

CHAPTER X

CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

In-situ composites were obtained from melt-blending of a thermoplastic with an LCP, while in-situ hybrid composites were obtained by introducing an inorganic filler as a third component. The matrices studied were PTT, PET, and PC. Mostly the modulus was improved by the presence of either an inorganic filler (ZnO, CNT) or an LCP (VA950, V400P). In general, partial fibrillation was observed without inorganic fillers. For PTT/VA950 blends, improvement in processibility, thermal stability and crystallization kinetics were also observed. Detailed studies on non-isothermal crystallization kinetics of this system was also made with the help of Ozawa, and Combined Avrami and Ozawa models. The studies confirmed the role of VA950 as a nucleating agent that accelerated PTT crystallization processes. ZnO powder as synthesized from microwave radiation was used to make PET/VA950/ZnO in-situ hybrid composites. The samples showed deterioration in crystallization speed, reduced LCP fibril fractions and reduced shear viscosity. No significance improvement in mechanical performance was found and thus it was assumed that little to none transesterification had occurred between PET and VA950 in the presence of ZnO. Another in-situ hybrid composites investigated was PC/LCP/CNT where the LCP was either VA950 or V400P. The electrical conductivity increased with increasing CNT content but not as much as expected because the formation of conductive pathways was inefficient; The LCP domains did not form fibrils as the embedded CNT suppressing their flowability by increasing local viscosity. The response of PET/VA950 to microwave energy was also investigated. The PET crystal structure was triclinic and its degree of crystallinity increased after microwave irradiation. VA950 was found to promote the PET crystallization upon microwave treating. Such increase in crystallization extent accounted for the observed better mechanical performance.

In summary, the use of an LCP most likely promoted processibility and mechanical performance of the resulting binary blends while an inorganic filler can

be added to introduce new properties upon demand. It must be cautious that this third inorganic component can negatively alter the blend properties, for example, prohibiting LCP fibrillation.

10.2 Recommendations

There are practical ways to further improve the mechanical performance of in-situ composites, for example, raising the degree of crystallinity, and improve interfacial properties by compatibilization. Transesterification (considered as in-situ compatibilization) not only promotes interfacial adhesion between the blend components, but also the crystallization extent. (Kugler and Zachmann, 1987). Therefore, future experiments may focus on the addition of an effective heterogeneous nucleating such as talc in PET-based in-situ composites. The epitaxial relationship between PET and talc may promote PET crystallization and finally enhance mechanical properties. Another interesting inorganic filler is tetra butyl titanate, $Ti(OC_4H_9)_4$, which has been reported to act as both a transesterification catalyst and a nucleating agent for PET (Liangbin *et al.*, 2001). Other well-known transesterification catalysts for terephthalate-based polyester (like PET, PTT) are manganese acetate, zinc acetate, zinc chloride or magnesium oxide, or a mixture of these compounds. Since they can withstand high temperature, they might be useful as an in-situ compatibilizer in the in-situ composites and their catalytic activities should be evaluated.

Future attempts may be made to find promising combinations of thermoplastic/LCP/inorganic filler that provide composites with novel properties unlikely to be achieved unless with a filler, such as microwave-absorbing properties, electrical, and thermal conductivity. If electrical conductivity is of interest, we propose the combination of polyether sulfone (PES), LCP, and carbon black. The LCP used should be less polar than the matrix polymer to prevent filler migration from the matrix to LCP which can consequently increase the LCP phase viscosity. PES was found to have a percent polarity of 16 ± 1 (James *et al.*, 1993) while those of Xydar (a copolyester of p-hydroxybenzoic acid, isophthalic and/or terephthalic acids, and 4,4'-biphenol), and Vectra B950 (a random copolyesteramide consisting of 60

mol % of 6-hydroxy-2-naphthoic acid, 20 mol % terephthalic acid, and 20 mol % para-aminophenol) are 14.1, and 11.7, respectively (Ma *et al.*, 1998). Therefore, PES can be blended with either of these LCPs. Also, they all have similar processing temperature and PES has been reported to show promising properties in blends with Vectra B950 (Kiss, 1987). It must be kept in mind that the higher the polarity of the matrix, the higher the content of a conductive filler is required to obtain good electrical conductivity. If the double percolation concept is to be realized by trapping the conductive filler within the continuous LCP phase, commercial LCPs having better electrical conductivity than VA950 (volume resistivity $6 \times 10^{16} \Omega \cdot \text{cm}$, Cheremisinoff, 1989) should be considered, for example, Rodrun (a copolyester of p-hydroxybenzoic acid and PET), and Xydar. Both of them have volume resistivity around $1 \times 10^{15} \Omega \cdot \text{cm}$ (Cheremisinoff, 1989).