

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Blend Preparation

Preliminary tests using Differential scanning calorimetry (DSC) and thermal gravimetric analysis (TGA) were carried on the materials received. The melting temperature (T_m), crystallization temperature (T_c) and degradation temperature (T_d) of low density polyethylene (LDPE), nylon 6 (PA6) and Surlyn[®] as determined by DSC and TGA are shown in Table 4.1, see also appendix A.

Table 4.1 Melting temperature and crystallization temperature of raw materials before blending.

Materials	T_m (°C)	T_c (°C)	T_d (°C)
PA6	222.20	183.20	451.00
LDPE	107.60	92.40	469.23
Surlyn [®]	87.30	-	462.00

These results were used to establish the processing condition for blending and compression molding. It was found that the optimum temperature used during mixing and compression molding was 240 °C. This is the temperature that will allow polymers to melt and mix but not high enough to degrade these polymers.

4.2 Mechanical Properties

The tensile properties and impact property of the blends were studied. This was investigate the effect of blend composition and compatibilizers.

4.2.1 Tensile Properties

4.2.1.1 *Blend of Nylon 6 and LDPE (without compatibilizer)*

The two tensile properties studied for nylon 6/LDPE blend without compatibilizer were tensile strength and tensile modulus. These properties were determined as function of LDPE content.

4.2.1.1 a) *Tensile Strength*

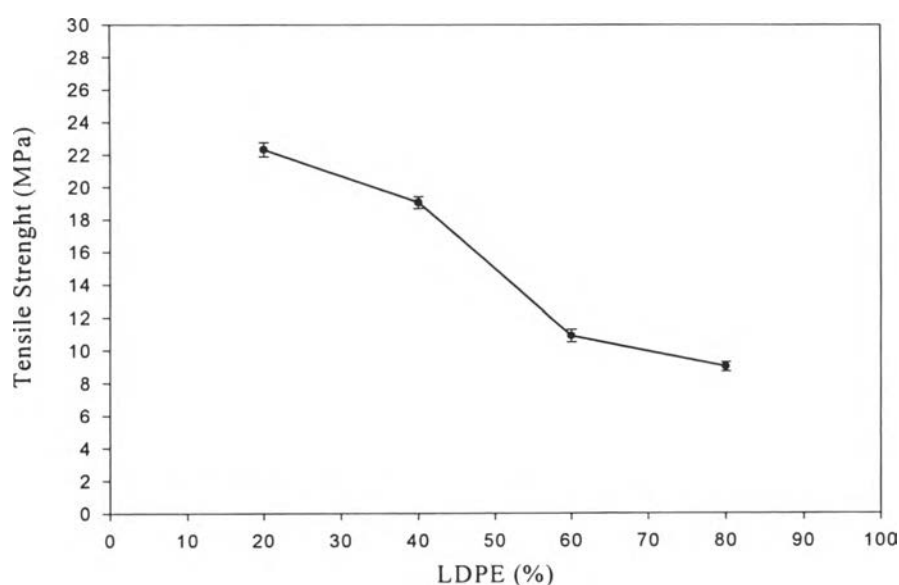


Figure 4.1 Effect of LDPE content on tensile strength of uncompatibilized nylon 6/LDPE blends.

Figure 4.1 shows the tensile strength of the uncompatibilized nylon 6/LDPE blends. A continuous decrease in tensile strength as the amount of LDPE increased was observed. This behavior was caused by decreased in crystallinity from the decreasing amount of nylon 6 composition in the blend. The structure of nylon 6 contains amide groups, which has the intermolecular hydrogen bonding, that give nylon 6 higher tensile strength than LDPE, which has structure contains ethylene repeat units with some alkyl substituents or short and long chain branches on the chain backbone. In addition, because of the poor interfacial adhesion between the disperse phase and the matrix phase, thus the applied stress can not be transfered through the dispersed phase particles, resulting in decrease in tensile strength.

4.2.1.1 b) Tensile Modulus

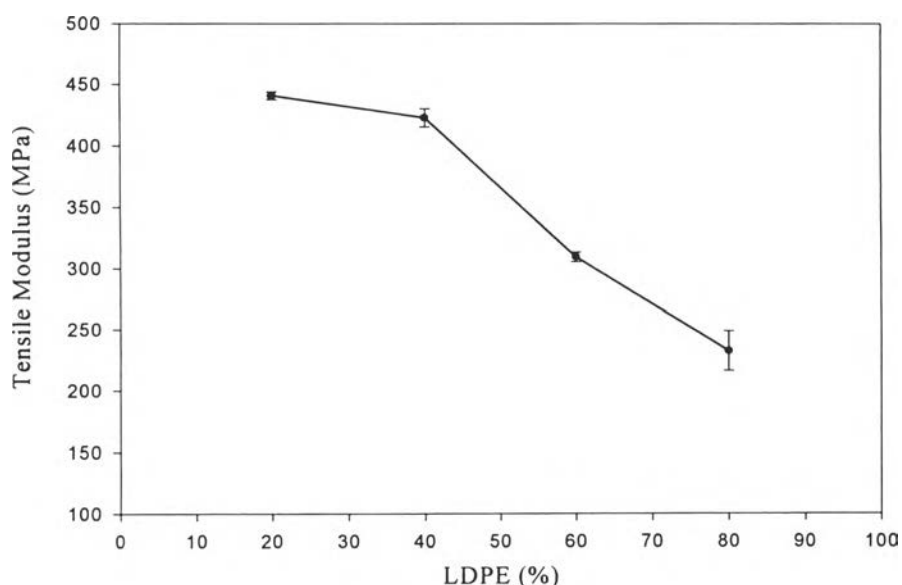


Figure 4.2 Effect of LDPE content on tensile modulus of uncompatibilized nylon 6/LDPE blends.

