MODIFICATION OF POLYPROPYLENE BY POLY(DIMETHYLSILOXANE) ELASTOMER AND NANO-SiO_2

by

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Dedicated to
My Parents and Brother

CERTIFICATE

This is to certify that the thesis entitled **"Modification of Polypropylene by Poly(dimethylsiloxane) Elastomer and Nano-SiO_2"** being submitted by **Mr. Prakashan K** to Centre for Polymer Science and Engineering (CPSE), Indian Institute of Technology, Delhi is worthy of consideration for the award of degree of **Doctor of Philosophy** and is a record of the original bonafide research work carried out by him, under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard.

The results contained in this thesis are original and have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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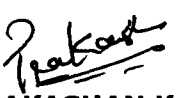

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ABSTRACT

Properties of a polymer can be modified by blending with other polymers and fillers. When a polymer is modified with another polymeric component and a filler the resultant product is a ternary composite. In this work, polypropylene (PP) has been modified with poly(dimethylsiloxane) PDMS elastomer and nano-SiO_2 to form a PP/PDMS/nano-SiO_2 ternary composite. In this ternary system, the dispersed phases, the PDMS and the nano-SiO_2, have good affinity between each other but at the same time poor compatibility with the PP matrix. The main objective of the study was to investigate the dispersion morphology development in the PP/PDMS/nano-SiO_2 ternary composite during mixing process in a twin screw extruder by using different mixing sequences, and the effect of different dispersion morphologies thus produced on the properties of the ternary composites. The other objective includes the investigation of the effect of PDMS and nano-SiO_2 on the properties of corresponding binary system with PP. The compatibilization studies of PP/PDMS blend using maleic anhydride grafted polypropylene (MAH-g-PP) was also an objective of the work. The dispersed phases possess distinctive surface properties- PDMS a flexible elastomer while nano-SiO_2 a rigid filler- may influence the crystallization behaviour of PP differently. Therefore, the effects of these additives on nonisothermal crystallization of PP has also been investigated in details.

The binary blends of PP and PDMS and the binary composite of PP and nano-SiO_2 have been studied for the individual effect of PDMS and nano-SiO_2, respectively, on the properties of PP. The ternary composite of PP, PDMS and nano-SiO_2 have been studied for the combined effect of PDMS and nano-SiO_2 on the properties of PP. The blends and the composite samples were prepared in a twin screw extruder and then injection molded

to prepare test specimens. The various studies done were: thermal properties by differential scanning calorimeter (DSC) and thermogravimetric analysis (TGA), the crystalline nature by wide angle X-ray diffraction (WAXD), the dispersion morphology by scanning electron microscopy (SEM) and transmission electron microscopy (TEM), the mechanical properties by tensile, flexural and impact testing and the melt rheology by a capillary rheometer.

The mixing sequences employed during the preparation of PP/PDMS/nano-SiO_2 ternary composite during twin screw compounding was found to be significantly influencing the dispersion morphologies of the ternary systems. The mixing sequence in which the components, PP, PDMS and nano-SiO_2, mixed in a single step and another mixing sequence, in which the PDMS is mixed with a pre-prepared PP/nano-SiO_2 composite in the second step, resulted in the predominantly separated dispersions of the PDMS and nano-SiO_2 phases in the PP matrix of the composite. In the third mixing sequence employed, where nano-SiO_2 mixed with a pre-prepared PP/PDMS blend, resulted in predominant encapsulation of nano-SiO_2 particles by the PDMS phase of the ternary composite.

The tensile and flexural properties of the ternary systems with separate dispersion morphology were superior to that of the ternary system with encapsulated dispersion morphology. The impact strength of ternary system with separate dispersion of the dispersed phases prepared by mixing PDMS in the second step to the pre-prepared PP/nano-SiO_2 was superior compared to the other separately dispersed ternary system, prepared by the one step mixing of all the components, and the ternary system with encapsulated dispersion morphology.

Significant improvement in impact strength was obtained at low phr addition (up to 10 phr) of PDMS in PP. The crazing and the debonding and subsequent shear yielding,

was the major deformation mechanisms activated in PP/PDMS blend during the impact and the tensile deformations, respectively. Fibrillation of the specimen occurred during the tensile stretching of PP/PDMS blend.

MAH-g-PP was found to be acting as an effective compatibilizer for PP/PDMS blend though it did not improve the impact strength of the blend significantly. Crazing was found to be the major deformation mechanisms activated during impact and tensile deformations as the improved interfacial adhesion prevented debonding and the subsequent shear deformation for the compatibilized blend. Due to the absence of shear deformation the fibrillation of the specimen was also absent for the compatibilized PP/PDMS blend.

The effect of flexible PDMS inclusions and the rigid nano-SiO_2 particles on the crystallization of PP was very different. PDMS did not show any nucleating effect on PP crystallization while nano-SiO_2 acted as a nucleating agent for PP. The PDMS facilitated the crystallization process of PP probably due to the high mobility of the PDMS molecular chain at the interface facilitating the molecular mobility of PP to enable it to orient and align in a crystalline lattice with ease. The reduced value of activation energy also supported this ease of crystallization in PP/PDMS blend. The effect of nano-SiO_2 addition on the rate of crystallization was found to be cooling rate dependent; the rate of crystallization was slower than that of PP at lower cooling rate while it was faster than that of PP at higher cooling rates.

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