

## CHAPTER II

### LITERATURE REVIEW

The meaning of polymer comes from “Poly”, a lot and “Meros”, unit, Polymer is the macromolecule which is composed of repeating unit of reacted monomer. Monomer is one type of micro molecule. Homopolymer is polymer which has one type of monomer, if polymer consists of more than one type of monomer, It is called copolymer.

#### 2.1 Polymer Blends

Polymer blending is a convenient way for the development of new polymeric materials, which combine the excellent properties of more than one existing polymer. This strategy is usually cheaper and less time-consuming than the development of new monomers and new polymerization routes, as the basis for entirely new polymeric materials. Polymer blending normally takes place in processing machines, such as twin-screw extruders, which are considered standard industrial equipment. An additional advantage of polymer blends is that a wide range of material properties is within reach by merely changing the blend composition. A significant drawback is, however, the difficult recyclability of these materials in comparison with neat or just reinforced resins.

Polymer blends are either homogeneous or heterogeneous. In homogeneous blends, both blend components lose part of their identity and the final properties usually are the arithmetical average of both blend components. In heterogeneous blends, the properties of all blend components are present. Weaknesses of one polymer can be camouflaged by strengths of the other. In a few exceptional cases, some properties of the either homogeneous or heterogeneous blend can be better than those of the individual components. This behavior is unfortunately hard to predict. Heterogeneous blends appear in a variety of morphologies. The best known and most frequently observed morphologies are:

- (i) a dispersion of one polymer in the matrix of the other polymer
- (ii) a co-continuous two-phase morphology.

Which type of morphology is obtained is dependent on the nature of the blend components.

## 2.2 Miscibility of polymers

Homogeneous miscibility in blending polymer materials requires a negative free energy:

$$\Delta G_{\text{mix}} = \Delta H_{\text{mix}} - T\Delta S_{\text{mix}}$$

However, if two high molecular weight polymers are blended entropy ( $\Delta S_{\text{mix}}$ ) must be insignificant, and the free energy of mixing can only be negative if the heat of mixing,  $\Delta H_{\text{mix}}$  is negative. In other words, the mixing must be exothermic reaction, which must have some interactions between the blend components. These interactions may range from strongly ionic to weak and nonbonding interactions, such as hydrogen bonding, ion-dipole, dipole-dipole and donor-acceptor interactions. Normally, only Van der Waals interactions occur.

## 2.3 Type of blends

Basically, three different types of blends can be classified.

### 2.3.1 Completely miscible blends

This kind of blend has specific interaction and also has  $\Delta H_{\text{mix}} < 0$ . A well known example of this miscible blend which is PS/PPO blend, that combines the heat resistance, the inflammability and the toughness of PPO with the good processability and the low cost of PS. This type of blend has only one glass transition temperature ( $T_g$ ), which is between the  $T_g$  of both blend components in a close relation to the blend components.

### 2.3.2 Partially miscible blends

Part of one blend component is dissolved in the other. This type of blend, which exhibits a fine phase morphology and satisfactory properties, is referred to as compatible. Both blend phases are homogeneous, and have their own  $T_g$ . Both  $T_g$ s are shifted from the values for the pure blend components. An example is the

PC/ABS blends, which combine the heat resistance and toughness of PC with the low temperature impact, processability, stress cracking resistance and low cost of ABS. In these blends, PC and the SAN phase of ABS partially dissolve in one another.

### 2.3.3 Fully immiscible

They have a rough phase morphology, the interface is sharp, and the adhesion between both blend phases. Tg of the pure blend components can be seen. Fully immiscible blends are poor properties in all directions, so that these blends are useless without being compatibilized. Well known example of this fully immiscible blend are PA/ABS, PA/EPDM and PA/PPO.

## **2.4 Role of compatibilizers in blending processes**

Compatibilizers can be small molecule or macromolecular species exhibiting interfacial activities in heterogeneous polymer blends. Usually the chains of a compatibilizer structure have a blocky structure, with one constitutive block miscible with one blend component and a second block miscible with the other blend component. These blocky structures can be generated in-situ or added to the immiscible polymer blend during blending process.