From Figure 4.2 the gradually decreased of Young's modulus of uncompatibilized blends was observed as the content of LDPE increased. This behavior could be attributed to the lower tensile modulus of LDPE compared with nylon 6. At higher composition of LDPE, the specimens elongated higher due to the lower crystallinity of LDPE than nylon 6.

4.2.1.2 Blend of Nylon 6 and LDPE (with Compatibilizer)

The tensile properties of the blend were studied to investigate the effect of Surlyn[®] ionomer as blend compatibilizer. The two mechanical properties determined as function of Surlyn[®] content were tensile strength and tensile modulus. In blends of nylon 6 and LDPE, the composition of the blends were controlled at 0.8:0.2, 0.6:0.4, 0.4:0.6 and 0.2:0.8 and the amount of Surlyn[®] were varied 0.1%, 0.5%, 1.0%, 1.5%, 2.5%, 3.5%, 5.0%, 7.5%, 10.0%, 15.0%, 25.0% and 35.0%. The amount of Surlyn[®] were studied in order to investigate the effect of blend composition and compatibilizers.

4.2.1.2 a) Tensile Strength

From Figure 4.3, tensile strength increased as the amount of Surlyn[®] was increased (0-10 % Surlyn[®]). At amount of Surlyn[®] exceeded 10 %, small changes in the tensile strength was observed until it reached the plateau. This could be due to the higher compatibility of the blend. For the compatible blend, the stress could transfer through the interfacial of the blend giving higher tensile strength. At large amount of Surlyn[®], the ionomer played an important role in trivial improved the tensile strength of the blend until reached the plateau.

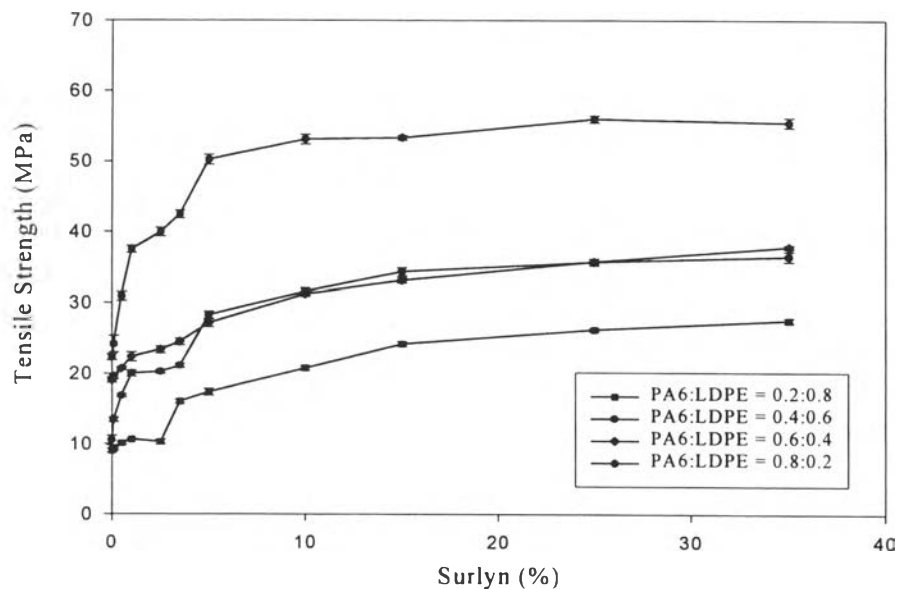


Figure 4.3 Effect of Surlyn[®] compatibilizer content on tensile strength of compatibilized PA6/LDPE blends.

4.2.1.2 b) Tensile Modulus

Sharp increase in tensile modulus was observed when small amount of Surlyn[®] (1-2 % Surlyn[®]) was added. At amount of Surlyn[®] exceeded 5 %, small changes in tensile modulus was observed until it reached the plateau due to the more compatibility of the blend was shown in Figure 4.4. At large amount of Surlyn[®], the ionomer played an important role in trivial improved the tensile modulus of the blend until reached the plateau. This is because the molecular chain of nylon 6 is a linear polymer chain, which has higher rigidity than both LDPE and ionomer. Therefore, blends which contain higher amount of nylon 6 will have higher modulus than blends which contain higher amount of LDPE and Surlyn[®] ionomer.

