, biological, moisture and high energy radiation effects. Adv Compos Mater 13 (3-4):171-197

Srisuwana, Prasoetsophaa N, Suppakarn N, Chumsamrong P (2014) The Effects of Alkalized and Silanized Woven Sisal Fibers on Mechanical Properties of Natural Rubber Modified Epoxy Resin. Energ Procedia 56:19 – 25

Srivastava R, Srivastava D (2015) Preparation and thermo-mechanical characterization of novel epoxy resins using renewable resource materials. J Polym Environ 23 (3):283-293

Sroka J, Rybak A, Sekula R, Sitarz M (2016) An Investigation into the Influence of Filler Silanization Conditions on Mechanical and Thermal Parameters of Epoxy Resin-Fly Ash Composites. J Polym Environ 1-11

Satyanarayana KG, Arizaga GGC, Wypych F (2009) Biodegradable composites based on lignocellulosic fibers—An overview. Prog Polym Sci 34:982–1021

Sun D, Yao Y (2011) Synthesis of three novel phosphorus-containing flame retardants and their application in epoxy resins. Polym Degrad Stab96: 1720-1724

Sun Y, Xu K, Zhang Y, Zhang J, Chen R, Yuan Z, Xie H, Cheng R (2016) Organic montmorillonite reinforced epoxy mortar binders. Constr Build Mater 107:378-384

Surata IW, Agung IG, Suriadi K, Arnis K (2014) Mechanical Properties of Rice Husks Fiber Reinforced Polyester Composites. Mater Mech Manuf 2:165–168

Suresha B, Devarajaiah RM, Pasang T, Ranganathaiah C (2013) Investigation of organo-modified montmorillonite loading effect on the abrasion resistance of hybrid composites. Mater Des 47:750–758

Suresh S, Saravanan P, Jayamoorthy K, Kumar SA, Karthikeyan S (2016) Development of silane grafted ZnO core shell nanoparticles loaded diglycidyl epoxy nanocomposites film for antimicrobial applications. Mater Sci Eng C 64:286-292

Szustakiewicz K, Kiersnowski A, Gazińska M, Bujnowicz K, Pigłowski J (2011) Flammability, structure and mechanical properties of PP/OMMT nanocomposites. Polym Degrad Stab96 (3):291-294

Tabari HZ, Nourbakhsh A, Ashori A (2011) Effects of nanoclay and coupling agent on the physico-mechanical, morphological, and thermal properties of wood flour/polypropylene composites. Polym Eng Sci 51:272–277

Taib RM, Hassan HM, Ishak ZAM (2014) Mechanical and Morphological Properties of Polylactic Acid/Kenaf Bast Fiber Composites Toughened with an Impact Modifier. Polym Plast Technol Eng 53:199–206

Tajvidi M, Falk RH, Hermanson JC (2006) Effect of natural fibers on thermal and mechanical properties of natural fiber polypropylene composites studied by dynamic mechanical analysis. J Appl Polym Sci 101:4341–4349

