



## CHAPTER IV RESULTS AND DISCUSSION

### Characteristic of ESCOR<sup>®</sup> 310/EAs Blends

The mechanical characteristics of ESCOR<sup>®</sup> 310/EAs blends were ascertained by measuring tensile properties, hardness, and gloss. The processing characteristics of these blends were ascertained by measuring storage modulus, loss modulus, melting temperature, and crystallization temperature. The crystal structures of these polymer blends were also studied using X-ray diffraction (XRD).

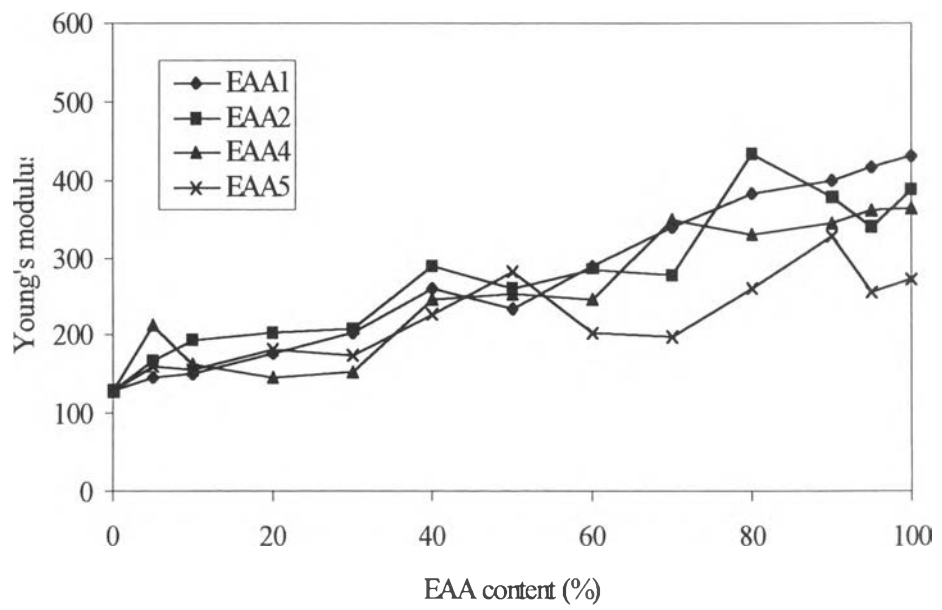
### 4.1 Mechanical Properties

#### 4.1.1 Tensile Properties

The tensile properties determined as a function of EAA content were Young's modulus, tensile strength at break, and elongation at break.

##### 4.1.1.1 *Young's modulus*

Young's modulus is primarily a function of percent crystallization and the amount of orientation. (George O.,1991).

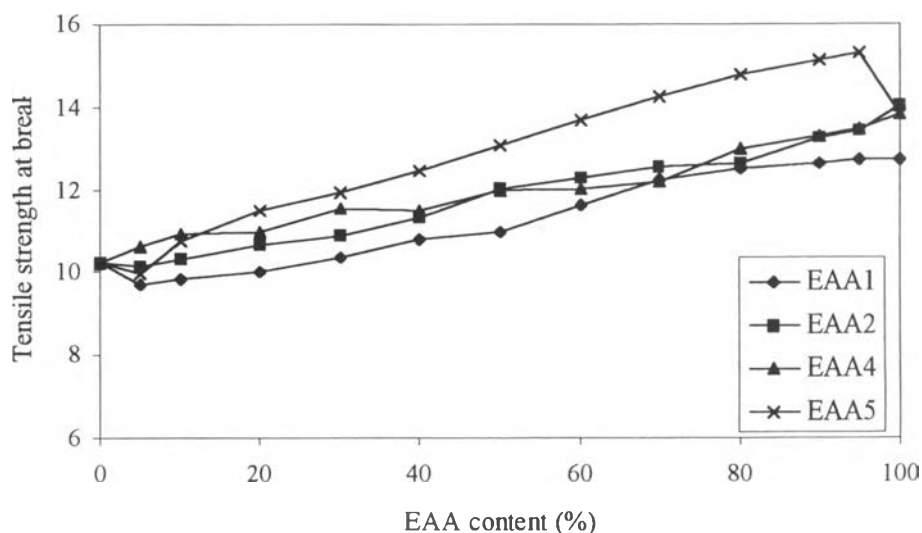


**Figure 4.1** Young's modulus of blends of ESCOR<sup>®</sup>310/EAA's.

It is evident from Figure 4.1 that Young's modulus of the blends increased slightly with EAA content, indicating higher resistance to deformation. ESCOR<sup>®</sup> 310/EAA2 at 80 %wt EAA2 content showed synergistic property, which can be explained by high percent crystallinity as was determined by X-ray diffraction measurement. The blend at 80%wt of EAA2 content showed the highest percent crystallinity.

In previous work by Worakanya *et al.*, The Young's modulus of ESCOR<sup>®</sup> 320/EAA's blends also increased with increasing EAA content. Synergistic behavior was exhibited by the ESCOR<sup>®</sup> 320/EAA2 at 90% wt and 95% wt EAA2 content.

#### 4.1.1.2 Tensile strength at break

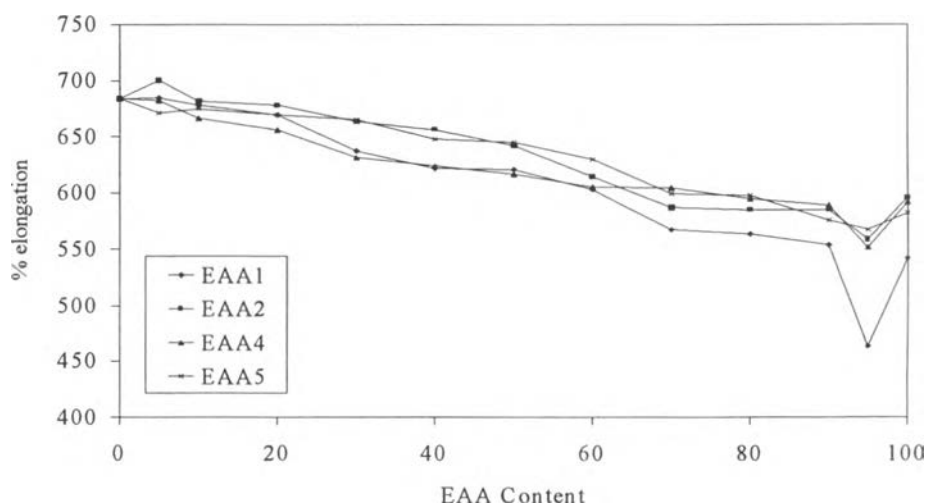


**Figure 4.2** Tensile strength at break of blends of ESCOR<sup>®</sup>310/EAA.

Figure 4.2 indicates that the tensile strength at break increased as the amount of EAA increased starting from 0% wt to 100% wt of EAA content. The tensile strength at break of the blends are intermediate to those of the pure components, but the EAA5 blends almost universally showed synergistic behaviors. This behavior occurs due to a result of greater interaction between the blend constituents. These observations are similar to that observed by Mohanty and co-workers in the case of the mechanical properties based on polymer blends of Epoxidized natural rubber (ENR) and poly(ethylene acrylic acid) (PEA). It has been reported that tensile strength and young's modulus of the blends gradually increased as increasing PEA content and exhibited a synergism behavior that calculated via the additivity rule due to increasing in the presence of interaction between molecule components. Peiffer D.G. *et al.*, demonstrated that the blend of carboxylated nitrile rubber (NBR) and poly(ethylene-co-methacrylic acid) (EMA) showed synergism in tensile strength, which may be ascribed to the formation of a technologically compatible polyblends, wherein intermolecular interactions assist in compatibilization.

Results from ESCOR<sup>®</sup>310/EAA blends were consistent with results from Worakanya *et al.* (ESCOR<sup>®</sup>320/EAA blends).

#### 4.1.1.3 Elongation at break

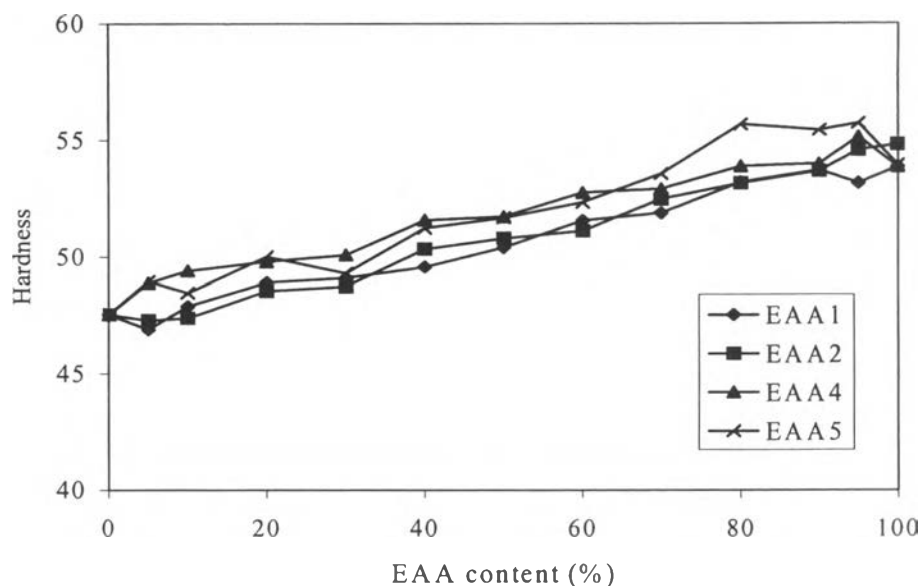


**Figure 4.3** Elongation at break of blends of ESCOR<sup>®</sup>310/EAA.

Elongation at break presented a monotonically decrease from 0% wt to 95% wt of EAA content as shown in Figure 4.3. It implies that the blends become very brittle as the EAA content increases. These observation might be proposed that the addition of EAAs content to ESCOR<sup>®</sup>310 exhibited the increase of presence of inhomogeneity in the blends.

#### 4.1.2 Hardness

Hardness or the resistance to local deformation defines the ease with which a material can be indented, drilled, sawed, or abraded. It involves a complex combination of properties (elastic modulus, yield strength). It can be important for assessing product quality and uniformity and is used in identification, classification, and quality control (McKnight W.J., 1983).

