

CONTENT OF THE THESIS

<i>Content</i>	<i>Page No.</i>
Abstract.....	i
Declaration.....	iii
Certificate of Supervisor.....	iv
Certificate of Examiners.....	v
Preface.....	vi
Acknowledgement.....	vii
Contents of the Thesis.....	ix
List of Abbreviations and Symbols.....	xv
List of Tables.....	xviii
List of Figures	xix
List of Schemes.....	xxiv

Chapter 1

General Introduction

Highlights	1-1
1.1. Introduction	1-2
1.2. Background.....	1-4
1.3. Materials and methods.....	1-5
1.3.1. Materials	1-5
1.3.1.1. Polyurethane.....	1-6
1.3.1.2. Nanomaterials.....	1-12
1.3.2. Methods	1-15
1.3.2.1. Preparative method of PU	1-15
1.3.2.2. Preparative methods of graphene	1-16
1.3.2.3. Preparative methods of graphene based nanohybrid.....	1-17
1.3.2.4. Formation of graphene based polymer nanocomposites	1-20
1.4. Characterization and testing	1-22
1.4.1. Spectroscopic techniques.....	1-22
1.4.2. Scattering techniques.....	1-23
1.4.3. Microscopy techniques	1-24
1.4.4. Other techniques	1-25
1.4.5. Testing methods.....	1-25

1.5. Property.....	1-27
1.5.1. Mechanical.....	1-27
1.5.2. Thermal.....	1-28
1.5.3. Electrical.....	1-29
1.5.4. Gas barrier.....	1-29
1.5.5. Catalytic.....	1-30
1.5.6. Flame retardancy.....	1-30
1.5.7. Antimicrobial.....	1-31
1.5.8. Shape memory properties.....	1-31
1.6. Applications.....	1-32
1.6.1. Surface coating.....	1-33
1.6.2. Shape memory materials.....	1-33
1.6.3. Sensor.....	1-34
1.6.4. Self-healing material.....	1-34
1.6.5. Self-cleaning materials.....	1-35
1.6.6. Biomaterials.....	1-35
1.7. Scopes and objectives of the present investigation.....	1-36
1.8. Plans of research.....	1-37
References.....	1-38

Chapter 2

Castor oil-based hyperbranched polyurethanes

Highlights.....	2-1
2. 1. Introduction.....	2-2
2. 2. Experimental.....	2-3
2.2.1. Materials.....	2-3
2.2.2. Characterization.....	2-5
2.2.3. Methods.....	2-6
2.2.3.1. Preparation of monoglyceride of castor oil.....	2-6
2.2.3.2. Synthesis of HPU.....	2-7
2.2.3.3. Sample preparation for performance study.....	2-8
2. 3. Results and discussion.....	2-8
2.3.1. Synthesis of HPU.....	2-8
2.3.2. FTIR analysis.....	2-9
2.3.3. NMR study.....	2-10

2.3.4. UV-visible study.....	2-12
2.3.5. XRD analysis.....	2-12
2.3.6. Morphological study.....	2-13
2.3.7. Physical properties.....	2-13
2.3.8. Thermal properties.....	2-13
2.3.9. Mechanical properties.....	2-16
2.3.10. Electrical property	2-16
2.3.11. Chemical resistance	2-19
2. 4. Conclusion.....	2-19
References	2-20

Chapter 3

Graphene based HPU nanocomposites as shape memory materials

Highlights	3-1
3A. Reduction of graphene oxide by phytoextract	3-2
3A.1. Introduction.....	3-2
3A.2. Experimental.....	3-3
3A.2.1. Materials	3-3
3A.2.2. Characterization.....	3-4
3A.2.3. Preparation of GO.....	3-5
3A.2.4. Reduction of GO by aqueous phytoextracts	3-5
3A.2.5. Reduction of GO by aqueous extract of <i>C. esculenta</i> in presence of different metal ions.....	3-6
3A.3. Results and discussion	3-6
3A.3.1. Reduction of GO by phytoextracts	3-6
3A.3.2. UV-visible absorption study	3-7
3A.3.3. FTIR study.....	3-7
3A.3.4. XRD study	3-8
3A.3.5. Raman study	3-9
3A.3.6. HRTEM analysis	3-10
3A.3.7. Thermal study	3-11
3A.3.8. Elemental analysis and electrical study	3-12
3A.3.9. Proposed mechanism of reduction of GO by phytoextract.....	3-14
3A.4. Conclusion	3-18