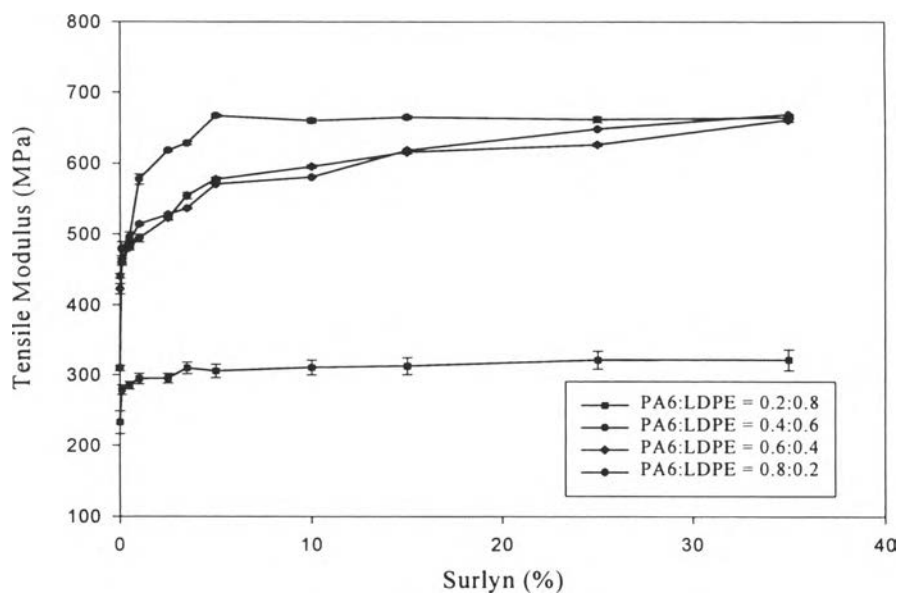


Figure 4.4 Effect of Surlyn[®] compatibilizer content on tensile modulus of compatibilized PA6/LDPE blends.

4.2.2 Impact Properties

4.2.2.1 *Blend of Nylon 6 and LDPE (without Compatibilizer)*

The relationship between impact strength and LDPE content is illustrated in Figure 4.5. The impact strength of the uncompatibilized blends was rapidly increased as the LDPE content increased. As LDPE increased, the phase which composed of LDPE absorb more energy than the phase which composed of nylon 6. This is due to more entanglement from the higher branches of LDPE, more energy required to move the entangled molecular chain.

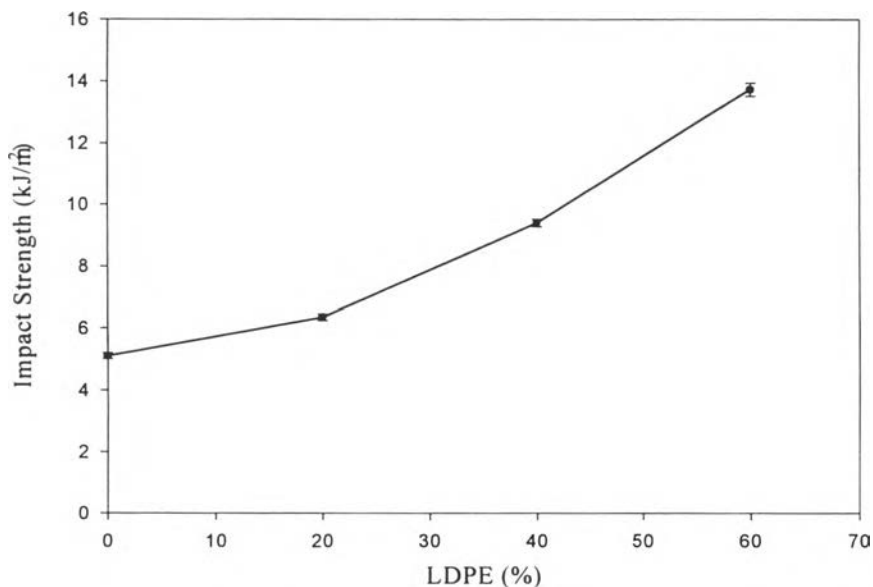


Figure 4.5 Effect of LDPE content on impact strength of uncompatibilized nylon 6/LDPE blends.

4.2.2.2 Blend of Nylon 6 and LDPE (with compatibilizer)

Impact strength of nylon 6/LDPE blends determined as a function of Surlyn[®] contents. The relationship between impact strength of different nylon 6/LDPE blends are illustrated in Figure 4.6. The rapid increased of impact strength of nylon 6/LDPE blend as the amount of Surlyn[®] increased was observed. This could be due to the ability of the compatible blend to absorb more energy. When the blend contained large amount of ionomer, the characteristic of the impact property of ionomer was dominant. The structure of ionomer contains clusters of ionic parts in LDPE matrix which make ionomer has high impact strength. Because at the point that ionic part was cluster, it composes of methacrylic part neutralized with zinc counter ion which could be act as the crosslinking point. In addition, at the cluster of ionic part, the divalent zinc atom might also act as the welding atom.

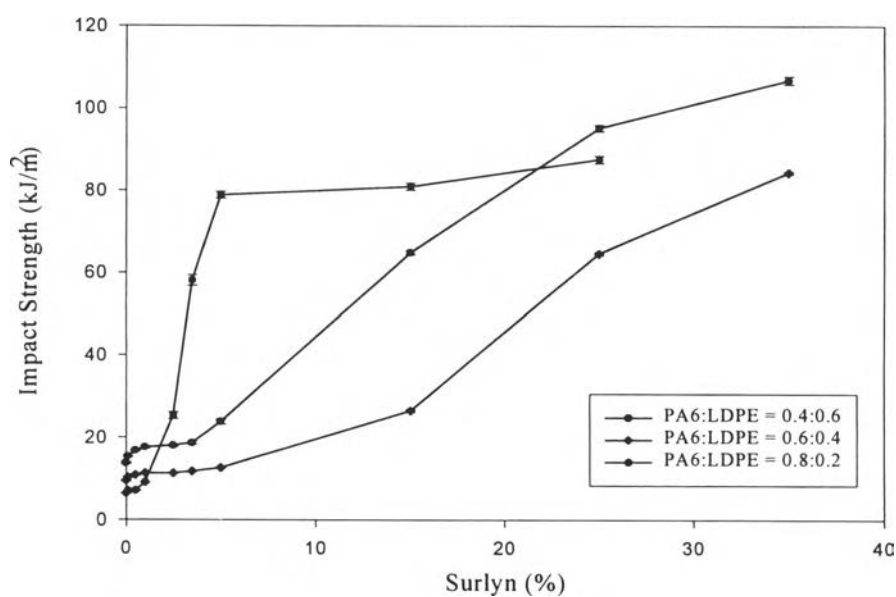


Figure 4.6 Effect of Surlyn[®] content on impact strength of compatibilized nylon 6/LDPE blends.