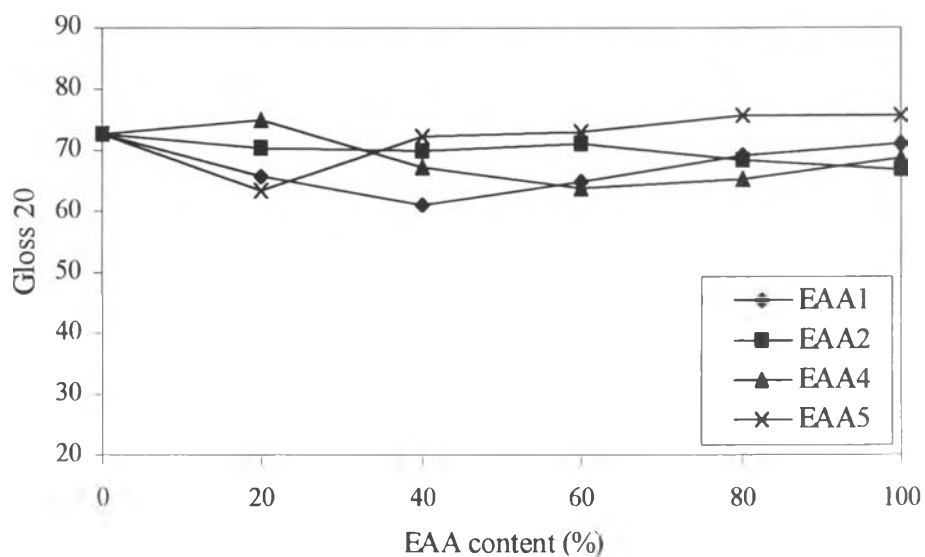


**Figure 4.4** Shore-D hardness of blends of ESCOR<sup>®</sup>310/EAA5.

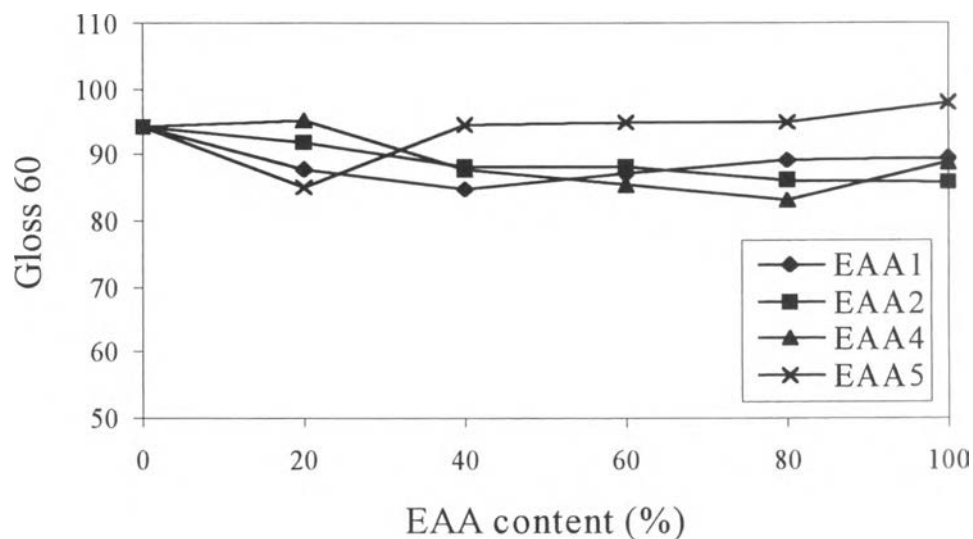
Figure 4.4 shows result from the hardness test of the blends measured on the shore-D scale. It is noticed that hardness gradually increased as EAA content increased. Some synergistic behaviors were shown in the blends made with EAA5, particularly at high EAA content. The hardness increase usually parallels the increase in stiffness; both measurements are related to the crystallization of the blends. From X-ray diffraction data, the percent crystallinity of these blends exhibited monotonically increased from 0% wt to 100% wt of EAA content. Similar observations have been made earlier by Worakanya *et al.* showed that hardness of ESCOR<sup>®</sup> 320/EAA5 blends increased as EAA content increased. It was suggested that this observation was due to increasing of hydrogen bonding between the components.

### 4.1.3 Gloss

Gloss is a measure of the relative reflectance of a surface in the direction of greatest intensity. The relative reflectance of a surface is mainly dependent on surface roughness (Painter P.C., 1997).



**Figure 4.5a** Gloss 20 of blends of ESCOR<sup>®</sup>310/EAA5.



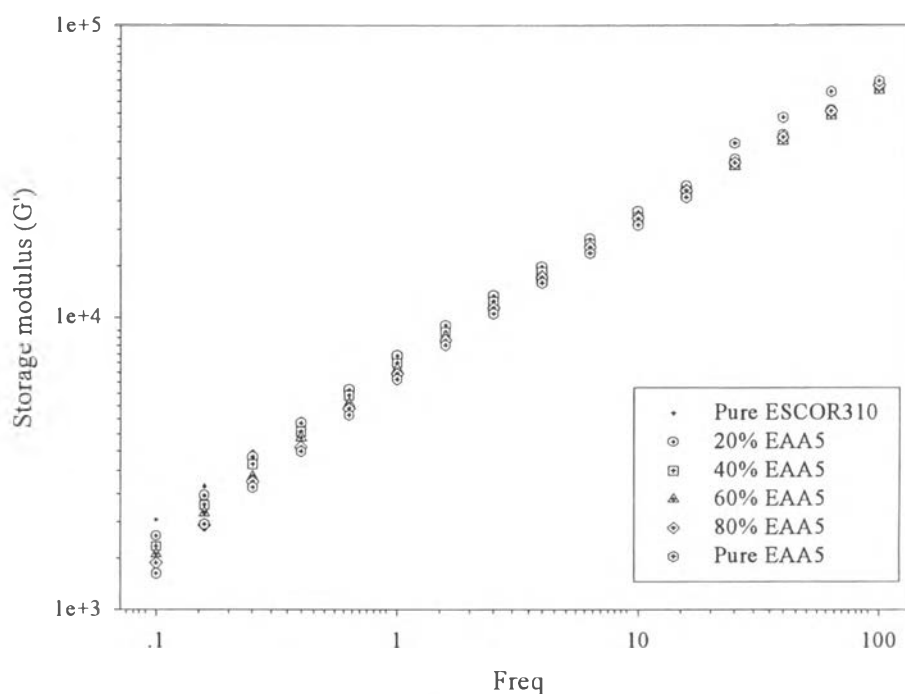
**Figure 4.5b** Gloss 60 of blends of ESCOR<sup>®</sup>310/EAA5.

The effect of EAA content on gloss of polymer blends is shown in Figure 4.5(a-b). The behavior of the gloss is difficult to rationalize, in most cases the blends are lower than the two homopolymers while in some cases the gloss is higher than in the two homopolymers. Typically, high gloss materials are more highly valued, so decreased in gloss of ESCOR<sup>®</sup>310/EAA5 blends was not desired. A one-phase non-crystalline material would presumably have the highest gloss, so the gloss drops probably indicates phase separation. However there are a few samples in which the gloss is actually higher than either pure components such as ESCOR<sup>®</sup>310/EAA5 blend at 80 %wt of EAA5 content suggesting the possible miscibility of these blends. A similar observation from a previous work was reported by Worakanya *et al.* for blends of ESCOR<sup>®</sup>320 and EAAs copolymers, which exhibited positive trend with EAA ratio in the blend increased, indicating the decrease in phase separation.

#### **4.2 Rheological Measurement**

A major portion of all the polymer shaping operations processing and elementary steps involves flow of polymer melts. It is appropriate to examine separately the rheological (flow) behavior of polymer melts in simple flow situations. The experiment method that yield the rheological information needed to characterize polymer melt flow behavior in simple flows.

ESCOR<sup>®</sup>310/EAA5 blends containing 0, 20, 40, 60, 80, and 100% wt of amount of EAA5 were chosen to study their storage modulus, loss modulus by ARES Rheometer.

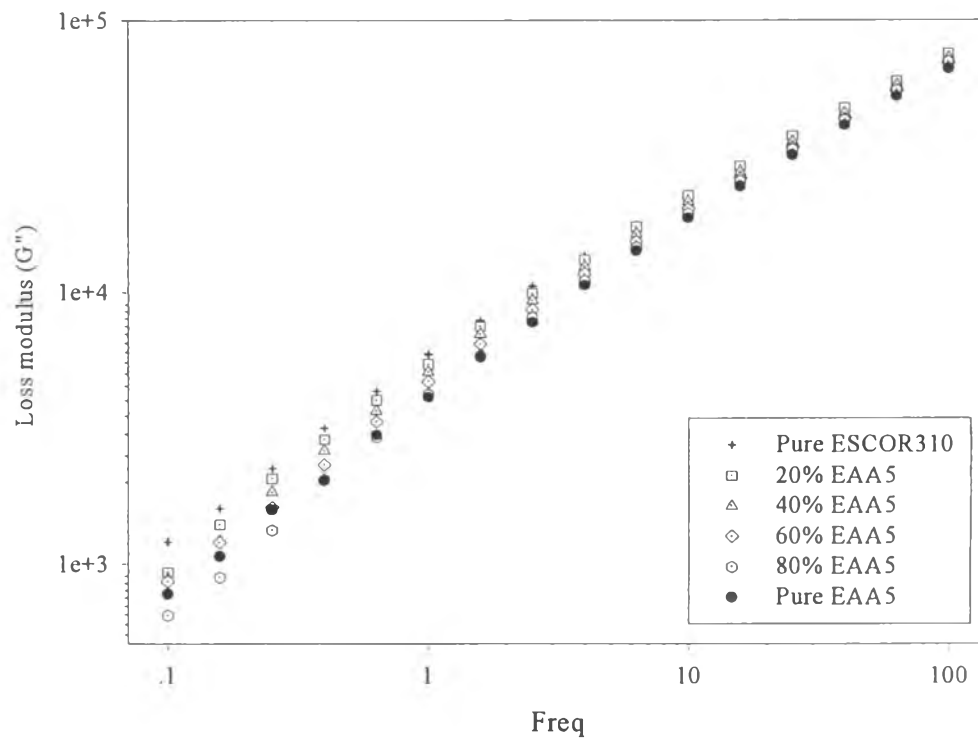


**Figure 4.6a** Shear storage modulus  $G'$  as a function of frequency.

Figure 4.6a shows  $G'$  as a function of frequency for the ESCOR<sup>®</sup>310/EAA5 blends of 0.2, 0.4, 0.6, and 0.8 EAA5 composition (ESCOR<sup>®</sup>310/EAA5 (80/20), (60/40), (40/20), and (20/80) blends) as well as for the pure materials for comparison. The  $G'$  of the blends lie between values of  $G'$  for pure ESCOR<sup>®</sup>310 and pure EAA5, but ESCOR<sup>®</sup>310/EAA5 (20/80) blends are inferior the value of  $G'$  for pure EAA5 at frequencies below 1.0 rad/s. The comparison between pure materials and polymer blends revealed that  $G'$  does not change much with the addition amount of EAA5 content, indicating the storage modulus during mixing of pure materials and polymer blends are almost the same.

It is also apparent that  $G'$  increased with increasing frequency. This suggestion that high frequency makes the polymer stiffer, thus resulting in a higher  $G'$ .





