

## CHAPTER II

### LITERATURE REVIEW

Polymer blending has been extensively studied for over two decades. High-density polyethylene (HDPE) and nylon blends have not been extensively studied, although some studies are discussed in the literature.

Chen *et al.* (1988) investigated the instability of phase morphology of blends of nylons with polyethylenes and polystyrenes and the effects of "compatibilizing" additives or "agents". Annealing coarsens the phase morphology of blends of nylons with polyethylenes and polystyrenes. Phase growth was observed for various periods of annealing time. The addition of compatibilizing agents, specifically maleic anhydride grafted polyolefins to polyethylene-nylon blends and styrene-maleic anhydride copolymers to polystyrene-nylon blends, stabilized the phase dimensions. Styrene-maleic anhydride copolymer was found to be more effective than styrene acrylonitrile copolymer as a compatibilizing agent.

The grafting of maleic anhydride (MAH) on high-density polyethylene in a counter-rotating twin screw extruder had been studied by Ganzeveld and Janssen (1992). From the study it was found that the reaction kinetics appear to be affected by mass transfer, and good micro mixing in the extruder was important. Due to the mechanisms of increasing mixing and decreasing residence times at increasing screw speed, and due to the complicated reaction scheme, various non-linearities exist that were prohibitive for simple optimization rules.

Armat and Moet (1993) investigated the effect of compatibilizing polyethylene and nylon6 on the morphology and mechanical properties of these blends. A maleic anhydride functionalized styrene-(ethylene-co-butylene)-styrene block copolymer (Ma/SEBS) was added to the blends as the compatibilizer. The compatibilizer was found to play a dual interfacial function. It reduces the interfacial tension of the system, resulting in reduction of the particle size of the dispersed polyethylene phase and also enhances the interfacial adhesion through the formation of micro-bridges. The fine polyethylene phase thus coupled to the matrix in compatibilized blends can carry load and deform co-continuously along with the

matrix. This causes extensive yielding of the blend to its failure and high ultimate elongation. Unexpectedly, at MA/SEBS contents higher than 10% the ductility of the blends drops sharply. This was attributed to flow-induced discontinuities within a large core in the tensile specimens. The lines of instabilities act as large notches within the specimen, causing brittle failure of the otherwise ductile blend.

In 1994, Lim and White studied the influence of a compatibilizing agent on phase morphology development in a 75/25 polyethylene/polyamide-6 blend in a modular co-rotating twin screw extruder. The development of phase morphology along the axis of the modular screw was observed by cooling the extruder and removing the polymer from the screw channels. Changes in phase morphology due to the addition of a compatibilizer had been investigated using a scanning electron microscopy. Sufficient quantities of compatibilizing agent produce significant increases in the rate of mixing and also reduce the scale of the phase morphology. Large quantities (5%) than actually required for interface coverage were needed for rapid mixing. This seems to be due to the high viscosity of the matrix.

Jurkowski *et al.* (1998) studied influence of chemical and mechanical compatibilization on structure and properties of polyethylene/polyamide blends. LDPE/PA6 binary blends and LDPE/PA6/compatibilizer ternary blends were prepared in a Brabender extruder, equipped with a prototype static mixer. Compatibility of the components was estimated by rheological properties (viscosity and melt flow index), and observations of the structure were made with the help of scanning electron microscopy and tensile strength. It was found that structure and properties of the blends were dependent on the recipe content of the polymer blends and the conditions of their manufacturing. Uniformity of the blends of the thermodynamically immiscible polymers was improved by using a prototype static mixer giving mechanical compatibilization and a compatibilizer giving chemical compatibilization. LDPE grafted with a maleic anhydride (LDPE-g-MAH) was used as a compatibilizer.

Kudva *et al.* (1999) studied the morphology and mechanical properties of compatibilized nylon6/polyethylene blends. Blends of nylon 6 and polyethylene were investigated over a range of compositions. The polyethylenes used were grafted with maleic anhydride and thus, have the potential to react with the amine

end groups of nylon 6 during melt processing. This study focuses on the effects of the concentration, viscosity and functionality of the maleated polyethylenes (PE-g-MA) on the rheological, morphological, and mechanical properties of nylon 6/PE-g-MA blends. The impact properties of these blends were strongly influenced by the amount and type of maleated polyethylenes used. A low viscosity maleated polyethylene was shown to be ineffective in toughening nylon 6; this was because of the propensity of polyethylene to become continuous even when nylon 6 was the majority component. Two higher viscosity maleated polyethylenes were able to produce blends with high impact strength and excellent low temperature toughness over a range of compositions. The result demonstrated that polyethylene materials containing a very low degree of anhydride functionality could generate blends with excellent impact properties. A brief portion of this study focused on ternary blends of nylon 6, maleated polyethylene and nonmaleated polyethylene; in general, the impact properties of these blends improved as the nylon 6 molecular weight increased and as the ratio of maleated polyethylene to nonmaleated polyethylene increased.