3B. Preparation of HPU/graphene oxide nanocomposite	3-19
3B.1. Introduction	3-19
3B.2. Experimental	3-20
3B.2.1. Materials	3-20
3B.2.2. Characterization	3-20
3B.2.3. Preparation of HPU/GO nanocomposite	3-21
3B.3. Results and discussion.....	3-21
3B.3.1. Characterization of HPU/GO nanocomposite	3-21
3B.3.2. Mechanical properties of HPU/GO nanocomposite.....	3-23
3B.3.3. Thermal properties of HPU/GO nanocomposite	3-26
3B.3.4. Shape memory behavior of HPU/GO nanocomposite	3-27
3B.4. Conclusion.....	3-29
3C. Preparation of HPU/reduced graphene oxide nanocomposite	3-30
3C.1. Introduction	3-30
3C.2. Experimental	3-31
3C.2.1. Materials.....	3-31
3C.2.2. Characterization	3-31
3C.2.3. Functionalization of RGO	3-32
3C.2.4. Preparation of HPU/RGO and HPU/f-RGO nanocomposites.....	3-32
3C.3. Results and discussion.....	3-33
3C.3.1. Functionalization of RGO	3-33
3C.3.2. Characterization of f-RGO	3-33
3C.3.3. Characterization of HPU/RGO and HPU/f-RGO nanocomposites.....	3-35
3C.3.4. Mechanical properties of HPU/RGO and HPU/f-RGO nanocomposites.....	3-36
3C.3.5. Thermal properties of HPU/RGO and HPU/f-RGO nanocomposites.....	3-40
3C.3.6. Electrical properties of HPU/RGO and HPU/f-RGO nanocomposites.....	3-41
3C.3.7. Shape memory behavior of HPU/RGO and HPU/f-RGO nanocomposites	3-42
3C.4. Conclusion.....	3-43
References.....	3-43

Chapter 4

HPU/iron oxide nanoparticles decorated RGO nanocomposite as a multi-stimuli responsive self-healing and shape memory materials

Highlights.....	4-1
-----------------	-----

4.1. Introduction	4-2
4.2. Experimental.....	4-3
4.2.1. Materials	4-3
4.2.2. Characterization.....	4-4
4.2.3. Preparation of IO-RGO nanohybrid	4-4
4.2.4. Preparation of HPU/IO-RGO nanocomposite	4-5
4.3. Results and discussion	4-5
4.3.1. Preparation of IO-RGO nanohybrid	4-5
4.3.2. Characterization of IO-RGO nanohybrid	4-6
4.3.3. Preparation of HPU/IO-RGO nanocomposite	4-9
4.3.4. Characterization of HPU/IO-RGO nanocomposite	4-10
4.3.5. Mechanical properties of HPU/IO-RGO nanocomposite	4-12
4.3.6. Thermal properties of HPU/IO-RGO nanocomposite	4-13
4.3.7. Shape-memory behavior of HPU/IO-RGO nanocomposite	4-14
4.3.8. Self-healing behavior of HPU/IO-RGO nanocomposite	4-16
4.4. Conclusion	4-20
References	4-21

Chapter 5

HPU/sulfur nanoparticles decorated RGO nanocomposite as an antimicrobial smart material

Highlights	5-1
5.1. Introduction	5-2
5.2. Experimental.....	5-3
5.2.1. Materials	5-3
5.2.2. Characterization.....	5-3
5.2.3. Preparation of SRGO nanohybrid.....	5-5
5.2.4. Preparation of HPU/SRGO nanocomposite	5-5
5.3. Results and discussion	5-5
5.3.1. Preparation of SRGO nanohybrid.....	5-5
5.3.2. Characterization of SRGO nanohybrid.....	5-7
5.3.3. Characterization of HPU/SRGO nanocomposite	5-10
5.3.4. Mechanical properties of HPU/SRGO nanocomposite	5-10
5.3.5. Thermal properties of HPU/SRGO nanocomposite	5-12
5.3.6. Shape memory behavior of HPU/SRGO nanocomposite.....	5-14