© COPYRIGHT UPM

Tammaro L, Vittoria V, Bugatti V (2014) Dispersion of modified layered double hydroxides in Poly(ethylene terephthalate) by High Energy Ball Milling for food packaging applications. Eur Polym J 52:172–180
Taşdemır M, Koçak D, Usta I, Akalin M, Merdan N (2008) Properties of recycled polycarbonate/waste silk and cotton fiber polymer composites. Int J Polym Mater 57 (8):797-805
Thiruchitrambalam M, Alavudeen A, Athijayamani A, Venkateshwaran N, Perumal AE (2009) Improving mechanical properties of banana/kenaf polyester hybrid composites using sodium laulryl sulfate treatment. Mater Phys Mech 8 (2):165-173
Thiruchitrambalam M, Alavudeen A, Venkateshwaran N (2012) Review on kenaf fiber composites. Rev Adv Mater Sci 32:106–111
Toldy A, Szolnoki B, Marosi G (2011) Flame retardancy of fibre-reinforced epoxy resin composites for aerospace applications. Polym Degrad Stab96 (3):371-376
Tue NM, Goto A, Takahashi S, Itai T, Asante KA, Kunisue T, Tanabe S (2016) Release of chlorinated, brominated and mixed halogenated dioxin-related compounds to soils from open burning of e-waste in Agbogbloshie (Accra, Ghana). J Hazard Mater 302:151-157
Thwe MM, Liao K (2003) Durability of bamboo-glass fiber reinforced polymer matrix hybrid composites. Compos Sci Technol 63 (3):375-387
Uddin F (2013) Studies in Finishing Effects of Clay Mineral in Polymers and Synthetic Fibers. Adv Mater Sci Eng 2013:1–13
Ursache O, Rodrigues S (2014) Combined effects of dam removal and past sediment mining on a relatively large lowland sandy gravel bed river (Vienne River, France). EGU Gen.16:3870
Usuki A, Kawasumi M, Kojima Y, Okada A, Kurauchi T, Kamigaito O (1993) Swelling behavior of montmorillonite cation exchanged for ω-amino acids by-caprolactam. J Mater Res 8 (05):1174-1178
Vahabi H, Lin Q, Vagner C, Cochez M, Ferriol M, Laheurte P (2016) Investigation of thermal stability and flammability of poly (methyl methacrylate) composites by combination of APP with ZrO_2, sepiolite or MMT. Polym Degrad Stab124:60-67
Velmurugan R, Manikandan V (2005) Mechanical properties of glass/palmyra fiber waste sandwich composites. Indian J Eng Mater Sci 12 (6):563-570
Villar J, Revilla E, Gómez N, Carbajo J, Simón J (2009) Improving the use of kenaf for kraft pulping by using mixtures of bast and core fibers. Ind Crops Prod 29 (2):301-307
Wang J, Su X, Mao Z (2014) The flame retardancy and thermal property of poly (ethylene terephthalate)/cyclotriphosphazene modified by montmorillonite system. Polym Degrad Stab109:154-161
Wang L, Shui X, Zheng X, You J, Li Y (2014) Investigations on the morphologies and properties of epoxy/acrylic rubber/nanoclay nanocomposites for adhesive films. Compos Sci Technol 93:46–53
Wang X, Song L, Pornwannchai W, Hu Y, Kandola B (2013) The effect of graphene presence in flame retarded epoxy resin matrix on the mechanical and flammability properties of glass fiber-reinforced composites. Compos Part A Appl Sci Manuf 53:88-96
Wu SH, Wang FY, Ma CCM, Chang WC, Kuo CT, Kuan HC, Chen WJ (2001) Mechanical, thermal and morphological properties of glass fiber and carbon fiber reinforced polyamide-6 and polyamide-6/clay nanocomposites. Mater Lett 49 (6):327-333

© COPYRIGHT UPM

Wypych F, Satyanarayana KG (2005) Functionalization of single layers and nanofibers: a new strategy to produce polymer nanocomposites with optimized properties. J Colloid Interface Sci 285 (2):532-543

Xie W, Xie R, Pan WP, Hunter D, Koene B, Tan LS, Vaia R (2002) Thermal stability of quaternary phosphonium modified montmorillonites. Chem Mater 14 (11):4837-4845

Yahaya R, Sapuan MS, Jawaid M, Leman Z, Zainudin ES (2016) Effect of fibre orientations on the mechanical properties of kenaf – aramid hybrid composites for spall-liner application. Def Technol 12:52–58

Yang HK, Lee JH, Hong WT, Jang HI, Moon BK, Jeong JH, Je JY (2015) Preparation and photoluminescence properties of nano-sized $SrZnO_2$:Sm_3 + phosphor powders obtained by high-energy ball milling. Ceram Int 41:991–994

Yang SY, Lin WN, Huang YL, Tien HW, Wang JY, Ma CCM, Li SM, Wang YS (2011) Synergetic effects of graphene platelets and carbon nanotubes on the mechanical and thermal properties of epoxy composites. Carbon 49 (3):793-803