**Figure 4.6b** Shear loss modulus  $G''$  as a function of frequency.

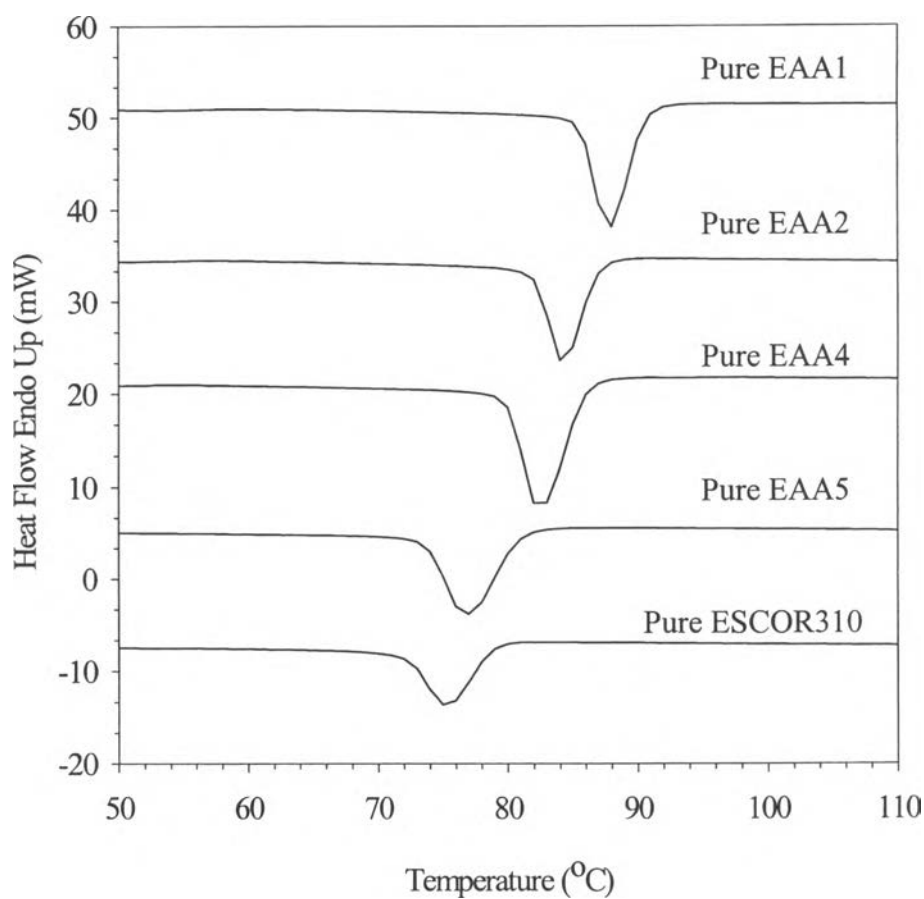
Shear loss modulus  $G''$  as a function of frequency is shown in figure 4.6b. The  $G''$  of all ESCOR<sup>®</sup>310/EAA5 blends lie between the values of  $G''$  for pure ESCOR<sup>®</sup>310 and pure EAA5, but at high frequencies the values are nearly equal to pure components. This is indicated that the addition of EAA5 to ESCOR<sup>®</sup>310 does not have much effect to shear loss modulus during mixing compared to pure components.

### 4.3 Thermal Analysis

#### 4.3.1 Differential Scanning Calorimetry

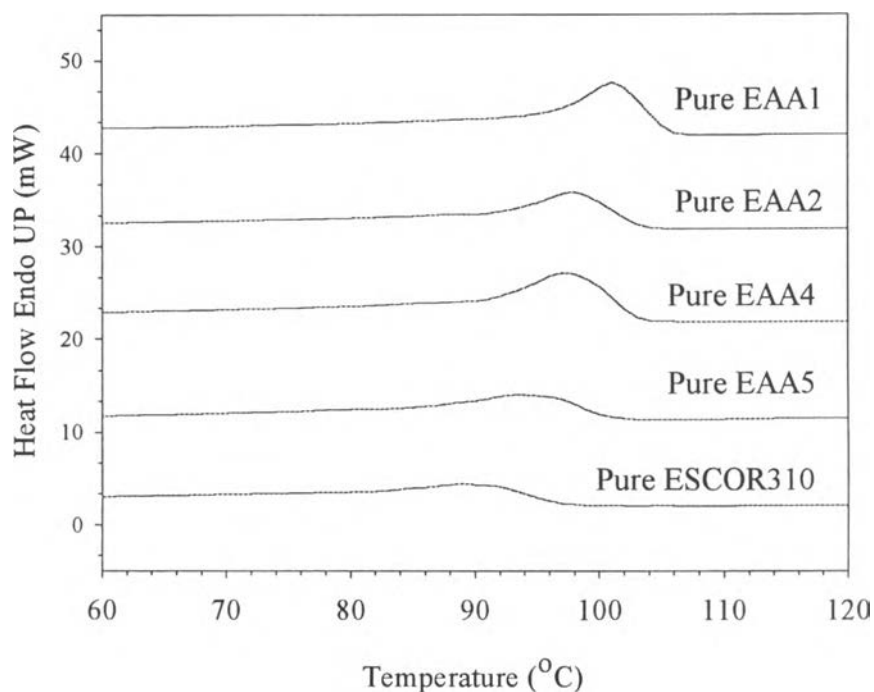
Differential scanning calorimetry was used to determine the crystallization temperature ( $T_c$ ), and melting temperature ( $T_m$ ) of ESCOR<sup>®</sup> 310 terpolymer and EAA copolymer blends.

##### 4.3.1.1 *Crystallization temperature ( $T_c$ ) and melting temperature ( $T_m$ )*



**Figure 4.7a** DSC crystallization curves of pure EAA1, EAA2, EAA4, EAA5 and pure ESCOR<sup>®</sup>310.

From Figure 4.7a shows crystallization curves of pure components from high to low temperature that are EAA1(87.8 °C), EAA2(84.2 °C), EAA4(82.5°C), EAA5(76.6 °C), and ESCOR<sup>®</sup>310(75.3 °C) respectively. EAA1 crystallized at the highest temperature; indicating the fastest rate. The crystallization rate depends on molecular structure of polymer. The minor monomer of random polymer acts as impurity, which acts as crystal defect. If the minor monomer content in the polymer chain is large, thinner thickness of crystals will result having low crystallization temperature (Pitt, 1999). As mention, all studied polymers are random co-and terpolymer. Hence, EAA1 probably has the lowest of acrylic acid. ESCOR<sup>®</sup>310 terpolymer consists of 13% of minor monomers that are acrylic acid and methyl acrylate. In other word, ESCOR<sup>®</sup>310 has 13% total defect content of forming crystal; resulting in the lowest crystallization temperature than other pure components. These observations suggest the amount from low to high of acrylic acid in EAA copolymers are probably to EAA1, EAA2, EAA4, and EAA5 respectively and all of EAA copolymers have the amount of acrylic acid less than 13%.



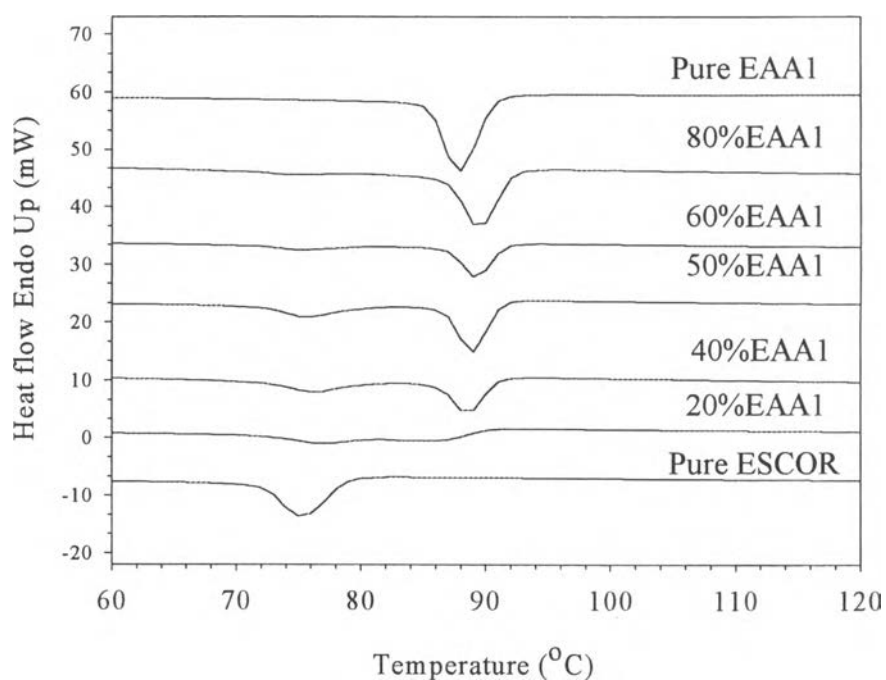
**Figure 4.7b** DSC melting curves of pure EAA1, EAA2, EAA4, EAA5 and pure ESCOR<sup>®</sup>310.

Melting temperature depends on thickness of crystal form during the cooling condition and total defect content of forming crystal are also effects to crystallization temperature. From Gibbs-Thomson Equation;

$$T_m = T_m^\circ (1 - (2\sigma / l\Delta H_f^\circ))$$

( $\sigma$  is the fold surface free energy,  $l$  is the crystal thickness or lamellae thickness, and  $\Delta H_f^\circ$  is the enthalpy of fusion) shows that melting temperature of polymers is proportional to the thickness of crystal in homopolymer. (Pitt, 1999) or alternatively the melting temperature is a inversely function of acrylic acid content. (Agarwal P.K., 1989). Figure 4.7b shows DSC melting curves of pure components. EAA1 and ESCOR<sup>®</sup>310 showed the highest and lowest melting temperature at 101.1 °C, and 88.9 °C respectively. EAA1 probably has the thickest of crystal thickness corresponding to the result of lowest amount of defect content of forming crystal whereas ESCOR<sup>®</sup>310 probably has the thinnest of crystal thickness. EAA2, EAA4,

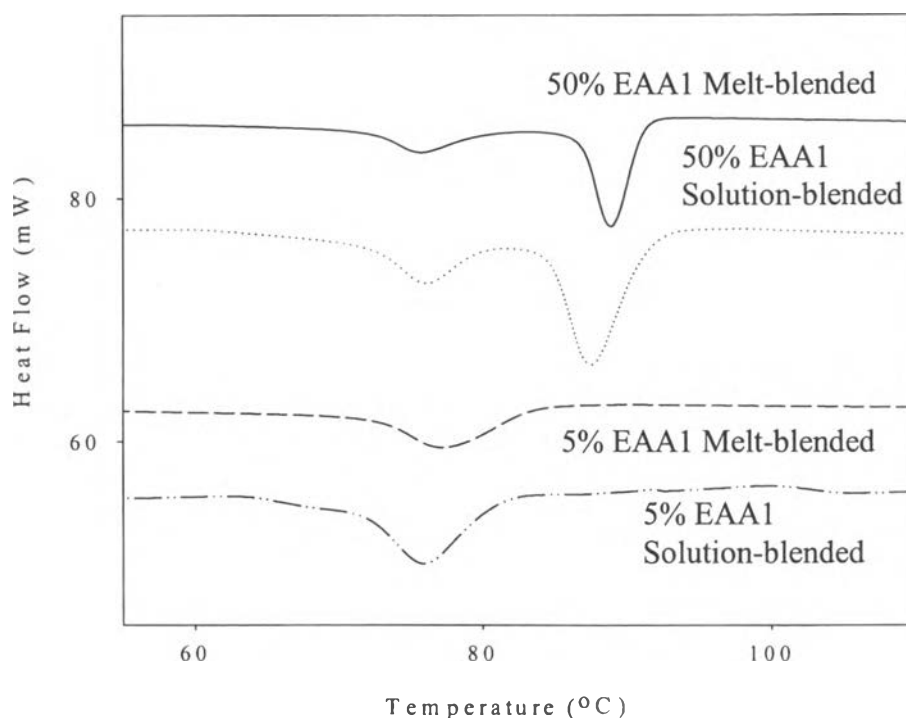
and EAA5 showed intermediate values with EAA1 and ESCOR<sup>®</sup>310, which are 97.8 °C, 97.3 °C, and 93.8 °C respectively. This appearance also is relates to their crystallization results.



**Figure 4.8** DSC crystallization curves of ESCOR<sup>®</sup>310/EAA1 blends at 0, 20, 40, 50, 60, 80, and 100%wt EAA1 content.