## **2.5 Strategies for compatibilization of polymer blends**

### 2.5.1 Addition of pre-made grafted and block copolymer

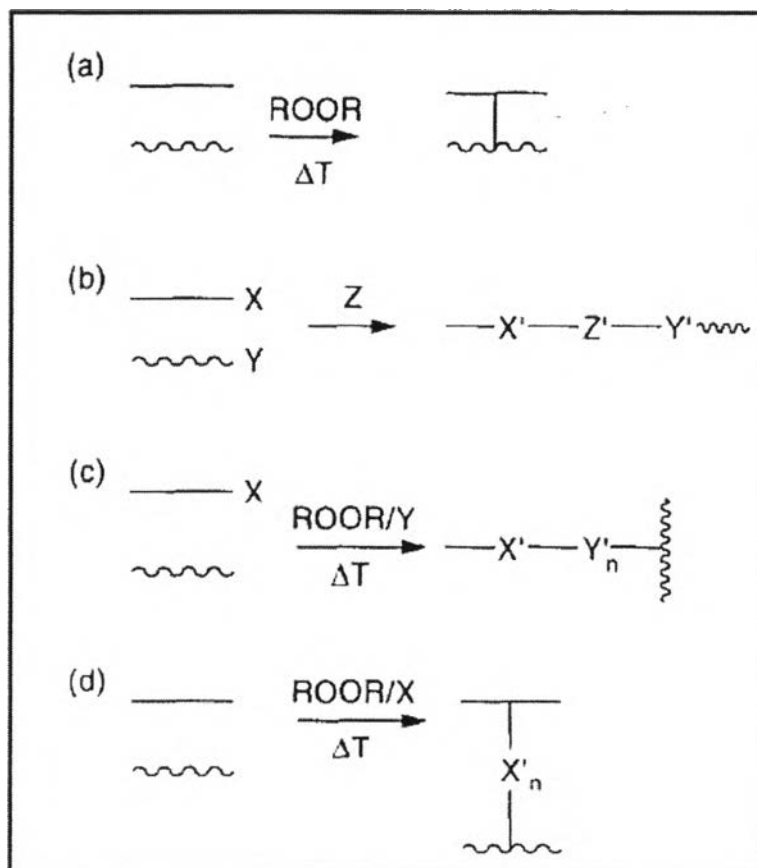
The emulsification of polymer blends has been proposed as the most efficient tool for obtaining a fine phase morphology and good mechanical properties. The best way to validate that concept is to tailor block and grafted copolymers and to investigate the beneficial effects that they can have on immiscible polymer blends. That approach allows the main molecular characteristic features of block and grafted copolymers to be changed in a systematic way, e.g. molecular architecture, composition and molecular weight, so that basic relationships can be drawn between the structural characteristics of these additives and the general properties of the polyblends.

### 2.5.2 Addition of reactive polymers

The addition of a reactive polymer, miscible with one blend component and reactive towards functional groups attached to the second blend component results in the “insitu” formation of block or grafted copolymers. This technique has certain advantages over the addition of premade block or grafted copolymers. Usually reactive polymers can be generated by free radical copolymerization or by melt grafting of reactive groups on to chemically inert polymer chains. Furthermore, reactive polymers only generate block or grafted copolymers at the site where they are needed.