5.3.7. Self-healing properties of HPU/SRGO nanocomposite.....	5-15
5.3.8. Antimicrobial activity of HPU/SRGO nanocomposite.....	5-17
5.4. Conclusion	5-19
References.....	5-20

Chapter 6

HPU/TiO₂ nanoparticles decorated RGO nanocomposite as a smart material with sunlight-induced self-cleaning attribute

Highlights.....	6-1
6.1. Introduction.....	6-2
6.2. Experimental	6-3
6.2.1. Materials	6-3
6.2.2. Characterization	6-3
6.2.3. Preparation of TiO ₂ -RGO nanohybrid.....	6-4
6.2.4. Preparation of HPU/TiO ₂ -RGO nanocomposite.....	6-4
6.3. Results and discussion	6-4
6.3.1. Characterization of TiO ₂ -RGO nanohybrid.....	6-4
6.3.2. Mechanical properties of HPU/TiO ₂ -RGO nanocomposite.....	6-7
6.3.3. Thermal properties of HPU/TiO ₂ -RGO nanocomposite.....	6-9
6.3.4. Shape memory behavior of HPU/TiO ₂ -RGO nanocomposite	6-10
6.3.5. Self-healing properties of HPU/TiO ₂ -RGO nanocomposite.....	6-11
6.3.6. Sunlight induced self-cleaning properties of HPU/TiO ₂ -RGO nanocomposite	6-13
6.4. Conclusions.....	6-16
References.....	6-17

Chapter 7

Conclusion and future scopes

Highlights.....	7-1
7.1. Summary and conclusions	7-2
7.2. Future directions	7-4

List of Publications	P-1
-----------------------------------	-----

LIST OF ABBREVIATIONS AND SYMBOLS

%	percentage
°	degree
°C	degree centigrade
ASTM	American Society for Testing and Materials
ATCC	American type culture collection
BD	1,4-butandiol
cm	centimeter(s)
CNT	carbon nanotubes
DMAc	<i>N,N</i> -dimethylacetamide
DMF	<i>N,N</i> -dimethylformamide
DMSO	dimethyl sulfoxide
DSC	differential scanning calorimetry
eV	electronvolt
F	Faraday
f-RGO	Functionalized reduced graphene oxide
FTIR	Fourier transform infrared
g	gram(s)
GO	graphene oxide
h	hour(s)
HPU	hyperbranched polyurethane(s)
HRTEM	high resolution transmission electron microscope
Hz	hertz
IO	iron oxide nanoparticles
IR	infrared
J	Joule
kg	kilogram(s)
kV	kilovolt
LSD	least significant difference
m	meter(s)
MB	methylene blue
MIC	minimum inhibitory concentration

List of Abbreviations and Symbols

min	minute(s)
mL	milli litre(s)
mm	milli meter(s)
mol	mole(s)
MPa	megapascal
MW	microwave
MWCNT	multiwalled carbon nanotube
N	Newton
nm	nanometer
NMR	nuclear magnetic resonance
OMMT	organically modified montmorillonite
Pas	pascal second
PCL	poly(ϵ -caprolactone)diol
PU	polyurethane
RGO	reduced graphene oxide
s	second(s)
S	Siemens
SAED	selected area electron diffraction
SCP	self-cleaning polymer (s)
SEM	scanning electron microscope
SERS	surface-enhanced Raman spectroscopy
SHP	self-healing polymer (s)
SME	shape memory effect
SMP	shape memory polymer (s)
SP	semiconductor photocatalyst
SRGO	sulfur nanoparticles decorated reduced graphene oxide
SWCNT	single walled carbon nanotube
T _c	crystalline temperature
TDI	2,4/2,6-toluene diisocyanate
TEM	transmission electron microscope
T _g	glass transition temperature
TGA	thermogravimetric analysis
THF	tetrahydrofuran

List of Abbreviations and Symbols

T _m	melting temperature
TMS	Tetramethylsilane
UTM	universal testing machine
UV	ultraviolet
W	watt (s)
wt	weight
XRD	X-ray diffraction
δ ppm	chemical shift
μg	micro gram(s)
μL	micro liter(s)
μm	micro meter(s)