Figure 4.8 shows typical crystallization curves for blends of ESCOR<sup>®</sup>310 and EAA1. The curve at the top represents pure EAA1, which is the highest crystallization temperature, and the curve at the bottom corresponds to pure ESCOR<sup>®</sup> 310, which is the lowest crystallization temperature. The intermediate curves correspond to blends containing 80, 60, 50, 40, and 20% wt of EAA1 content that showed intermediate crystallization temperatures between pure components. It is obviously seen that ESCOR<sup>®</sup>310/EAA1 blends at 60, 50, 40, and 20% wt of EAA1 content exhibited two crystallization temperatures. This observation might be due to phase separation or possible an artifact from blending efficiency. In order to clarify this occurrence, blends (ESCOR310/EAA1 at 5% wt and 50% wt of EAA1 content)

were prepared by solution blending and studied at the same conditions compared results to melt blending preparation.

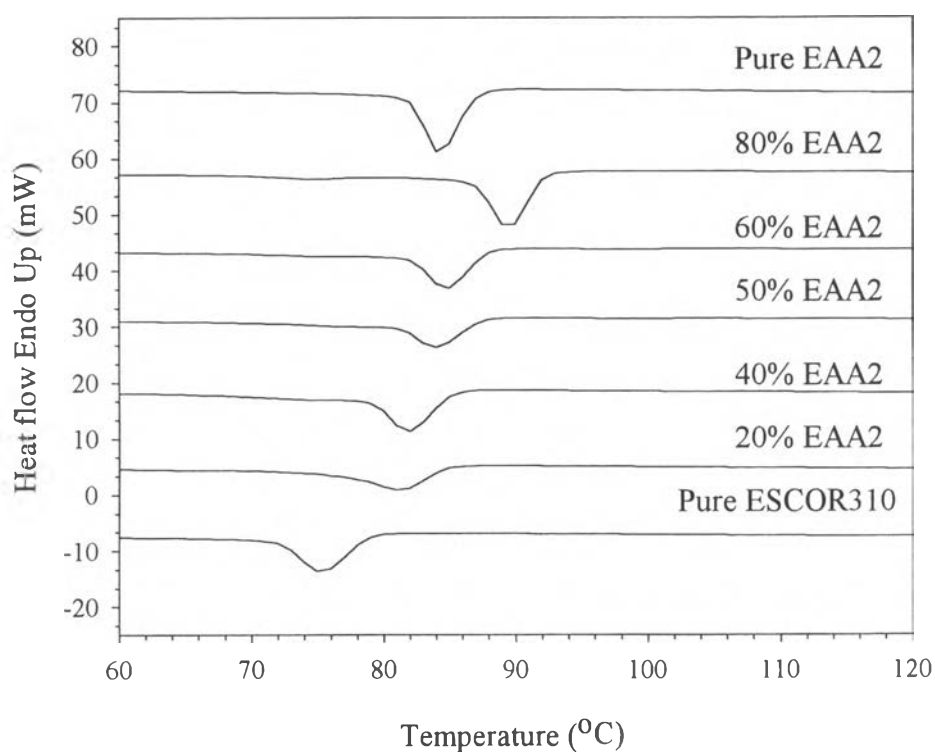


**Figure 4.9** Comparison of DSC crystallization curves of ESCOR<sup>®</sup>310/EAA1 at 5, and 50% wt of EAA1 content that were prepared by melt blending and solution blending.

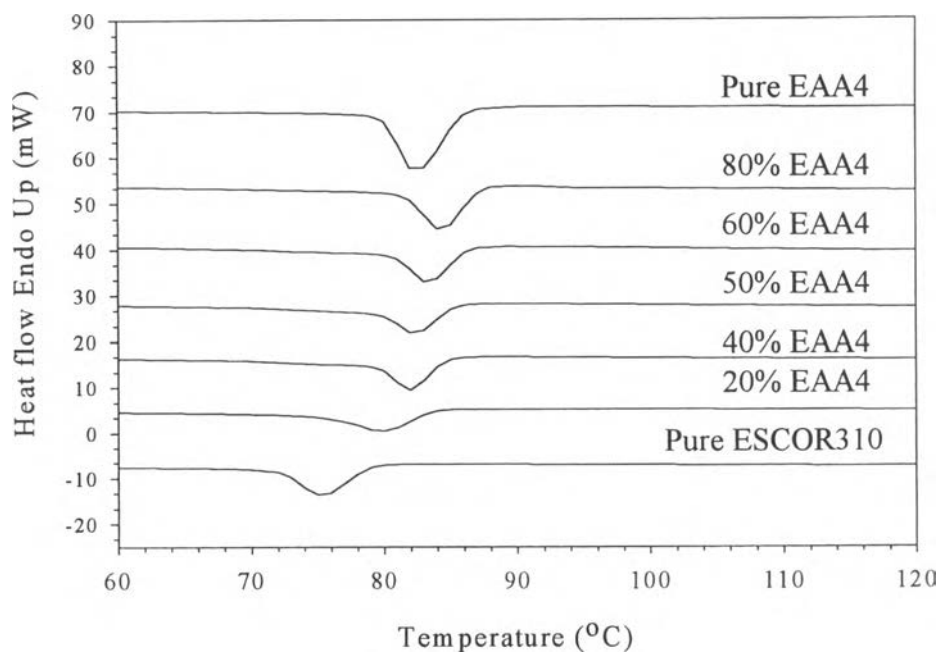
Crystallization curves of ESCOR<sup>®</sup>310/EAA1 blends at 5% wt, and 50% wt of EAA1 content prepared by melt blending and solution blending are shown in figure 4.9. The preparation procedure of the solution-blended between ESCOR<sup>®</sup> 310 and EAA1 was started by dissolving ESCOR<sup>®</sup> 310 terpolymer and EAA1 in xylene:butanol (3:1) at 100 °C. Then the blends were precipitated by pouring the solution into ethanol, filtering and drying at room temperature for a day.

It is clear that both melt-blended and solution-blended of ESCOR<sup>®</sup>310/EAA1 containing 50% wt of EAA1 showed two crystallization peaks at slightly different crystallization temperatures. . Hence blending efficiency is not the source of the two peaks; these materials are clearly not thermodynamically miscible. The blend

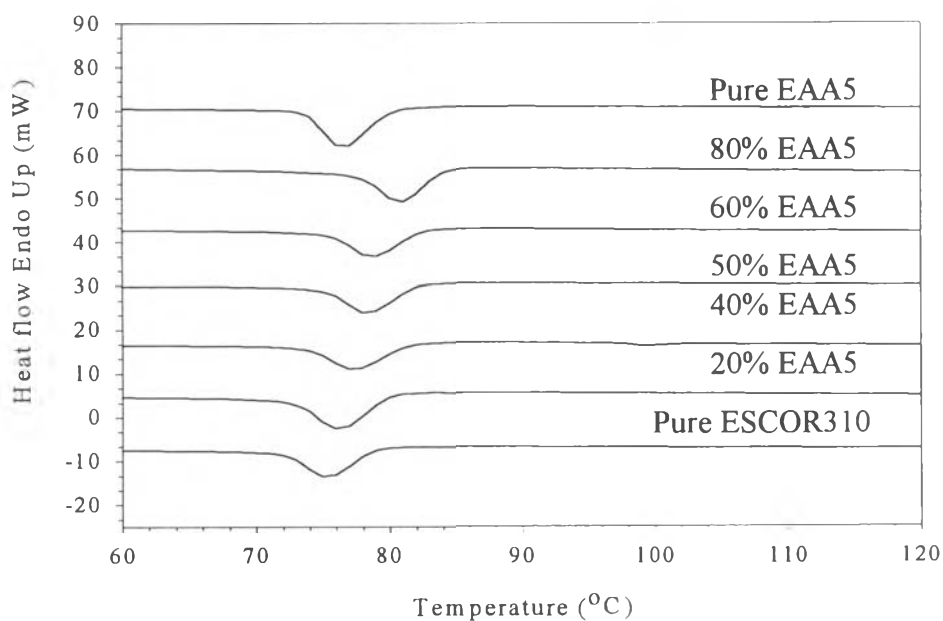
ESCOR<sup>®</sup>310/EAA1 at 5% wt of EAA1 exhibited one crystallization peak in both of two method preparations; however given the small amount of the EAA1 it is still possible this material is phase separated; the enthalpy associated with this peak is necessarily small and might not be noticeable above the baseline.



**Figure 4.10a** DSC crystallization curves of ESCOR<sup>®</sup>310/EAA2 blends at 0, 20, 40, 50, 60, 80, and 100%wt EAA2 content.



**Figure 4.10b** DSC crystallization curves of ESCOR<sup>®</sup>310/EAA4 blends at 0, 20, 40, 50, 60, 80, and 100%wt EAA4 content.

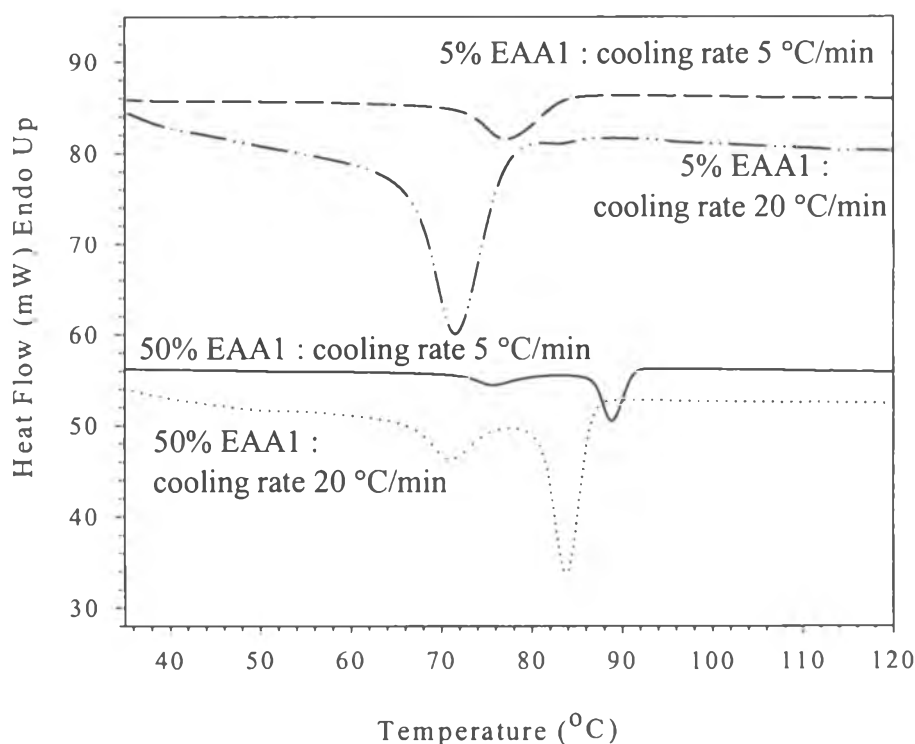


**Figure 4.10c** DSC crystallization curves of ESCOR<sup>®</sup>310/EAA5 blends at 0, 20, 40, 50, 60, 80, and 100%wt EAA5 content.



Figure 4.10 (a-c) show typical crystallization curves of ESCOR<sup>®</sup>310/EAA2, EAA4, and EAA5 blends. It could be seen that these blends exhibited single crystallization peak due to their co-crystallization; indicating the miscibility of these blends. Some blends such as ESCOR<sup>®</sup>310/EAA2, EAA4, and EAA5 at 80% ,60%, 50%, and 40% wt of EAAs content presented higher crystallization temperature than those of pure components. It was proposed the increase of interaction between blend components of these blends.

