Studies on Radar Transparent High Performance Polymeric Nanocomposites

By

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Submitted

In fulfillment of the requirements of the degree of Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

August 2009

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STUDIES ON RADAR TRANSPARENT HIGH PERFORMANCE POLYMERIC NANOCOMPOSITES

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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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Acknowledgement

I would like to express my deep sense of gratitude to my research advisor Prof. Anup K. Ghosh for his invaluable guidance, never ending encouragement and constant support. His positive attitude and ingenious insight of research was a great motivational force during this research work. Under his supervision, it was not only a great learning on scientific research but also on righteous approach in all endeavours. I would also like to express my deep sense of gratitude to my co supervisor, Dr. Sarfaraz Alam for his able guidance and full support. He has been a constant source of encouragement throughout this work. Their expertise in processing of composites and nanocomposites improved my research skills and knowledge and prepared me for future challenges. I am fortunate and proud of my supervisors who have made my journey to this research memorable.

I would like to thank the members of my 'Student Research Committee (SRC)'. Prof. SN Maiti, Chairman SRC, has been very supportive and his suggestions were very useful for meaningful direction to this work. SRC member, Prof. Naresh Bhatnagar, provided much more needed support to complete this work. His guidance and support for mechanical design of equipment and moulds was immense help to me and I owe special thank to him. My special thanks to Prof. Alok Ray, SRC member, for his support and penetrative questions to make my work better. I wish to thank all member of Centre Research Committee (CRC), Prof. Veena Choudhary, Prof. BL Deopura, Prof. A.K. Gupta, Dr. J. Jacob and Dr. BK Satpathy. My special thanks to Prof. Veena Choudhary for her suggestions on thermal analysis. I would like to express my gratitudes to Prof. BL Deopura for discussion and suggestions on structure-property relationship.

This work would have been not possible without the support and encouragement from my office. My special thanks to Dr. A. Sivathanu Pillai for giving me opportunity to carry out this research work and his cooperation. I would like to thank Mr. Brij Mohan, Mr. PC Gupta, Mr. KK Gaur, Mr. K. Hariharan and Mr. Vinod Kumar Singh for their cooperation and support during this research work.

My special thanks to Dr. Surendra Ponrathnam, Dr. CR Rajan and Dr. Rajkiran Tiwari of National Chemical Laboratory, Pune for their kind support. I would like thank Dr. KUB Rao, Mr. Alok Dixit and Dr. RK Singh of DMSRDE, Kanpur for their support in materials characterization and testing. I would like to convey my special thanks to Dr. Shashi Motilal for her support and encouragement. My special thanks to Mr. Surendra Sharma, Mr. Shiv Kant, Mr. Ashok Kapoor, Mr. Joginder Singh and all the students at CPSE, IIT Delhi for their support. My special thanks to Mr. Satpal Singh, Dr. K. Senthil Kumaran, Dr. Sangita Nandi, Mr. Saiket Banerji, Ms. Pooja Singh, Ms. Geeta Saini, Mr. Manas Kashyap, Mr. K. Satish, Ms. Sneh Bharti, Dr. K. Dilip and Mr. Arnav Ghosh for their cooperation. I would like to convey my thanks to Ms. Suchitra Singh, Ms. Rama Sharma, Ms. Aditi Vasishtha, Ms. Mamta and Mr. Narendra Kumar for their all possible support.

My special thanks are reserved for my parents and parents in law for their support and encouragement in completing my Ph.D. I am thankful to my wife, Ms. Jaya, to whom I deeply indebted for encouraging me for this research work. Finally, I am extremely thankful to my loving daughter, Ms. Malvika, for her love and understanding through out this work.

Mayank Dwivedi

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.

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