

Studies on Radar Transparent High Performance Polymeric Nanocomposites

By

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**STUDIES ON RADAR TRANSPARENT HIGH PERFORMANCE
POLYMERIC NANOCOMPOSITES**

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INDIAN INSTITUTE OF TECHNOLOGY DELHI
AUGUST 2009**

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Dedicated to my Wife
Jaya

Certificate

This is to certify that the thesis entitled “**Studies on Radar Transparent High Performance Polymeric Nanocomposites**” being submitted by **Mayank Dwivedi** is the report of bonafide research work carried by him under our supervision. This thesis has been prepared in conformity with the rules and regulations of the Indian Institute of Technology Delhi, New Delhi. We further certify that the thesis has attained a standard required for a Ph.D. degree of the institute. The research reported and results presented in the thesis have not been submitted in part or full to any other institute or university for the award of any other degree or diploma.

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Abstract

Polymeric nanocomposites (PNCs) are one of the advanced materials which have applications in many areas such as aerospace, defence, packaging, stealth, etc. PNCs can revolutionize the advanced composites with their use as matrices for microreinforcement such as glass fibre, carbon fibre, etc. PNCs based on high performance plastics such as polyetherimide, polyetheretherketone, polysulfones, etc. have superior mechanical strength and thermal stability to that of their neat polymers. The use of PNC as matrix for reinforcement with glass fabric leads to a concept of fabric reinforced nanocomposite-matrix composite (FRNC).

Among many advanced applications, radar transparent structures are in demand to shield the antenna from operating environment. The applications require these materials to be structurally strong, thermally stable and transparent to radar i.e. electromagnetic (EM) waves. In the present study PEI/nanoclay composites have been prepared, characterized and evaluated and the PEI/nanoclay composite film, with optimum properties, was used as matrix with E-glass fabric as the reinforcement to make FRNC.

Organoclay (ONC) (Grade: Cloisite 30B) reinforced polyetherimide (PEI) and untreated nanoclay (UNC) (Grade: K10) reinforced PEI nanocomposites were prepared by vibration casting method and properties were evaluated and compared. Vibration casting apparatus was designed and fabricated. Vibrations not only prevented the settling of nanoclay particles, but also, led to intercalation and exfoliation of nanoclay. The processing parameters for vibration casting were established. N,N'-dimethyl acetamide was used as the solvent for dissolving PEI and as the casting medium. The samples were fabricated with varying content (0.5%, 1.0%, 2.0% and 3.0%) of ONC and UNC. Intercalation and exfoliation were observed in PEI/ONC nanocomposites in wide angle X-ray diffraction (WAXD), scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Whereas, formation of tactoids was observed for PEI/UNC nanocomposites in WAXD and SEM. In PEI/UNC nanocomposites, the phase separation and segregation of UNC was observed in SEM micrographs. UNC tactoids were present in PEI/UNC nanocomposites. There was uniform dispersion of nanoclay in the form of

intercalation and exfoliation in PEI/ONC nanocomposites. Minor segregation and phase separation of ONC were observed at 2 wt. % and above for ONC, but, in case of UNC, even at 1 wt. % content, this effect was profound. The morphology was in correlation with thermal, mechanical and dielectric properties.

Thermal behaviour of PEI/ONC and PEI/UNC nanocomposites was evaluated by differential scanning calorimetry, thermo gravimetric analysis and isothermal aging process. Thermal stability of PEI/ONC nanocomposites were found to be superior to that of PEI/UNC nanocomposites. The best thermal behaviour was observed for 1 wt. % ONC reinforced PEI nanocomposite.

The values of dielectric constant, loss tangent, transmission loss and reflection loss were measured at 8 to 12 GHz frequency. These properties were found to be lesser for PEI/ONC nanocomposites than that for PEI/UNC nanocomposites. Here, too, the least transmission and reflection losses were observed for PEI/ONC (1 wt. % composition). Therefore, PEI/ONC (1 wt. % composition) was found to have optimum mechanical, thermal and dielectric properties along with least transmission and reflection losses among all other composition developed in this study.