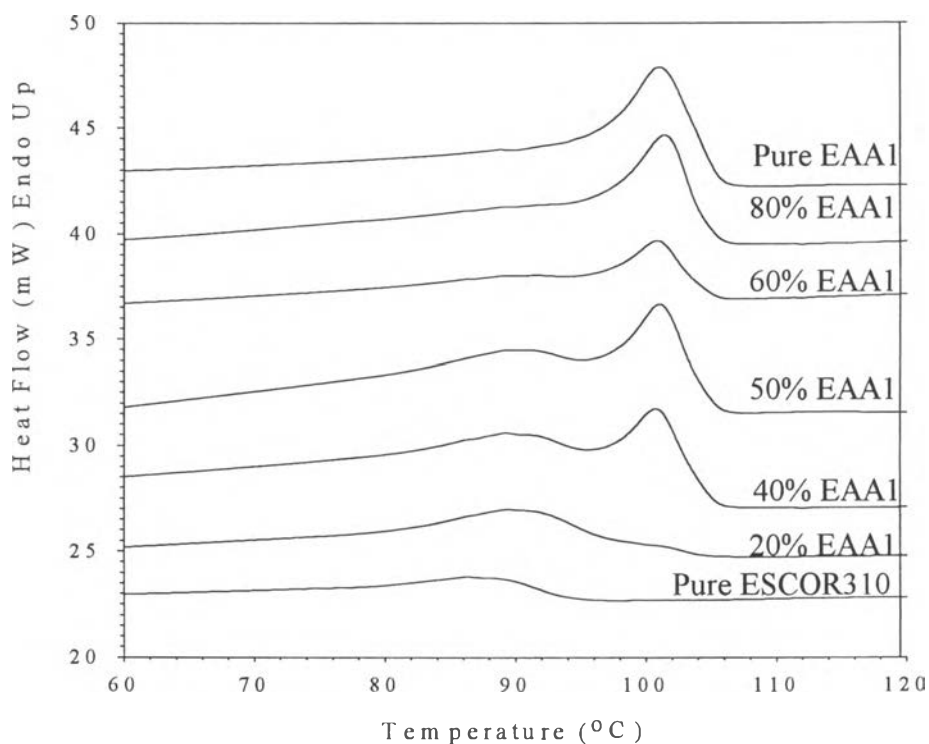
In order to study effect of cooling rate to crystallization peak, ESCOR<sup>®</sup> 310/EAA1 at 5, and 50% wt of EAA1 content were chosen to study.



**Figure 4.11** Effect of cooling rate to DSC crystallization curves of melt-blended ESCOR<sup>®</sup>310/EAA1 at 5, and 50% wt EAA1 content.

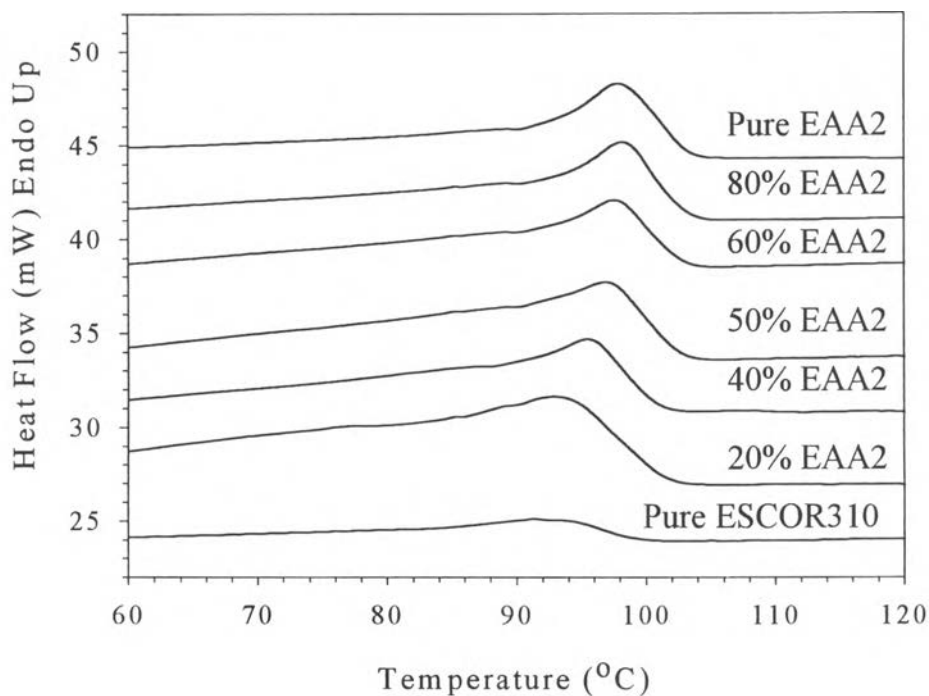
Compared to the both of melt-blended and solution-blended of ESCOR<sup>®</sup> 310/EAA1 at 5 and 50% wt EAA1 content, the crystallization peaks of these blends using 20 °C/min of cooling rate exhibited lower crystallization temperature and

sharper peak than those of blends using 5 °C/min of cooling rate as shown in figure 4.11.

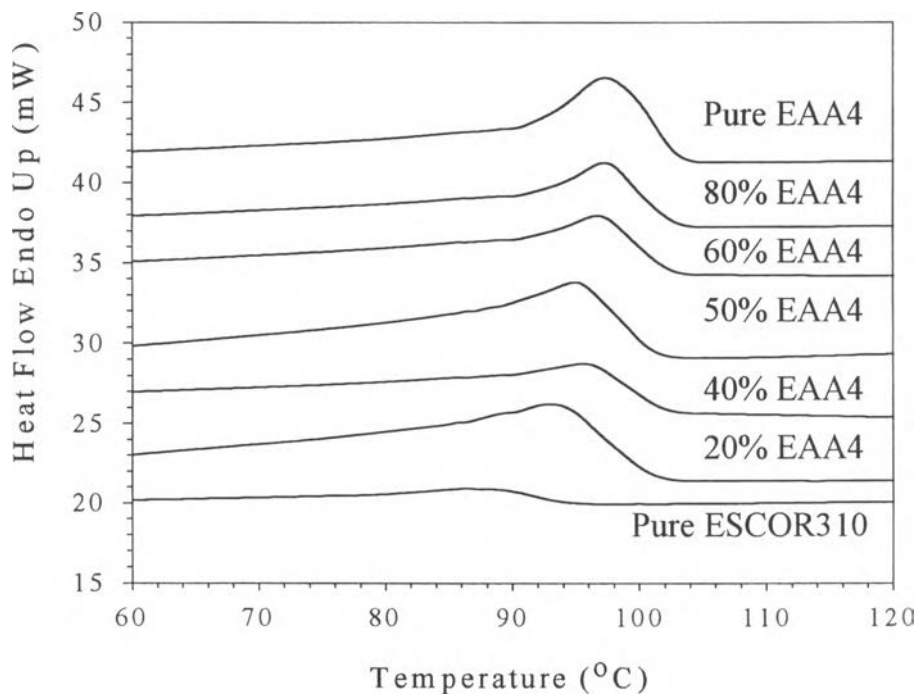


**Figure 4.12a** DSC melting curve of ESCOR<sup>®</sup>310, EAA1, and ESCOR<sup>®</sup>310/EAA1 blends containing 20, 40, 50, 60, and 80 %wt EAA1.

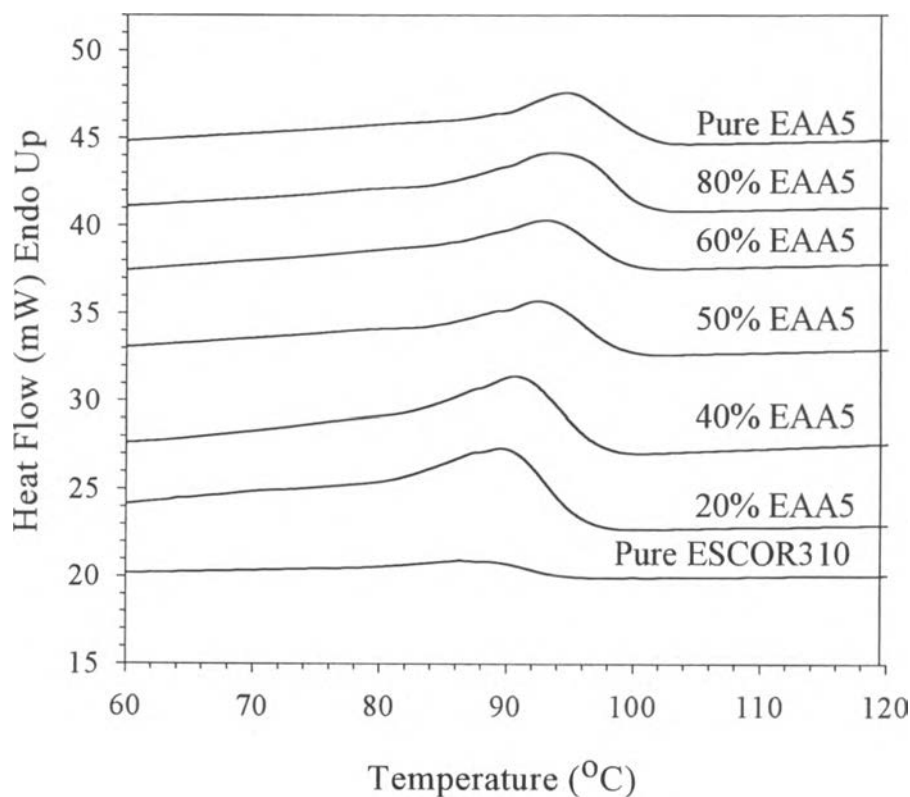
Figure 4.12a shows typical DSC results in the melting region for blends of ESCOR<sup>®</sup>310 and EAA1. The upper most curve represents the thermogram of pure EAA1, and the lower most represents that of pure ESCOR<sup>®</sup>310. The intermediate curves correspond to blends containing 80, 60, 50, 40, and 20% wt of EAA1. The blends at 50, 40, and 20% of EAA1 content showed two melting peaks indicating that the distribution of crystal thickness is bimodal, i.e. the polyethylene from ESCOR<sup>®</sup>310 form a separate crystalline phase from the polyethylene in the acrylic acid copolymer.



**Figure 4.12b** DSC melting curve of ESCOR<sup>®</sup>310, EAA2, and ESCOR<sup>®</sup>310/EAA2 blends containing 20, 40, 50, 60, and 80 %wt EAA2.



**Figure 4.12c** DSC melting curve of ESCOR<sup>®</sup>310, EAA4, and ESCOR<sup>®</sup>310/EAA4 blends containing 20, 40, 50, 60, and 80 %wt EAA4.