Morphology, thermal behavior and mechanical properties of PA6/UHMWPE blends with HDPE-g-MAH as a compatibilizing agent was studied by Yao *et al.* (2000). A functionalized high-density polyethylene (HDPE) with maleic anhydride (MAH) was prepared using a reactive extruding method. This copolymer was used as a compatibilizer of blends of polyamide 6 (PA6) and ultrahigh molecular weight polyethylene (UHMWPE). Morphologies were examined by a scanning electron microscope. This study was found that the dimension of UHMWPE and HDPE domains in the PA6 matrix decreased dramatically compared with that of the uncompatibilized blending system. The size of the UHMWPE domains was reduced from 35  $\mu\text{m}$  (PA/UHMWPE, 80/20) to less than 4  $\mu\text{m}$  (PA6/UHMWPE/HDPE-g-MAH, 80/20/20). The tensile strength and Izod impact strength of PA6/UHMWPE/HDPE-g-MAH (80/20/20) were 1.5 and 1.6 times as high as those of PA6/UHMWPE (80/20), respectively. This behavior could be attributed to chemical reactions between the anhydride groups of HDPE-g-MAH and the terminal amino groups of PA6 in PA6/UHMWPE/HDPE-g-MAH blends.

Thermal analysis was performed to confirm that the above chemical reactions took place during the blending process.

In 2001, Sailaja and Chanda studied the use of maleic anhydride-grafted polyethylene as compatibilizer for HDPE-tapioca starch blends. Tapioca starch in both glycerol-plasticized and in unplasticized states was blended with high-density polyethylene (HDPE) using HDPE-g-maleic anhydride as the compatibilizer. The impact and tensile properties of the blends were measured according to ASTM methods. The results reveal that blends containing plasticized starch have better mechanical properties than those containing unplasticized starch. High values of elongation at break at par with those of virgin HDPE could be obtained for blends, even with high loading of plasticized starch. Morphological were studied by SEM microscopy of impact-fractured specimens of such blends revealed a ductile fracture, unlike blends with unplasticized starch at such high loading, which showed brittle fracture, even with the addition of compatibilizer. In other research (Kang *et al.*, 1996) studied the blends of HDPE and plasticized starch with added compatibilizer showed better mechanical properties than similar blend containing unplasticized starch.

In the same year, Gonzalez-Nunfez *et al.* studied determination of a limiting dispersed phase concentration for coalescence in PA6/HDPE blends under extensional flow. Blends of PA6/HDPE at different compositions and melt-draw ratio were prepared using a twin-screw extruder with a rectangular slit at 250°C. The morphology results show that at low take up velocity, the final state of deformation is independent of the dispersed phase composition. However, at high take up velocity the drop deformation increases with the composition. To determine a lower limiting concentration, at which coalescence occurs, the average particle volume of the dispersed phase was evaluated. In the concentration range of 1±4 vol% of PA6, the average volume of the particles remains constant (no coalescence) during the stretching process. However, at higher concentrations (0.5 vol% of PA6) coalescence takes place and the volume increases with stretching. These results clearly indicate the limiting dispersed phase concentration for coalescence in this system under extensional flow. The approach used here represents a possible technique to separate

out the relative contribution of single particle deformation and particle-particle coalescence in dispersed phase fiber formation in an extensional flow field.

Leewajanakul *et al.* (2003) investigated the use of zinc-neutralized ethylene/methacrylic acid copolymer ionomers as blend compatibilizers for polyamide 6 and low-density polyethylene. The effect of the composition on the morphologies and properties of uncompatibilized and compatibilized blends of polyamide 6 and low-density polyethylene were studied over a wide range of weight fractions. The uncompatibilized blends had substantially reduced mechanical properties after mixing, and this was almost certainly due to poor interfacial adhesion between the two polymers. The addition of a zinc-neutralized poly(ethylene-co-methacrylic acid) ionomer (Surlyn<sup>®</sup> 9020) as a compatibilizer improved the mechanical properties in comparison with those of the material blended without the compatibilizer. The clearest evidence of this improvement came from dynamic mechanical studies; for selected blends with high polyethylene contents, the drop in the modulus corresponding to the transition of a solid to a melt occurred at higher temperatures with the added compatibilizer. This improvement in the properties was accompanied by a reduction in the dispersed-phase size due to the interaction between the ionic part of the ionomer and the amide groups of polyamide 6, especially when polyamide 6 was the dispersed phase of the blend.