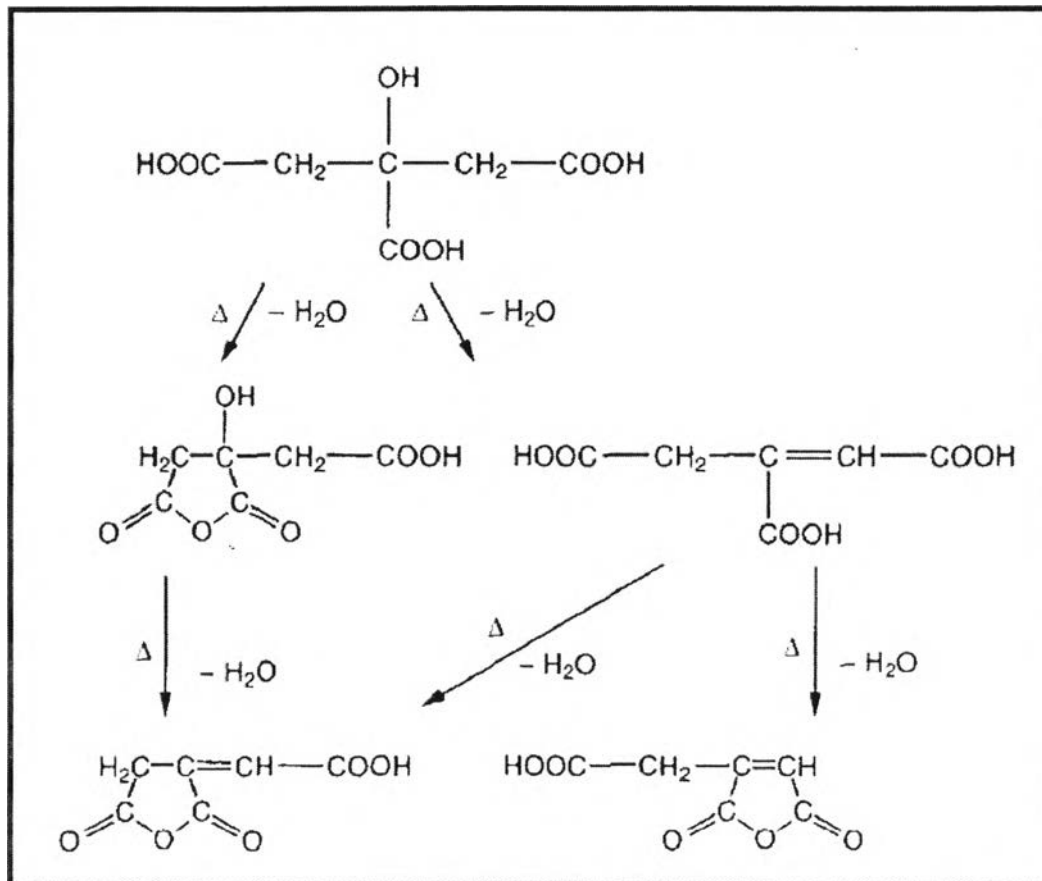
### 2.5.3 Addition of low molecular weight chemicals

The different strategy for polymer blend compatibilization relies upon the addition of a low molecular weight chemical. The actual compatibilizer is formed during a reactive blending process. Various procedures may be distinguished, depending on the added chemical. A peroxide activates inert polyolefins and results in the formation of branched copolymers. This compatibilization strategy seems to be quite simple, but the lack of chemical selectivity is quite a problem. Competition between in-situ compatibilization, crosslinking and degradation makes the control of blend properties very difficult, which is illustrated by the lack of convincing examples in the literature. Grafting, enhancement of phase dispersion and/ or small improvements of properties have been reported for PE/PP, PE/PS, LDPE/EVA and poly( $\beta$ -hydroxybutyrate)/PBA blends.



**Figure 2.1** Addition of low molecular weight chemicals and the type of copolymer formed during the reactive blending process.

Although industrial applications have not been reported yet, this simple compatibilization procedure might find applications in the future for upgrading polymer waste mixtures. Addition of 1 wt% peroxide to a representative LDPE/HDPE/ PVC/ PS/ HIPS/ PP/ PET: 45/ 15/ 15/ 7.5/ 7.5/ 5/ 5 blend results in an increase in the unnotched Izod from 133 to 465 J/m, the stress at break from 10.2 to 16.9 MPa and the elongation at yield from 3.9 to 6.8%. A bifunctional chemical forms block copolymers.