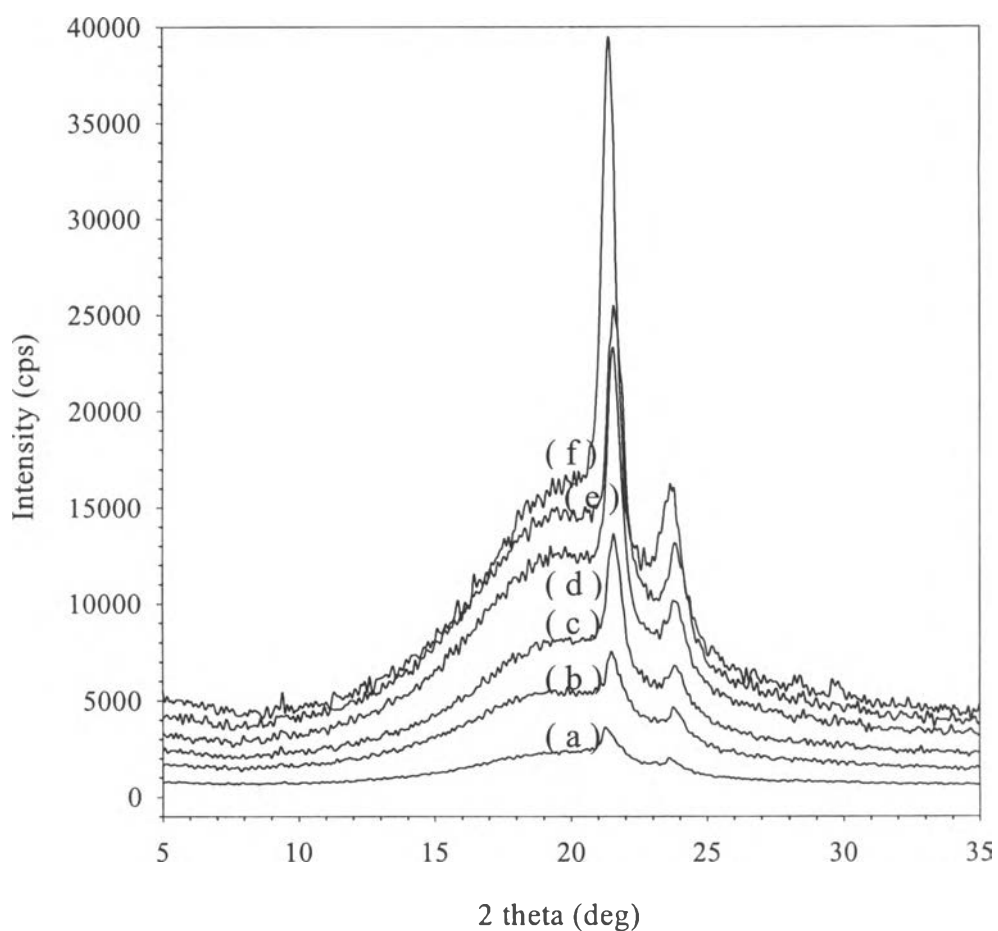
**Figure 4.12d** DSC melting curve of ESCOR<sup>®</sup>310, EAA5, and ESCOR<sup>®</sup>310/EAA5 blends containing 20, 40, 50, 60, and 80 %wt EAA5.

DSC melting curve of the blends of ESCOR<sup>®</sup>310/EAA2, EAA4, and EAA5 are shown in Figure 4.12(b-d). All of these blends exhibited one melting peak and the melting temperature showed values between those of pure components. In these materials, unlike with the EAA1 materials, the polyethylene segments from the terpolymer and the copolymer are mixed together.

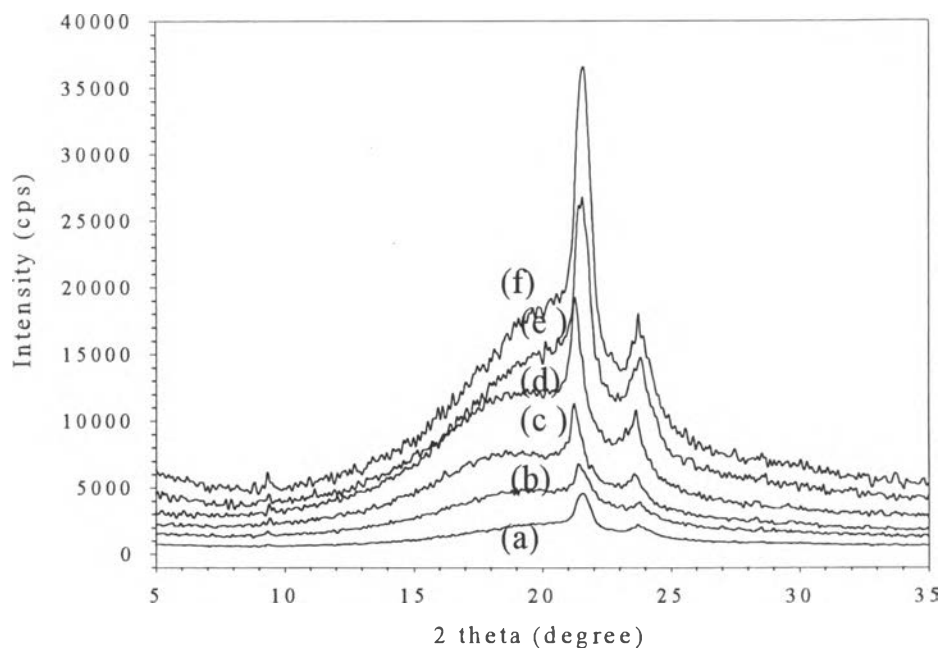
## 4.4 X-ray Diffraction Measurement

The crystal lattice spacings and the degree of crystallization is determined by X-ray diffraction

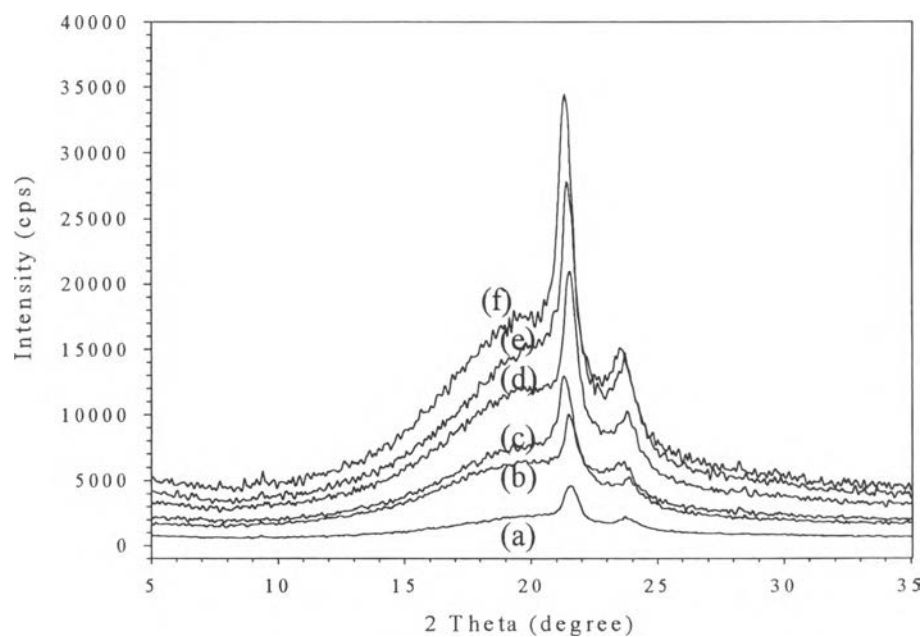
### 4.4.1 Crystal Lattice Spacing



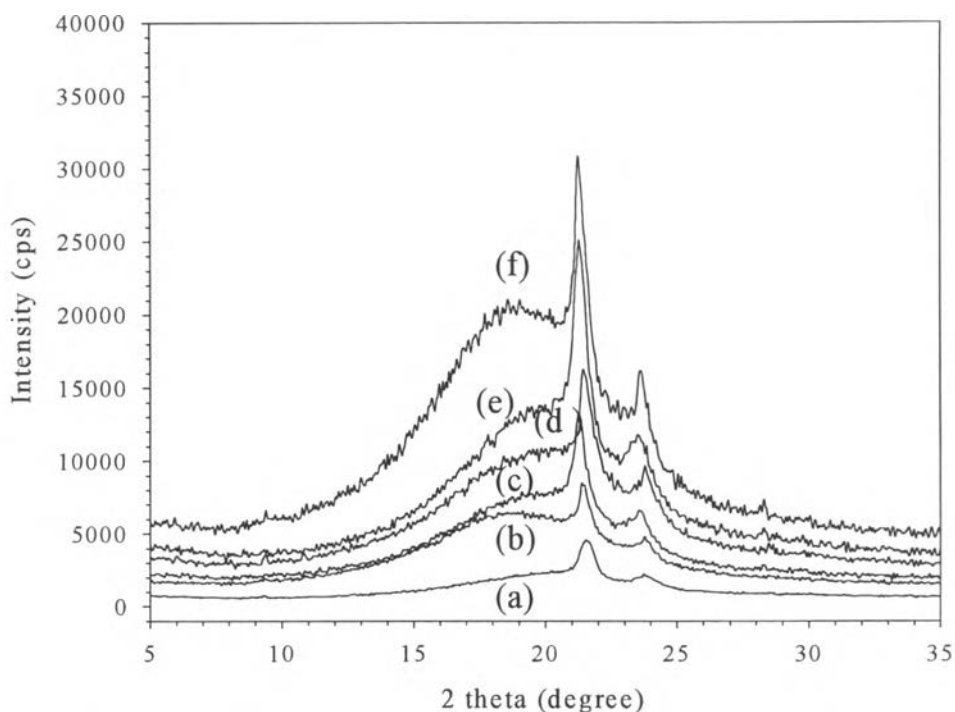
**Figure 4.13a** X-ray diffraction pattern of ESCOR<sup>®</sup>310/EAA1 blends: (a) pure ESCOR<sup>®</sup>310, (b) 20% EAA1, (c) 40% EAA1, (d) 60% EAA1, (e) 80% EAA1, (f) pure EAA1.



**Figure 4.13b** X-ray diffraction pattern of ESCOR<sup>®</sup>310/EAA2 blends: (a) pure ESCOR<sup>®</sup>310, (b) 20% EAA2, (c) 40% EAA2, (d) 60% EAA2, (e) 80% EAA2, (f) pure EAA2.



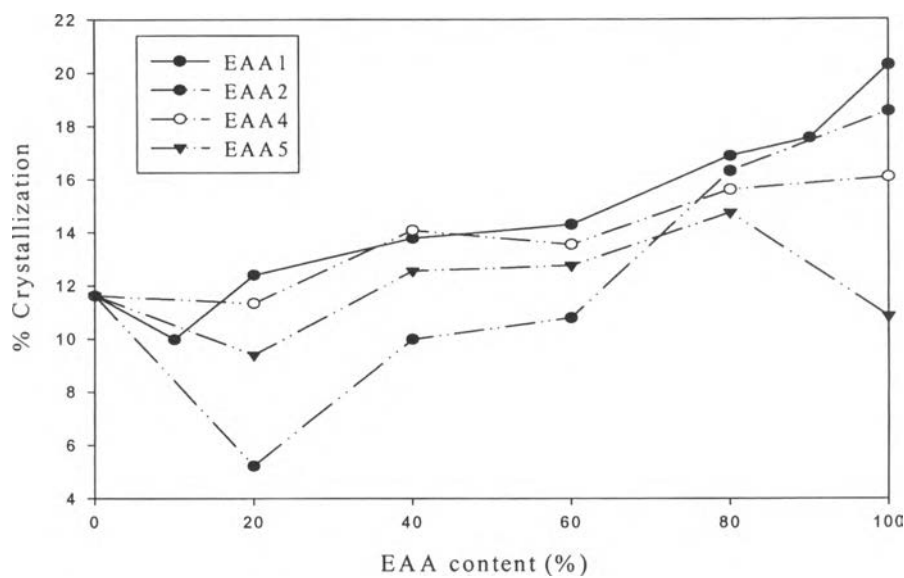
**Figure 4.13c** X-ray diffraction pattern of ESCOR<sup>®</sup>310/EAA4 blends: (a) pure ESCOR<sup>®</sup>310, (b) 20% EAA4, (c) 40% EAA4, (d) 60% EAA4, (e) 80% EAA4, (f) pure EAA4.



**Figure 4.13d** X-ray diffraction pattern of ESCOR<sup>®</sup>310/EAA5 blends : (a) pure ESCOR<sup>®</sup>310, (b) 20% EAA5, (c) 40% EAA5, (d) 60% EAA5, (e) 80% EAA5, (f) pure EAA5.