4.3 Physical Property

4.3.1 Blend of Nylon 6 and LDPE (without compatibilizer)

Hardness of the blends was studied in order to investigate the effect of LDPE contents of the blend. The hardness of uncompatibilized nylon 6/LDPE blends was rapidly decreased as the LDPE content increased. LDPE has short and long branches causing the density of LDPE to be lower than nylon 6 because the steric effect of the branch chains. Nylon 6 contains amide groups in the backbone, which can have some intermolecular hydrogen bonding and the chain of nylon 6 are linear chain, which can be tightly packed. These make the blends containing higher amount of nylon 6 harder than the blends containing higher amount of LDPE.

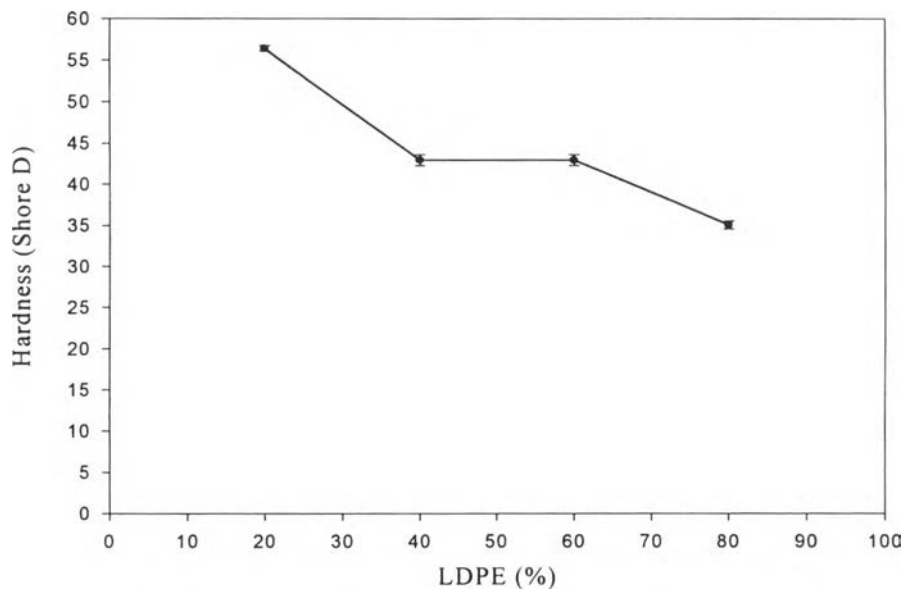


Figure 4.7 Effect of LDPE content on hardness of uncompatibilized nylon 6/LDPE blends.

4.3.2 Blend of Nylon 6 and LDPE (with Compatibilizer)

Hardness of nylon 6/LDPE blends determined as function of Surlyn[®] contents was studied. The relationship between hardness and LDPE content is illustrated in Figure 4.8. The hardness of nylon 6/LDPE blend was increased as the amount of Surlyn[®] increased. This is due to the increased in compatibility of the blends.

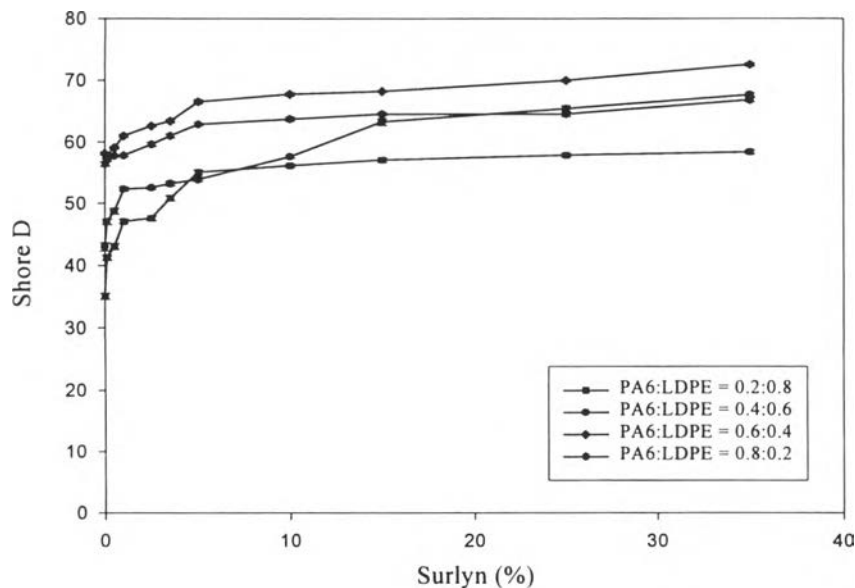


Figure 4.8 Effect of Surlyn[®] content on hardness of compatibilized nylon 6/LDPE blends.