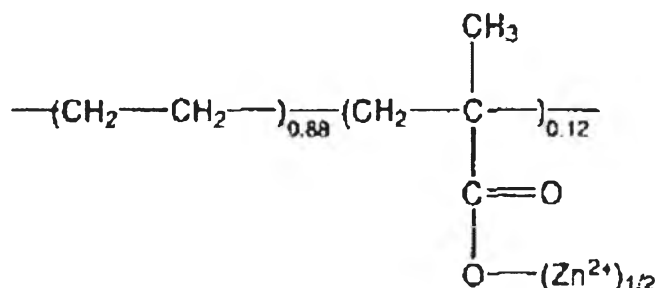


**Figure 2.2** Dehydration of the activated  $\beta$ -hydroxyl group of citric acid during extrusion with formation of unsaturation.

A mixture of a peroxide and a bifunctional chemical, which leads to the formation of branch/graft copolymers.

#### 2.5.4 Addition of a third polymer miscible with all blend phases

This case where a polymer C is (partially) miscible with the two constitutive polymers (A and B) of a two-phase binary blend. C is actually a common solvent for A and B, and it can accordingly promote the complete or the partial miscibility of the originally immiscible polymers. This strategy may thus be a convenient way to produce a variety of potentially useful blends.



**Figure 2.3** Commercially available ethylene-methacrylic based inomer used in blending studies.

## 2.6 Blending of PTT, PA and PE,PP with compatibilizers

Multicomponent polymeric materials are frequently made by blending two or more immiscible or miscible polymers. It is difficult to obtain good dispersion in polymer blend. PA6/UHMWP blend is one of the example using HDPE-g-MAH as a compatibilizer, Zhanhau Yao *et al.*,(1999). HDPE-g-MAH show an abilities to be a good compatibilizer for PA6/UHMWPE blending system. The morphology of blends was significantly improve. The average size of the PE particles was reduced from 30-35 to 2-4  $\mu\text{m}$ . Moreover mechanical properties such as tensile strength, Young's modulus, elongation at break, flexural strength, flexural modulus and Izod impact strength are also dramatically increase. Morphology and mechanical improvement due to the chemical reaction takes place between HDPE and terminal amino group of PA6. Such a chemical reaction occurrence, PA6 and UHMPE blending with HDPE-g-MAH as a compatibilizer seem to be the best solution for overcoming immiscible blend of these polymer blend components.

In another research, there is the study of reactive compatibilization of Poly(trimethylene terephthalate)/Polypropylene blends by Polypropylene-graft-Maleic Anhydride and their crystallization behavior, Mei-Ling Xue *et al.*,(2007). In this publication demonstrated that PTT and PP crystallization rates were accelerated by the presence of each other. Furthermore the addition of PP-g-MAH in PTT/PP blend was a larger effects on crystallization temperature( $T_c$ ) of PTT and PP. The crystallization of PTT and PP shifted significantly to lower temperature. Beside the

shift of PTT's  $T_c$  was larger than that of the PP, suggesting that addition of PP-g-MAH had a larger effect on PTT's crystallization than on PP due to chemical reaction between maleic anhydride ring and PTT.

In 2009. PTT/PP blends by using maleic anhydride grafted polypropylene as compatibilizer was studied non-isothermal crystallization kinetic and compatibility, Yingjin Wang et al.,(2009). The research indicated the concept of addition PP-g-MAH in blends accelerated the crystallization of PTT however PP component is retarded by introduction of PP-g-MAH. Moreover the results showed that PP-g-MAH as an effective compatibilizer decreases the interfacial tension and increase the compatibility of the blend.

## **2.7 Blending of and PBT/PE**

Morphology development of PBT and HDPE blends were studied during extrusion and its reflection on the rheological properties, S.H Jafari *et al.*, (2005). As people know PBT and HDPE have a huge different gap of melting temperature. Moreover it is hard to get good dispersed phase. This research reveals that the proper blending condition in order to make good dispersed phase. Condition A (170/190/220/210) indicated the morphology development and viscosity improvement.



## **OBJECTIVES**

- Prepare PBT/Fusabond and HDPE/PBT/Fusabond
- Study thermal and mechanical properties