Yang X, Song G, Li P, Gu Z, Wang L, Sun L, Gao L (2010) The Structure, Properties and Application of NR/BR/OMMT Nanocomposites. High Perform Polym 22:649–665

Yin J, Li G, He W, Huang J, Xu M (2011) Hydrothermal decomposition of brominated epoxy resin in waste printed circuit boards. J Anal Appl Pyrol 92:131–136

Ying Z, Xianggao L, Bin C, Fei C, Jing F (2015) Highly exfoliated epoxy/clay nanocomposites : Mechanism of exfoliation and thermal/mechanical properties. Compos Struct 132:44–49

Yoon OJ, Jung CY, Sohn IY, Kim HJ, Hong B, Jhon MS, Lee NE (2011) Nanocomposite nanofibers of poly(d, l-lactic-co-glycolic acid) and graphene oxide nanosheets. Compos Part A Appl Sci Manuf 42:1978–1984

Yucel O, Unsal E, Harvey J, Graham M, Jones DH, Cakmak M (2014) Enhanced gas barrier and mechanical properties in organoclay reinforced multi-layer poly (amide-imide) nanocomposite film. Polym (Guildf) 55:4091–4101

Yunos NSHM, Baharuddin AS, Yunos KFM, Hafid HS, Busu Z, Mokhtar MN, Sulaiman A, Som AM (2015) The Physicochemical Characteristics of Residual Oil and Fibers from Oil Palm Empty Fruit Bunches. Bioresour 10:14–29

Zainudin ES, Yan LH, Haniffah WH, Jawaid M, Alothman OY(2014) Effect of coir fiber loading on mechanical and morphological properties of oil palm fibers reinforced polypropylene composites. Polym Compos 35:1418–1425

Zare Y (2016a) Modeling the yield strength of polymer nanocomposites based upon nanoparticle agglomeration and polymer–filler interphase. J Colloid Interface Sci 467: 165-169

Zare Y (2016b) Study of nanoparticles aggregation/agglomeration in polymer particulate nanocomposites by mechanical properties. Compos Part A Appl Sci Manuf 84: 158-164

Zhang G, Schlarb AK, Tria S, Elkedim O (2008) Tensile and tribological behaviors of PEEK/nano-SiO2 composites compounded using a ball milling technique. Compos Sci Technol 68:3073–3080

Zhang M, Buekens A, Li X (2016) Brominated flame retardants and the formation of dioxins and furans in fires and combustion. J Hazard Mater 304:26-39

Zhang RL, Gao B, Du WT, Zhang J, Cui HZ, Liu L, Ma QH, Wang CG, Li FH (2016a) Enhanced mechanical properties of multiscale carbon fiber/epoxy composites by fiber surface treatment with graphene oxide/polyhedral oligomeric silsesquioxane. Compos Part A Appl Sci Manuf 84:455–463

Zhang S, Hull TR, Horrocks AR, Smart G, Kandola BK, Ebdon J, Joseph P, Hunt B

© COPYRIGHT UPM

(2007a) Thermal degradation analysis and XRD characterisation of fibre-forming synthetic polypropylene containing nanoclay. Polym Degrad Stab92 (4):727-732

Zhang X, Huang Y, Wang T, Liu L (2007b) Influence of fibre surface oxidation–reduction followed by silsesquioxane coating treatment on interfacial mechanical properties of carbon fibre/polyarylacetylene composites. Compos Part A Appl Sci Manuf 38 (3):936-944

Zhang Y, Tang A, Yang H, Ouyang J (2015) Applications and interfaces of halloysite nanocomposites. Appl Clay Sci 119: 8-17

Zhong Y, Poloso T, Hetzer M, De Kee D (2007) Enhancement of wood/polyethylene composites via compatibilization and incorporation of organoclay particles. Polym Eng Sci 47 (6):797-803

Zotti A, Borriello A, Ricciardi M, Antonucci V, Giordano M, Zarrelli M (2015) Effects of sepiolite clay on degradation and fire behaviour of a bisphenol A-based epoxy. Compos Part B Eng 73:139-148