4.4 Microstructure Characterization

Morphology of the blend is one of the most important thing, which can explain a lot of properties of the blend such as mechanical properties and physical properties. Scanning electron microscope (SEM) was used to study the morphology of these blends.

4.4.1 Effect of Blend Composition on Blend Morphology of Uncompatibilized Blends

Morphology of nylon 6/LDPE blends without compatibilizer were shown in Figure 4.9

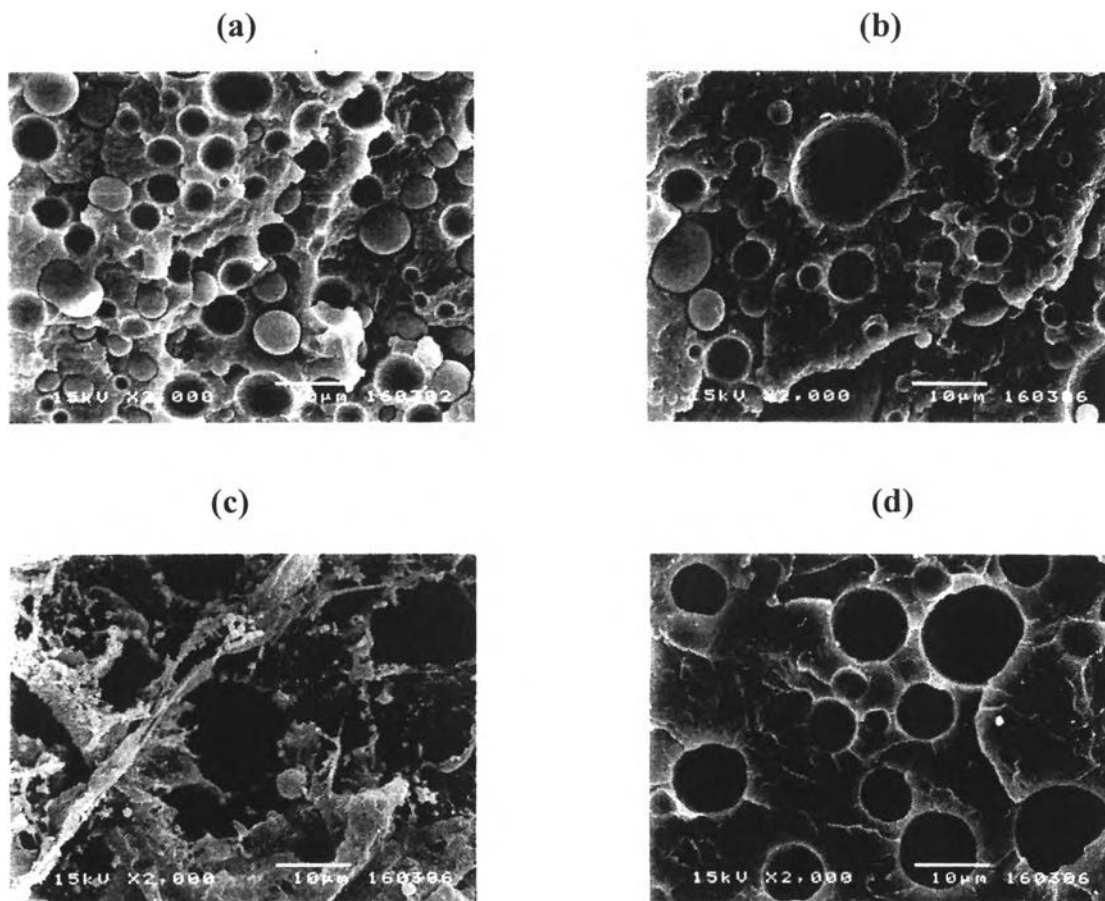


Figure 4.9 Effect of LDPE composition on Morphology of Nylon 6/LDPE blends at magnification 2000:
(a) 20 % of LDPE, (b) 40 % of LDPE, (c) 60 % of LDPE, (d) 80 % of LDPE.

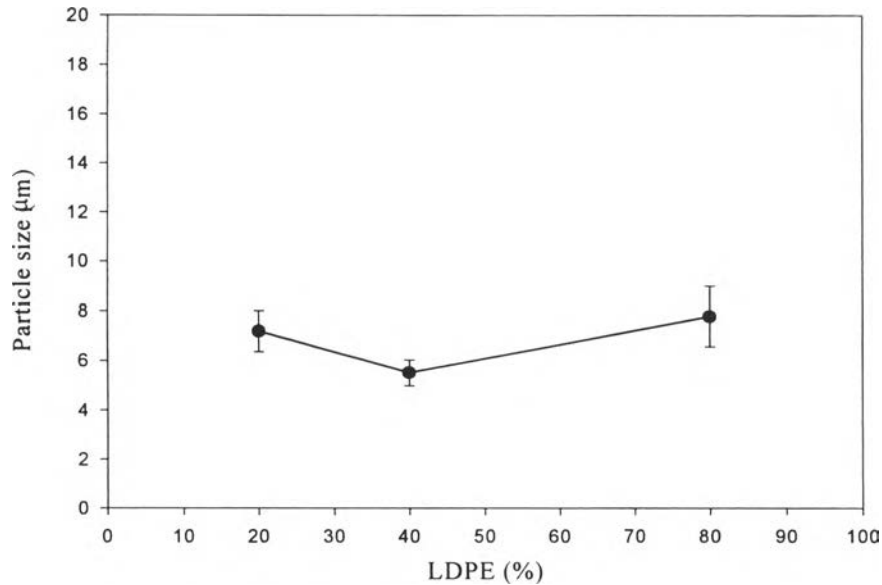


Figure 4.10 Effect of LDPE content on the particle size of uncompatibilized nylon 6/LDPE blend.

