

## CHAPTER II

### LITERATURE REVIEW

#### 2.1 Blends of Nylon/PE with Compatibilizers

Over recent decades the importance of polymer blends has been studied. One of them was a Nylon/PE blends. This blend was incompatible, and many researches have been studied to improve the compatibilization of Nylon/PE blends using the functional reactive groups on the polyolefin chains.

In 1988, Wills and Favis studied the effect of an ionomer compatibilizer on the morphology of polyolefin/polyamide blends. The morphology of compatibilized polyolefin/polyamide blends was found to be significantly dependent on the concentration of an ionomer compatibilizer (polyethylenemethacrylic acid-isobutyl acrylate terpolymer) in the blend. For a dispersed phase content of 10% by weight, a maximum reduction in phase size was observed when only 0.5% by weight of ionomer was added to the blend. A more significant reduction of the dispersed phase size was observed when the minor phase was polyamide, due to interaction, which existed between the ionomer and the polyamide. These interactions have been confirmed by FT-IR Spectroscopy. At high concentrations of the ionomer, flocculation of the polyamide dispersed phase was observed. In comparison to one-step mixing, blends prepared by two-step of batch mixing were characterized by a small dispersed phase when polyamide was the matrix and a large particle size when polyamide was the minor phase. The results observed were explained in terms of a speculative model of the interaction occurring across the polyamide-polyolefin interface.

Silva and Soares (1996) investigate the effect of poly(ethylene-co-vinyl alcohol-co-vinyl mercaptoacetate) (EVASH) on the compatibilization of polyamide6 (Nylon 6)/low-density polyethylene (LDPE). EVASH was prepared from hydrolyzed EVA through an esterification reaction with mercaptoacetic acid. Mechanical Properties, differential scanning calorimetry, and scanning electron microscopy results were discussed. The mechanical properties were improved within the addition of EVASH. The compatibilizing agent also affected the crystallinity degree of both

components of blend, as indicated by the results obtained from DSC studies. The addition of EVASH resulted in a reduced dispersed-phase particle size.

Morphological, calorimetric, rheological, dielectric and mechanical behaviour of blends made with Polyamide-6 (Nylon 6) and linear low density polyethylene (LDPE) were studied by Valenza et al. (1997). The LDPE was functionalized grafting ester and alcohol groups in a Brabender mixer with methacrylic acid derivatives. These groups induced “compatibilization” effects in the blends with respect to blends made with the functionalized polyethylene. The difference effect on the behavior of the various functional groups were shown. In particular, the interactions at the interface change depending on the chemical nature of grafted groups. Ethyl and isobutyl-methacrylate essentially caused dipolar interactions and hydrogen bonding whereas hydroxyethyl-methacrylate gave rise to condensation reaction with the functional groups of polyamide. This last blend presented the highest increase of the elongation at break.

## **2.2 Nylon 6/PE Blends with Compatibilizer Based on Maleic Anhydride Functionalized**

The grafting of maleic anhydride (MAH) on high-density polyethylene in a counter-rotating twin screw extruder was studied by Ganzeveld 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 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 polyamide6 on the morphology and mechanical properties of their 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 reduced 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 caused extensive yielding of the blend its failure and high ultimate elongation. Unexpectedly, at MA/SEBS content 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/ Nylon 6 binary blend and LDPE/Nylon 6/compatibilizer ternary blends were prepared in a Brabender extruder, equipped with a prototype static mixer. Compatibility of the component was estimated by rheological properties (viscosity and melt flow index), and observation of the morphologies 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 polymer 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 nylon 6/polypropylene blends. Blends of nylon 6 and polyethylene

were investigated over a range of compositions. The polypropylene used was 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 polyethylene (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 Nylon 6/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 (Nylon 6) and ultrahigh molecular weight polyethylene (UHMWPE). Morphology was examined by a scanning electron microscope. This study was found that the dimension of UHMWPE and HDPE domains in the Nylon 6 matrix decreased dramatically compared with that of the uncompatibilized blending system. The size of UHMWPE domains was reduced from 35 micrometers (PA/UHMWPE, 80/20) to less than 4 micrometers (Nylon 6/UHMWPE/HDPE-g-MAH, 80/20/20). The tensile strength and Izod impact strength of Nylon 6/UHMWPE/HDPE-g-MAH (80/20/20) were 1.5 and 1.6 times as high as those of Nylon 6/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 Nylon 6 in Nylon 6/UHMWPE/HDPE-g-

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

In 2001, Gonzalez-Nunfez *et al.* studied determination of a limiting dispersed phase concentration for coalescence in Nylon 6/HDPE blends under extensional flow. Blends of Nylon 6/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 AEnal state of deformation is independent of the dispersed phase 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 Nylon 6, the average volume of the particles remains constant (no coalescence) during the stretching process. However, at higher concentrations (0.5 vol% of Nylon 6) coalescence takes place and the volume increases with stretching. The results clearly indicate the limiting dispersed phase concentration for coalescence in this system under extensional flow. The approach used 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.

### **2.3 Nylon 6/PE Blends with Compatibilizer Based on Ionomeric**

Leewajanakul *et al.* (2003) investigated the use of zinc-neutralized ethylene/methacrylic acid copolymer ionomers as blends compatibilizers for polyamide 6 and low-density polyethylene. The effect of 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 zinc-neutralized poly(ethylene-co-methacrylic acid) ionomer (Surlyn® 9020) as a compatibilizers improved the mechanical properties in comparison with those of the materials blends without the compatibilizer. The clearest evidence of this improvement came from dynamic mechanical studied; 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 amide groups of polyamide 6, especially when polyamide 6 was the dispersed phase of the blend.

In 2008, Wachiraphon *et al.* studied blends of Nylon 6 with LDPE compatibilized with sodium-, zinc-, and lithium-neutralized ethylene-methacrylic acid ionomers were investigated at 11, 33, and 55 wt% neutralization of the ionomers. Blends of Nylon 6 with LDPE without a compatibilizer had poor properties characteristic of incompatible polymer blends. After the addition of a compatibilizer, tensile properties improved, the modulus drop associated with melting point increased to higher temperature, and the dispersed phase size decreased. The improvement of the mechanical properties and thermomechanical properties was less with the acid copolymer than with the ionomers. Overall, ionomers neutralized with sodium, zinc, or lithium showed little difference in their compatibilization efficiency.

In 2007, Benjamaad *et al.* study effect of zinc oxide addition on the compatibilized efficiency of maleic anhydride grafted High-density Polyethylene compatibilizer for High-density Polyethylene/Polyamide 6 blends. The materials act as an effective compatibilizer, causing a marked reduction in dispersed phase size as well as an increase in tensile strength and toughness. Compatibilizer also affects the glass-transition temperature, crystallization kinetics, and amount of crystalline material for certain blend compatibilizations. The addition of zinc cations, which are effective in increasing ethylene acid copolymer compatibilizer.