Zuliahani A, Rozman HD, Tay GS (2011) Preparation of Epoxy-Kenaf Nanocomposite Based on Montmorillonite. Adv Mater Res 264-265:469–474

© COPYRIGHT UPM

LIST OF PUBLICATIONS

Journal Articles

Saba N, Paridah MT, Jawaid M: A Review on Potentiality of Nano Filler/Natural Fiber Filled Polymer Hybrid Composites. Polymers 08/2014; 6(8). [Q2, Impact factor: 2.944]

Saba N, Paridah MT, Abdan K, Ibrahim NA: Preparation and Characterization of Fire Retardant Nano Filler from Oil Palm Empty Fruit Bunch Fibers. BioResources 05/2015; 10(3). [Q1, Impact factor: 1.334]

Saba N, Paridah MT, Abdan K, Ibrahim NA: Fabrication of Epoxy Nanocomposites from Oil Palm Nano Filler: Mechanical and Morphological Properties. BioResources 07/2016; 11(3). [Q1, Impact factor: 1.334]

Saba N, Paridah MT, Abdan K, Ibrahim NA: Effect of oil palm nano filler on Mechanical and Morphological Properties of Kenaf Reinforced epoxy Composites. Construction and Building Materials 06/2016; 123. [Q1, Impact factor: 2.421]

Saba N, Paridah MT, Abdan K, Ibrahim NA: Dynamic Mechanical Properties of Oil Palm Nano Filler/Kenaf/Epoxy Hybrid Nanocomposites. Construction and Building Materials 07/2016; 124. [Q1, Impact factor: 2.421]

Saba N, Paridah MT, Abdan K, Ibrahim NA: Physical, Structural and Thermomechanical Properties of Oil Palm Nano Filler/Kenaf/Epoxy Hybrid Nanocomposites. Materials Chemistry and Physics 09/2016; 184. [Q2, Impact factor: 2.101]

Conference paper

Saba N, Paridah MT, Abdan K, Ibrahim NA: Thermal Properties of Oil Palm Nano Filler/Kenaf Reinforced Epoxy Hybrid Nanocomposites. International Congress on Fundamental and Applied Sciences (ICFAS 2016). 15th to 17th August 2016. Kuala Lumpur, Malaysia.

© COPYRIGHT UPM

UNIVERSITI PUTRA MALAYSIA

STATUS CONFIRMATION FOR THESIS / PROJECT REPORT AND COPYRIGHT

ACADEMIC SESSION : SECOND SEMESTER 2016/2017

TITLE OF THESIS / PROJECT REPORT :

DEVELOPMENT AND CHARACTERIZATION OF FLAME RETARDANT OIL PALM FILLER/KENAF REINFORCED HYBRID COMPOSITES

NAME OF STUDENT: NAHEED SABA

I acknowledge that the copyright and other intellectual property in the thesis/project report belonged to Universiti Putra Malaysia and I agree to allow this thesis/project report to be placed at the library under the following terms:

1. This thesis/project report is the property of Universiti Putra Malaysia.
2. The library of Universiti Putra Malaysia has the right to make copies for educational purposes only.
3. The library of Universiti Putra Malaysia is allowed to make copies of this thesis for academic exchange.

I declare that this thesis is classified as :

*Please tick (√)

☐	**CONFIDENTIAL**	(Contain confidential information under Official Secret Act 1972).
☐	**RESTRICTED**	(Contains restricted information as specified by the organization/institution where research was done).
☐	**OPEN ACCESS**	I agree that my thesis/project report to be published as hard copy or online open access.

This thesis is submitted for :

☐	**PATENT**	Embargo from_____________ until _____________ (date) (date)

Approved by:

_______________________ (Signature of Student)
New IC No/ Passport No.:

Date :

_______________________ (Signature of Chairman of Supervisory Committee)
Name:

Date :

[Note : If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization/institution with period and reasons for confidentially or restricted.]

© COPYRIGHT UPM