From Figure 4.13 (a-d), there are two sharp reflections at  $2\theta$  values of  $21.3^\circ$  and  $23.8^\circ$ , which are assigned to the 110 and 200 reflections of orthorhombic subcell. D-spacing of the unit cell and  $2\theta$  value of ESCOR<sup>®</sup>310, EAAs and ESCOR<sup>®</sup>310/EAAs blends are almost the same. The X-ray diffraction data indicate that there is no detectable modification of the crystal structure of the components in the blends, as compared to those observed separately. This observation illustrates that the two components of the mixtures crystallize at the same position.

#### 4.4.2 Percent Crystallinity



**Figure 4.14** Percent crystallinity measured by XRD of blends of ESCOR<sup>®</sup> 310/EAA1.

From figure 4.14, it is clearly noticed that percent crystallinity ESCOR<sup>®</sup> 310/EAA1 blends increased gradually with EAA content increased. These results are related to mechanical properties.



## Miscibility of ESCOR<sup>®</sup>310/EAA Blends

The miscibility of ESCOR<sup>®</sup>310/EAA blends was deduced by Dynamic Mechanical Analysis (DMA) and the melt behavior in various miscible blends were examined by Rheometer.

### 4.5 Rheological Measurement

Detail studies of ESCOR<sup>®</sup>310/EAA Blends were carried out and ESCOR<sup>®</sup>310/EAA5 Blends were chosen for this study.

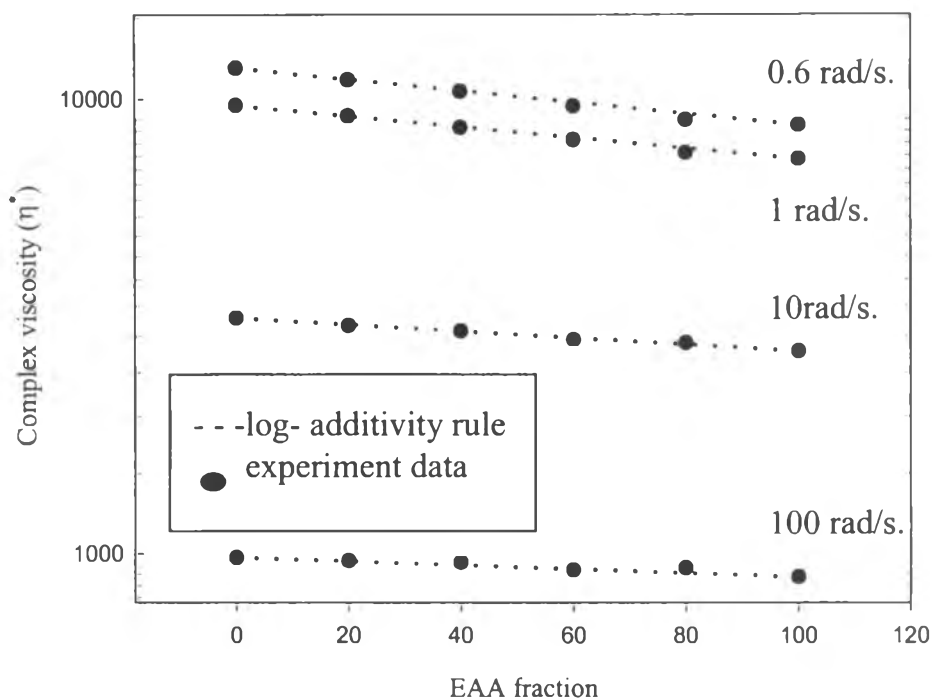
In this study, Complex viscosity  $\eta^*(\omega)$  at constant frequency was plotted against the blend composition to test the miscibility of ESCOR<sup>®</sup>310/EAA5 Blends

In blends, the composition dependence of viscoelastic functions gives much information about the degree of miscibility of the blend material. For the miscible blends, the viscoelastic functions usually follow the log-additivity rule.

$$\text{Log } F_b = \phi_m \log F_m + \phi_d \log F_d$$

Where F is a viscoelastic function,  $\phi$  is a volume fraction and subscripts “b”, “m” and “d” indicates the value of the blend, the matrix and the disperse phase, respectively. (Yoshikawa K.,1994 ).

On the other hand, the viscoelastic functions for immiscible blends deviated from the log-additivity rule. Immiscible polymer blends can be classified into three categories, depending on the blend composition dependence of the viscoelastic function. These categories as (i) positive deviation, (ii) negative deviation, and (iii) positive-negative deviation depending on whether the deviation from the log-additivity rule is positive, negative or both in different composition regions.



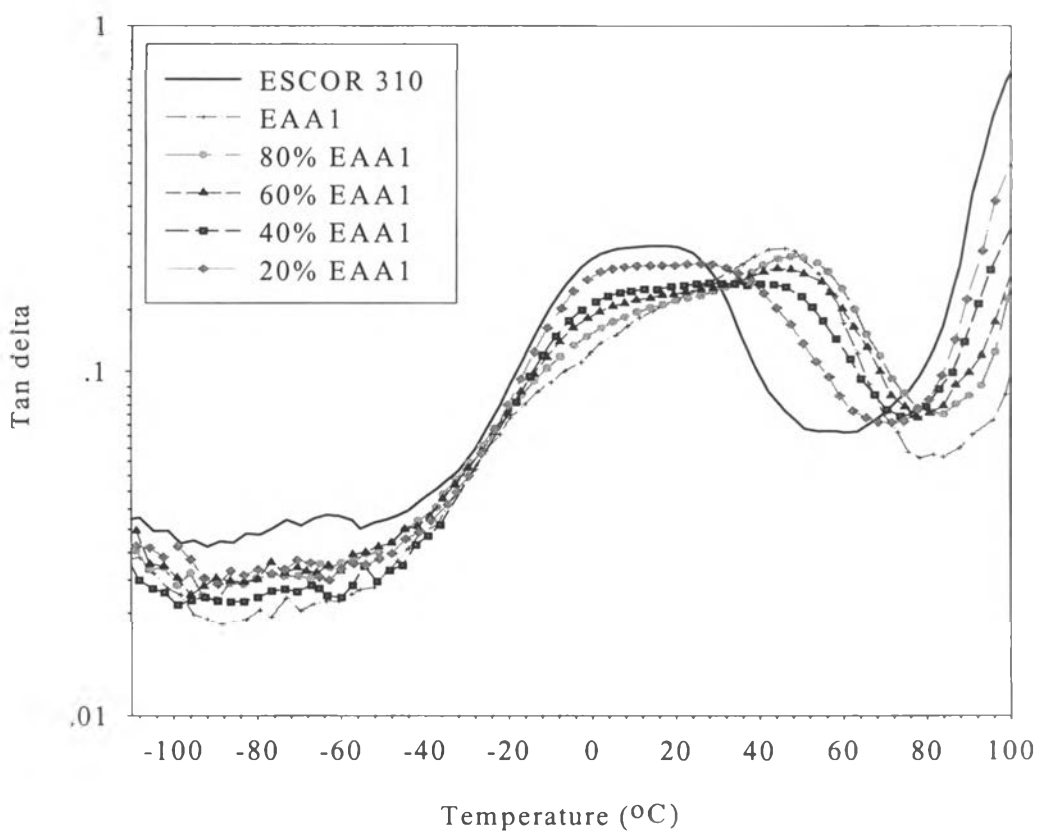
**Figure 4.15** Complex viscosity,  $\eta^*(\omega)$  as a function of blend composition for ESCOR<sup>®</sup>310/EAA5 Blends at various frequency.

As can be seen in Figure 4.15, the relations between  $\eta^*(\omega)$  and the EAA5 fraction is quite linear at frequency of 0.6, 1, 10, and 100 rad/s. Experiment data lied on the data of log-additivity rule. It indicates this type of behavior that is the typical for miscible blends. It also clearly took place in these ESCOR<sup>®</sup>310/EAA5 blends, where the chemical nature of the compared blends are very similar, and most of processing parameters are the same.

It has been reported that for the miscible blends of linear low-density polyethylene and for 1,4-polybutadiene with 1,2-polybutadiene the limiting viscosity at zero shear rate follows the log-additivity rule. (Utracki, L.A. *et al*).

#### 4.6 Dynamic Mechanical Properties

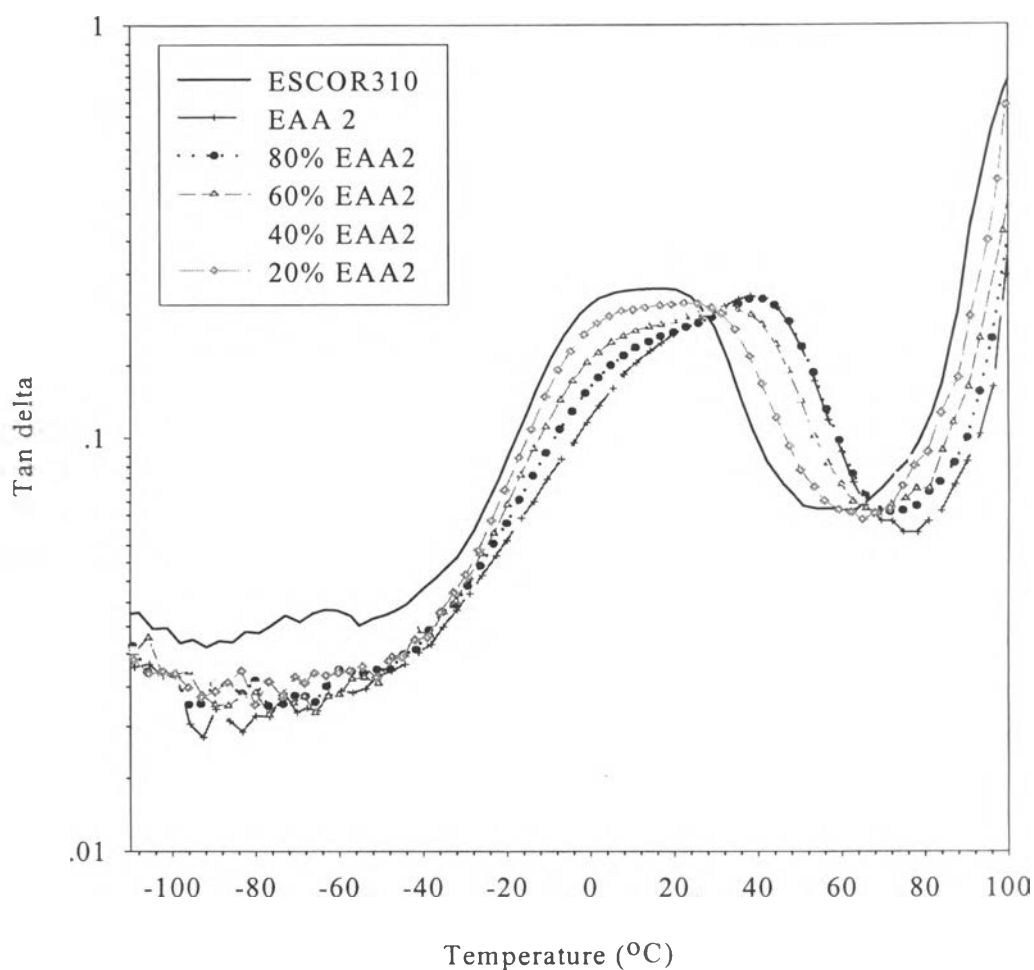
The dynamic mechanical properties of polymer blends are determined primarily by the mutual solubility of the two homopolymers. If two polymers are compatible and soluble in one another, the properties of the blends are nearly the same as those of a random copolymer of the same composition. However, many polymer mixtures form two-phases, due to the insolubility of the components. The dampening temperature curve shows two peaks; each peak is characteristic of the glass-transition temperature of one of the components. The two-steps in the dynamic-modulus-temperature curves are characteristic of an immiscible two-phase system.