The SEM micrographes of uncompatibilized blends are shown in Figure 4.9. The compositions of the nylon 6/LDPE blends were varied from 20, 40, 60 and 80 % of LDPE. In the blend of nylon 6/LDPE which contained higher percentage of nylon 6 (LDPE was the dispersed phase). It was found that the particle size of the dispersed phase (LDPE) were smaller and finer than the blend which contains higher percentage of LDPE (nylon 6 is the dispersed phase) as shown in Figure 4.10

It was found that in the composition which contain nylon 6 as the dispersed phase (lower percentage of nylon 6), the trivial larger dispersed particle size than the other composition which contain LDPE as the dispersed phase (lower percentage of LDPE) was due to the lower viscosity of LDPE. Nylon 6 had higher viscosity than LDPE by reason of intermolecular hydrogen bonding of nylon 6 and the higher crystallinity of nylon 6 than LDPE. In

blending process, the dispersed phase, which had lower viscosity could be broken up easier than the one which had higher viscosity. So, the larger droplet was obtained in the composition containing nylon 6 as a dispersed phase.

4.4.2 Effect of Ionomer Compatibilizer on Blend Morphologies of Compatibilized blends

Morphology of compatibilized nylon 6/LDPE blends compared with uncompatibilized blend were shown in Figure 4.11 (LDPE as a dispersed phase) and 4.12 (nylon 6 as a dispersed phase) respectively. It is obvious that the presence of ionomer in these blends resulted in a decrease in the size of the dispersed phase. The dispersed particles size were reduced due to the ability of ionomer to reduced the interfacial tension between dispersed phase and matrix phase. The dipole-dipole interaction of the ionic cluster part of ionomer and the partially polar part of nylon 6 increased interfacial adhesion of the blend.

Comparing between Figure 4.11 and Figure 4.12 it was found that the extent of particle size reduction was more pronounced when nylon 6 was the dispersed phase. This may be related to the high affinity which ionomer has for polyamide.