Fabric reinforced nanocomposite-matrix Composites (FRNC) were fabricated by compression moulding technology using 1 wt. % ONC reinforced PEI as a matrix and E-glass fabric as reinforcement. The processing parameters were established. In order to compare the effect of PEI/ONC matrix, E-glass reinforced PEI composites were fabricated using the same processing parameters. The mechanical, thermal and dielectric performances of FRNC were found to be superior to E-glass/PEI composites. There was no significant difference in transparency to electromagnetic wave between these two composites.

In all, the developed glass/PEI/organoclay based FRNC was radar transparent high and performance polymeric nanocomposite which had potential to be used for specialized applications in aerospace, defence, automotives, pressure vessels, etc. Radar transparent FRNCs are the promising materials for nose cones of supersonic aircrafts, radar domes (radomes) for missiles, domes for satellite communication antenna, covers for radio frequency sensors for automobiles, etc.

Table of Contents

	Page No.
<i>Certificate</i>	iii
<i>Acknowledgements</i>	iv
<i>Abstract</i>	vi
<i>List of figures</i>	xii
<i>List of tables</i>	xvi
Chapter 1: Introduction and Literature Survey	1
<i>Summary</i>	2
1.1 Introduction	3
1.2 Need for advanced materials	5
1.3 Scope of the present work	7
1.4 Approach	9
1.5 High performance plastics	11
1.5.1 Polyetherimide (PEI)	11
1.5.2 Solvent induced crystallization in PEI	13
1.6 Polymeric composites	15
1.6.1 Composites and its phases	16
1.6.2 Classification of composites based on matrix material	16
1.6.3 Classification of composite materials based on reinforcing material structure	17
1.6.4 Processing and applications of polymeric composites	18
1.6.5 Radar transparent composites	21
1.6.5.1 Dielectric constant	22
1.6.5.1 Loss tangent	22
1.6.5.1 Transmission loss	23
1.6.5.1 Reflection loss	23
1.7 Nanoclay	26
1.7.1 Nanoclays and their properties	28
1.7.2 Surface modification of nanoclays	31
1.7.3 Mechanisms of dispersion of nanoclay	32
1.7.4 Thermodynamics of nanoclays	35
1.7.5 Benefits of nanoclay over nanofibres	36
1.7.6 Advantages of nanoclays	38
1.8 Polymeric nanocomposites (PNCs)	39
1.8.1 Types of PNCs	40
1.8.2 Processing and applications of PNCs	41

1.8.3	Structure property relationship in PNCs	45
1.9	PEI based nanocomposites	47
1.10	Fabric reinforced nano-reinforced-matrix composites (FRNCs)	49
1.10.1	Current status of short fibre reinforced nanocomposites and FRNCs	55
1.11	Objectives of the present study	57
Chapter 2:	Processing of Polyetherimide/Nanoclay Composites	60
	<i>Summary</i>	61
2.1	Background	62
2.2	Experimental	63
2.2.1	Procurement of raw materials	63
2.2.2	Characterisation of raw materials	64
2.2.2.1	Polyetherimide (PEI)	64
2.2.2.2	Nanoclay	69
2.2.2.3	N,N'- dimethyl acetamide (DMAc)	78
2.2.3	Composition of PEI/nanoclay nanocomposites	78
2.2.4	Design and development of vibration casting apparatus	79
2.2.5	Casting of nanoclay reinforced PEI film	82
2.2.6	Concept of homogenous dispersion	83
2.2.6.1	Viscosity of polymer solution	85
2.2.7	Morphology examination	85
2.3	Results and discussion	86
2.3.1	Evaluation of forces on nanoclay in PEI/ DMAc solution	86
2.3.2	Optimisation of frequency to energise nanoclay particle	87
2.3.3	Effect of viscosity on casting	88
2.3.4	Morphology of nanoclay reinforced PEI	90
2.3.4.1	WAXD	90
2.3.4.2	SEM	91
2.3.4.3	TEM	94
2.4	Conclusion	97
Chapter 3:	Thermal Characterization of Polyetherimide/Nanoclay Composites	98
	<i>Summary</i>	99
3.1	Background	100
3.2	Experimental	101