**Figure 4.16a** Tan delta of ESCOR<sup>®</sup>310/EAA1 blends as a function of temperature.

The dynamic mechanical tan delta in figure 4.16a shows broad transition with a peak at 15 °C and 45 °C attributed to the glass transition of ESCOR<sup>®</sup>310 and EAA1, respectively. For tan delta curve of EAA1, it is also seen a shoulder in this transition (-5 °C) believed to be the  $\beta$ -transition typical of branched low-density polyethylene. (Robeson L.M, 1996). The blends of ESCOR<sup>®</sup>310/EAA1 with 40, 60, and 80% wt of EAA1 showed a broad second-order transition ( $T_g$ ) with two distinct humps corresponding to two  $T_g$ 's. These values are not the same as those of the pure components, but are intermediate between them and are very close to each other. This is characteristic of presence of microinhomogeneity in the blend. Thus these blends can be categorized as a partially miscible blends. (Mohanty S., 1995 ). Whereas the blends of ESCOR<sup>®</sup>310/EAA1 with 20% wt of EAA1 presented single second-order transition; indicating its miscibility.

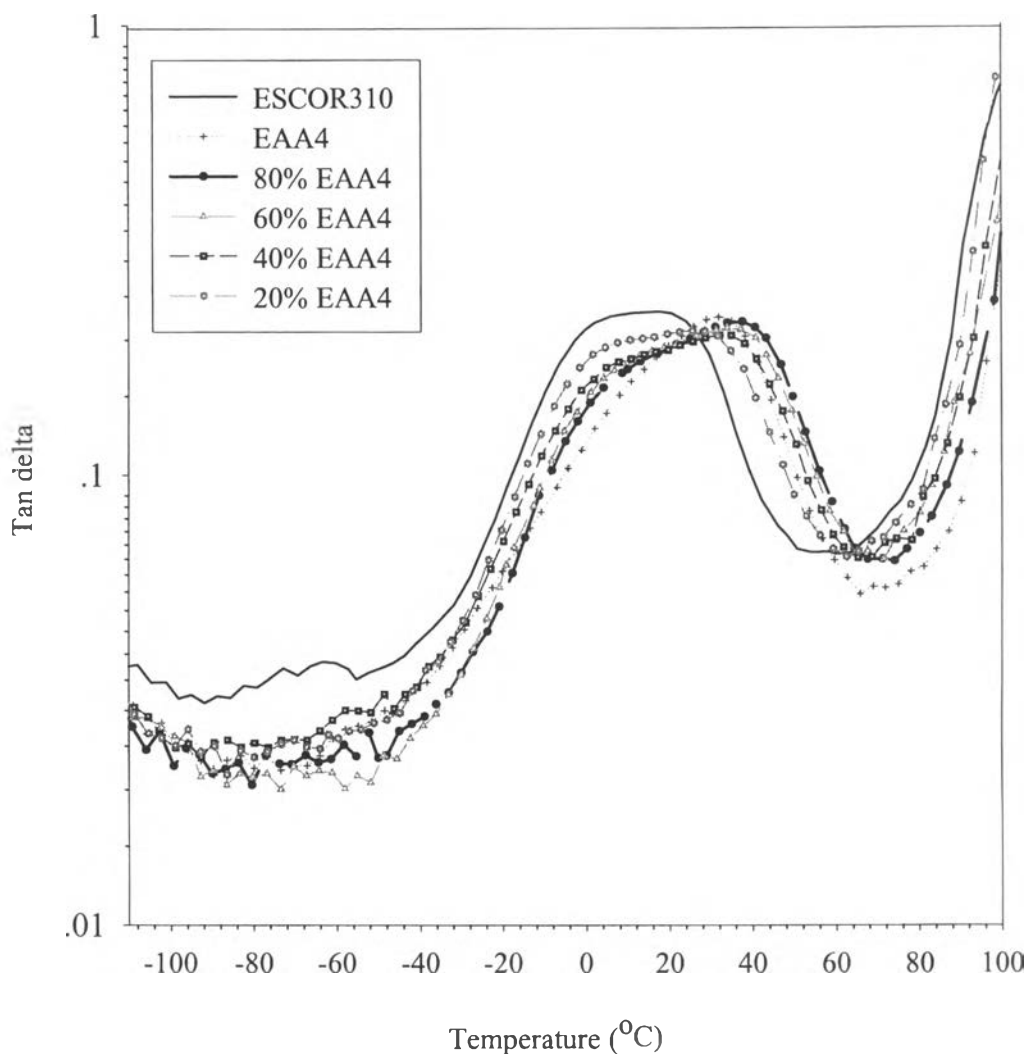
Studying dynamic mechanical properties of ESCOR<sup>®</sup>320/EAA1 blends by Worakanya *et al.*, 2000, it has been reported that ESCOR<sup>®</sup>320/EAA1 containing 0, 80, and 100% wt of EAA1 content showed miscible blends at temperature -10, 40, and 50 °C respectively.



**Figure 4.16b** Tan delta of ESCOR<sup>®</sup>310/EAA2 blends as a function of temperature.

It is found in figure 4.16b that tan delta curve of EAA2 showed a broad second-order transition with peak at 4.5 °C explained to the glass transition of EAA2, and also showed shoulder at 5 °C indicated to be  $\beta$ -transition. With the addition 20% wt of EAA2 to ESCOR<sup>®</sup>310, the transition appeared single second-order transition at 10 °C; resulting in a completely miscible blend. Whereas others showed partially miscible blends

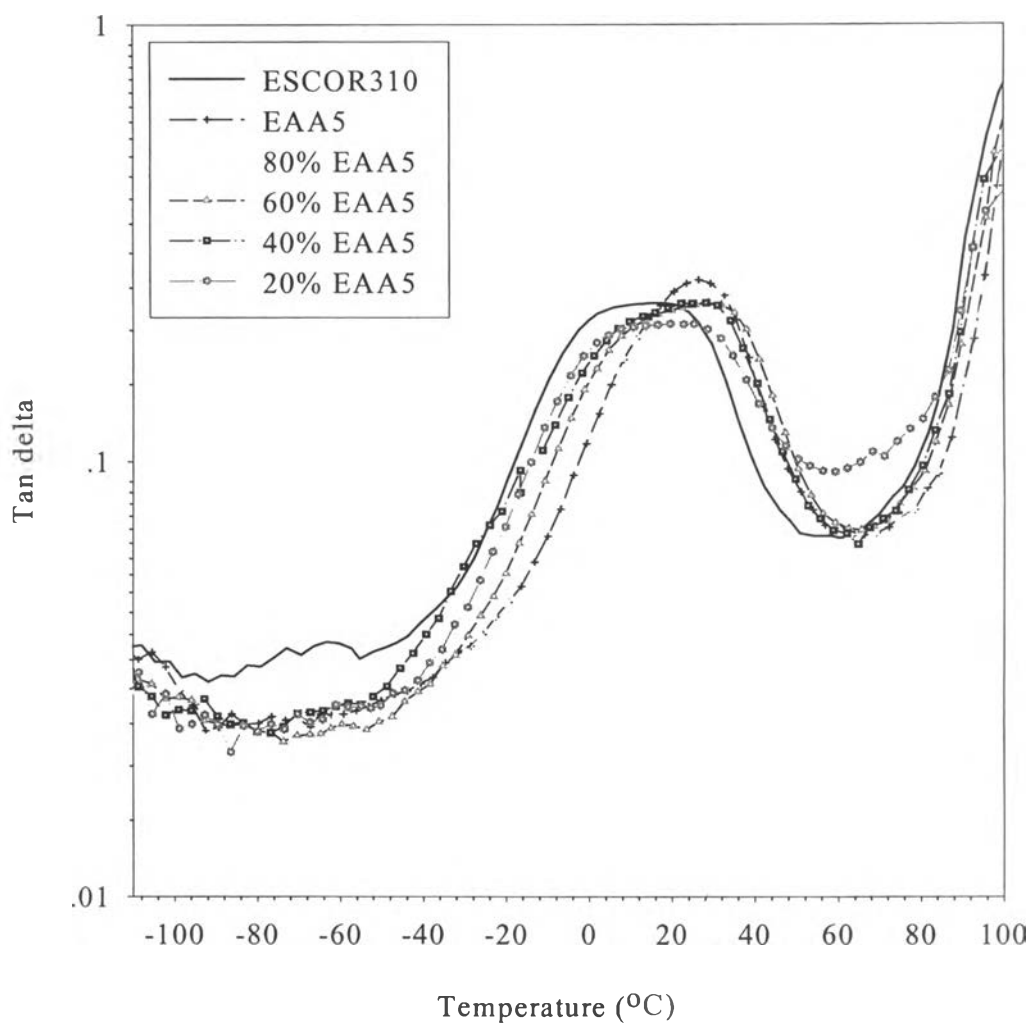
The blends of ESCOR<sup>®</sup>320/EAA2 were studied by Worakanya *et al.* It has been presented that at 0, 90, 95, and 100% wt of EAA2 content of these blends exhibited single second-order transition at -10, -20, 40, and 50 °C, respectively, which indicated their miscibility.



**Figure 4.16c** Tan delta of ESCOR<sup>®</sup>310/EAA5 blends as a function of temperature.

From figure 4.16c, it could be seen that tan delta curve of EAA4 exhibited broad second-order transition with peak at 35 °C attributed to the glass-transition of EAA4. All ESCOR<sup>®</sup>310/EAA4 blends showed partially miscible blends.

As compared to preliminary work by Worakanya *et al.*, ESCOR<sup>®</sup>320/EAA4 blends at 0, 80, and 100% wt of EAA4 showed miscible blends, which second-order transition exhibited at temperature -10, -40, and 10 °C respectively. Whereas these blends at 20, 40, and 60% wt of EAA4 presented phase separation.



**Figure 4.16d** Tan delta of ESCOR<sup>®</sup>310/EAA5 blends as a function of temperature.

The glass transition of EAA5 is appeared at 25 °C as shown in figure 4.16d. Tan delta curves of all ratio of ESCOR<sup>®</sup>310/EAA5 blends exhibited single second-order transition; indicating totally miscible blends. This observation is related to mechanical results.

From preliminary work by Worakanya *et al.*, it has been reported that ESCOR<sup>®</sup>320/EAA5 containing 0, 80, and 100% wt of EAA5 content showed single second-order transition that showed peak at temperature of -10, 10, and 40 °C respectively.

To predict the dampening efficiency, tan delta or internal friction must be provided because it indicates the amount of energy dissipated as heat during the deformation of the material. High dampening is essential in decreasing the effect of undesirable vibration and in reducing the amplitude of resonance vibrations to safe limits. (Murayama T.,1978). The effect of polymer blend on the dampening efficiency is illustrated in figure 4.16 (a-d). It is found that pure component exhibited high dampening peak than blends. Similar observation has also been reported by Chen T.S. *et al.* that blend of PVB and PEA showed lower dampening peak than pure PVB and PEA. As can be seen in figure 4.16 (a-d), ESCOR<sup>®</sup> 310/EAA5 at 80 %wt of EAA5 content showed the highest dampening peak than other blends; indicating good dampening efficiency material.