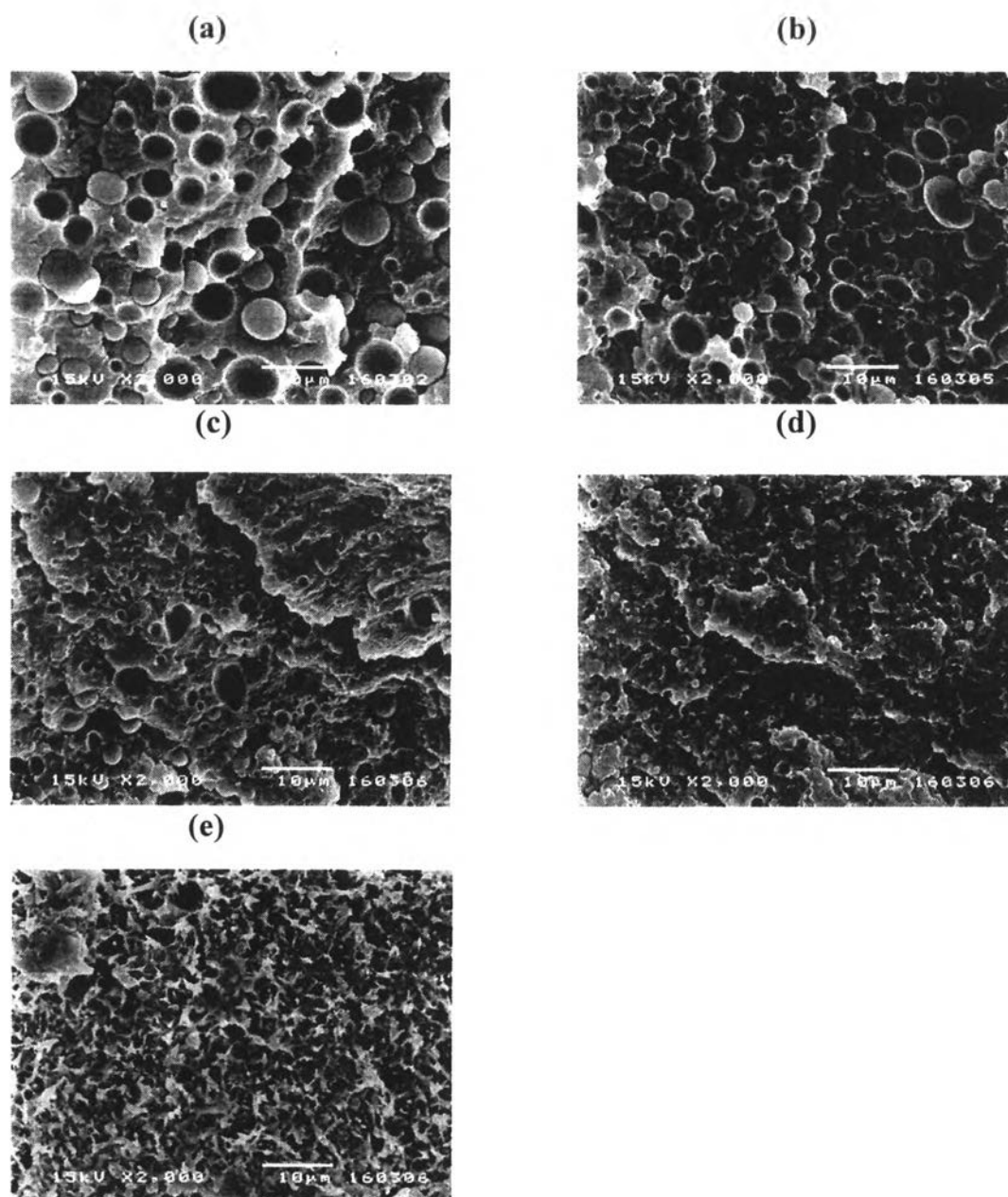


Figure 4.11 Effect of compatibilizer on morphology of Nylon 6/LDPE blend containing 80 % of nylon 6 and 20 % of LDPE (LDPE as a dispersed phase): (a) The uncompatibilized blend, (b) The compatibilized blend with 0.1 % Surlyn[®], (c) The compatibilized blend with 0.5 % Surlyn[®], (d) The compatibilized blend with 1.0 % Surlyn[®], (e) The compatibilized blend with 2.5 % Surlyn[®].

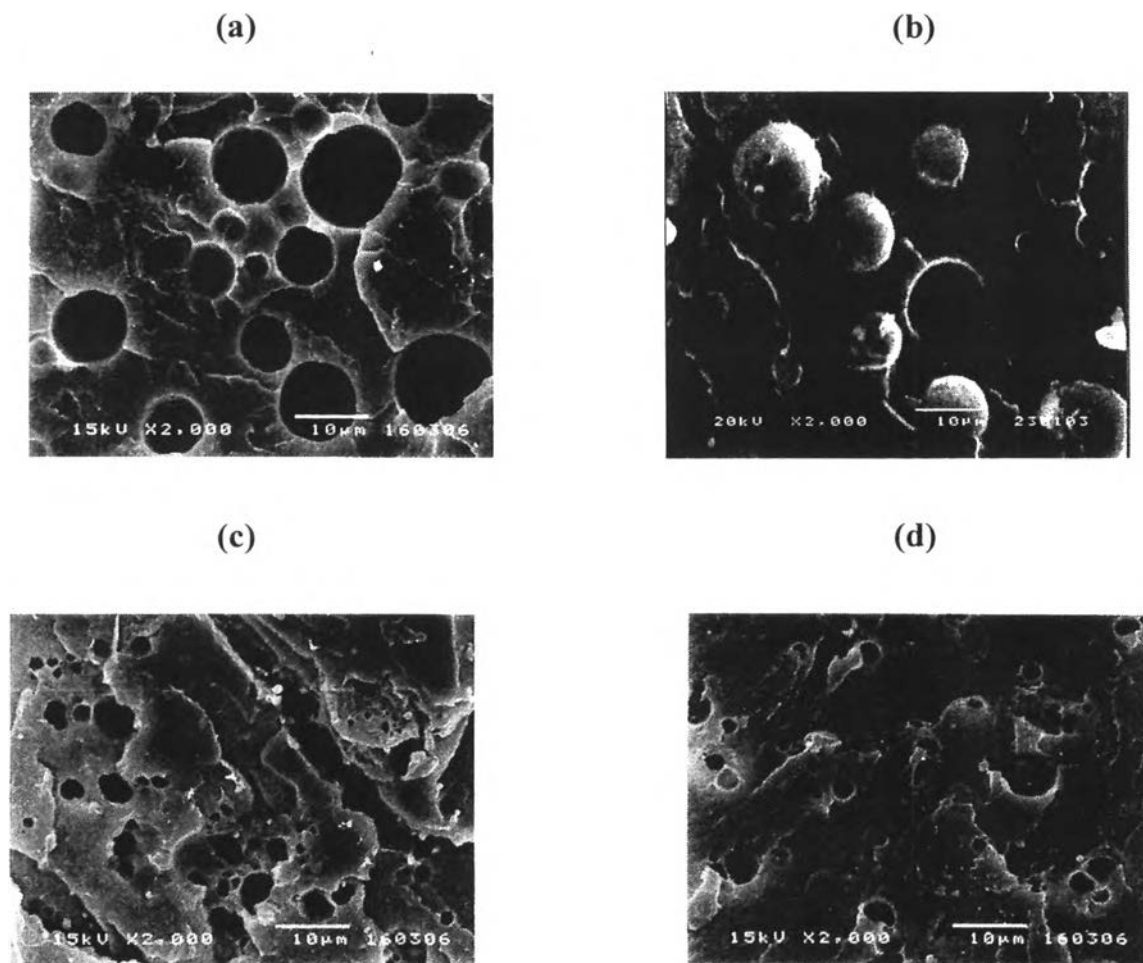


Figure 4.12 Effect of compatibilizer on morphology of nylon 6/LDPE blend containing 80 % of LDPE and 20 % of nylon 6 (nylon 6 is dispersed phase): (a) The uncompatibilized blend, (b) The compatibilized blend with 0.1 % Surlyn[®], (c) The compatibilized blend with 0.5 % Surlyn[®], (d) The compatibilized blend with 1.0 % Surlyn[®].