3.3 Results and discussion	102
3.3.1 Differential scanning calorimetry (DSC) of PEI, PN and PEN samples	102
3.3.2 Thermo gravimetric analysis (TGA) of PEI, PN and PEN samples	110
3.3.3 Isothermal aging of PEI, PN and PEN samples	117
3.4 Conclusion	120
Chapter 4: Tensile and Electromagnetic Behaviour of Polyetherimide/Nanoclay Composites	121
<i>Summary</i>	122
4.1 Background	123
4.2 Experimental	125
4.3 Results and discussion	126
4.3.1 Mechanical response	126
4.3.1.1 Tensile strength, modulus and elongation at break	126
4.3.1.2 Correlation of morphology with mechanical response	131
4.3.2 Electromagnetic behaviour	132
4.3.2.1 Dielectric constant	132
4.3.2.2 Correlation of morphology with dielectric dispersion	135
4.3.2.3 Loss tangent	135
4.3.2.4 Transmission loss	138
4.3.2.5 Reflection loss	140
4.4 Conclusion	142
Chapter 5: Processing and Properties of Glass Fabric Reinforced PEI/Organoclay Composites	143
<i>Summary</i>	144
5.1 Background	145
5.2 Experimental	146
5.2.1 Mould design and fabrication	146
5.2.2 Lay up sequence and moulding cycle	148
5.2.2.1 Mould preparation	148
5.2.2.2 Lay up sequence	149
5.2.3 Compression moulding of composite laminates	150
5.2.4 Sample preparation and test methods	153
5.2.4.1 Measurement of density	153
5.2.4.2 Measurement of void content	154
5.2.4.3 Ultrasonic through transmission test	154
5.2.4.4 Evaluation of constituent content	155

5.2.4.5	Mechanical tests	155
5.2.4.6	Thermal tests	158
5.2.4.7	Electromagnetic performance	159
5.3	Results and discussion	159
5.3.1	Lay up sequence	159
5.3.2	Physical properties and nondestructive tests	159
5.3.2.1	Specific gravity	159
5.3.2.2	Void content	160
5.3.2.3	Ultrasonic through transmission test	160
5.3.2.4	Evaluation of constituent content	160
5.3.3	Mechanical response	161
5.3.3.1	Hardness	161
5.3.3.2	Tensile test	161
5.3.3.3	Flexural test	163
5.3.3.4	Inter laminar shear strength (ILSS)	164
5.3.3.5	Izod impact test	164
5.3.4	Thermal analysis	164
5.3.4.1	DSC	164
5.3.4.2	TGA	166
5.3.4.3	DMA	167
5.3.5	Electromagnetic performance	169
5.3.5.1	Dielectric constant and loss tangent	169
5.3.5.2	Transmission and reflection losses	170
5.4	Structure property relationship in CRNC	173
5.5	Conclusion	175
Chapter 6	Executive Summary and Conclusion	176
6.1	Executive summary	177
6.1.1	Vibration casting of PNCs	177
6.1.2	Thermal behavior of PEI/nanoclay composites	178
6.1.3	Morphology and mechanical behavior of PEI/nanoclay composites	179
6.1.4	Dielectric behavior and electromagnetic transparency of PEI/nanoclay composites	180
6.1.5	Processing and properties of fibre reinforced nano-reinforced-matrix composite (FRNC)	181
6.2	Overall conclusion	182
6.3	Future scope of work	182
	<i>References</i>	183
	<i>Author's biography</i>	191
	<i>List of patents and publications</i>	192