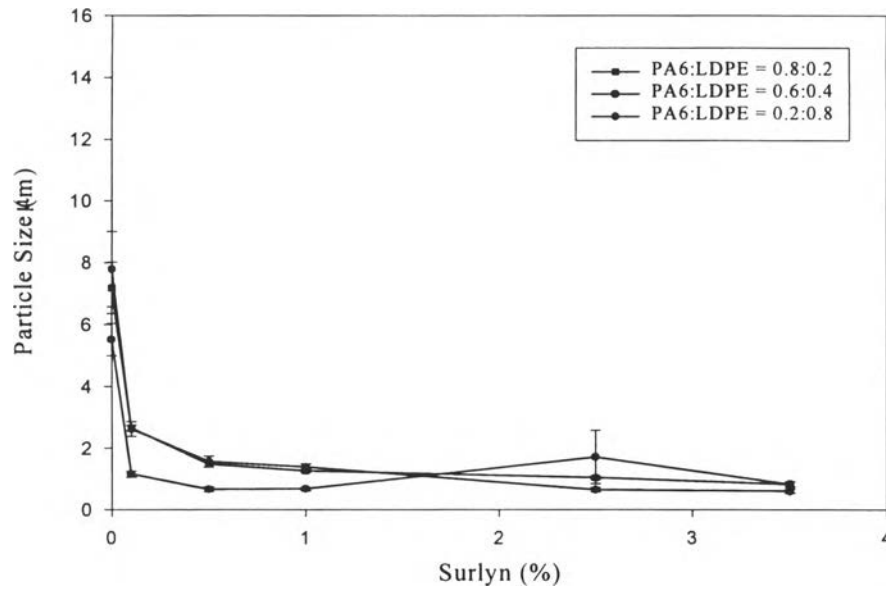


Figure 4.13 Effect of compatibilizer on morphology of compatibilized nylon 6/LDPE blends.

At around 1 % ionomer, there was no further decreased in particle size of compatibilized blends (for all blend compositions). From Figure 4.13. This is observed for all blend compositions. The dramatically decreased of particle size of dispersed phases as the content of ionomer compatibilizer increased until reached the plateau is due to the ability of the ionomer to reduce the interfacial tension between the dispersed phase and the matrix phase. 1 % weight of Surlyn[®] is the quantity of ionomer required to fully cover an interface.

4.5 Fourier Transform Infrared Spectroscopy (FT-IR)

Fourier Transform Infrared Spectroscopy (FT-IR) was used to probe the specific interpolymer interaction between Surlyn[®] ionomer and nylon 6/LDPE blends. The composition dependent perturbation of the metal and the amide groups.

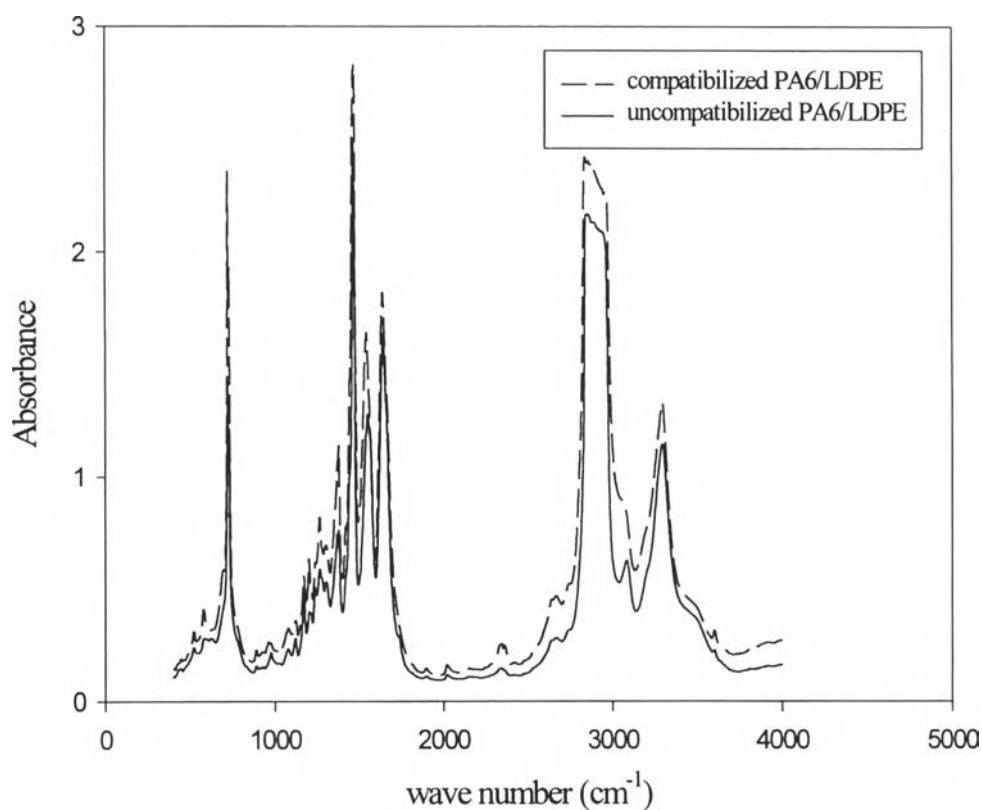


Figure 4.14 FTIR spectra of uncompatibilized and compatibilized nylon 6/LDPE blends.

The FT-IR spectra of uncompatibilized and compatibilized blend of nylon 6 and LDPE were relatively similar in every wave number as shown in

Figure 4.14. There was no chemical interaction between ionomer and the blend. The interaction of compatibilizer and the two polymers are both dipole-dipole interaction and hydrophobic interaction. The ionic parts of ionomer, which contain methacrylic acid neutralized with zinc counter ions, could have dipole-dipole interaction with partially polar part of nylon 6.