Chapter 5

Summary and Conclusion

The summary and conclusion of this work is discussed below in following points.

1. Halloysite nanotubes (HNTs) and intumescent flame retardant (IFR) filled 80/20 (wt/wt) PP/ABS blends and its composites in presence of dual compatibilizer have been prepared using twin screw extruder followed by injection moulding. ABS and SEBS-g-MA act as a $\beta$-nucleating agent for the formation of trigonal $\beta$-form of PP crystals. The $\beta$-form of PP crystals is more in the case of HNTs and IFR filled 80/20 (wt/wt) PP/ABS blends and its composites in presence of dual compatibilizer as compared to 80/20 (wt/wt) PP/ABS blends in presence of dual compatibilizer. The addition of HNTs and IFR in 80/20 (wt/wt) PP/ABS blends in presence of dual compatibilizer enhance the PP crystal phase formation. SEM micrograph of HNTs and IFR filled 80/20 (wt/wt) PP/ABS blends and its composites in presence of dual compatibilizer reveal matrix-droplet morphology. Tensile and impact properties of HNTs and IFR in 80/20 (wt/wt) PP/ABS blends in presence of dual compatibilizer increases with an addition of 3 and 5 wt.% of HNTs and IFR. The reason for the increase in tensile and impact properties of HNTs and IFR in 80/20 (wt/wt) PP/ABS blends in presence of dual compatibilizer is due to well dispersed HNTs in PP phase and refinement in morphology. Thermal stability of HNTs and IFR in 80/20 (wt/wt) PP/ABS blends in presence of dual compatibilizer increases. It is due to the formation of intumescent char. The addition of 3 and 5 wt.% HNTs and 20 wt.% IFR in 80/20 (wt/wt) PP/ABS blends in presence of dual compatibilizer passed the V-2 test of UL-94, and less dripping was observed. Additional research needs to be carried out to optimize the ratio of APP:PER on flame retardancy of HNTs and IFR filled 80/20 (wt/wt) PP/ABS blends in presence of dual compatibilizer to achieve a V-0 rating.
2. The influence of hybrid fillers on mechanical and thermal properties of 80/20 (wt/wt) PP/ABS blends and its composites in presence of dual compatibilizer was studied. In this study, three filler materials were used. They are Halloysite nanotubes (HNTs), carbon black (CB) and intercalated graphite (IG). The combination of the different concentration of these filler materials was melt-mixed with PP/ABS blends using counter-rotating twin screw extruder followed by injection moulding. The maximum increase in tensile modulus and impact strength is for CB and IG reinforced PP/ABS blends in presence of dual compatibilizer. The enhancement in tensile modulus and impact strength is due to melt interfacial reaction in between the maleic anhydride (MA) group of compatibilizer and the amine group of melamine, selective localization of hybrid fillers in PP phase, refinement in morphology, increase in percent crystallinity of PP phase and formation of $\beta$-form of PP crystals. Thermal stability increases for hybrid fillers reinforced PP/ABS blends in presence of dual compatibilizer as compared to pure blend. Thus, the CB and IG reinforced PP/ABS blend can be used to manufacture automotive instrument panel due to enhanced tensile and impact properties.

3. Hybrid fillers and IFR filled PP/ABS blends and its composites have been prepared using melt mixing method. All composites samples show the formation of monoclinic $\alpha$-phase and trigonal $\beta$-phase PP phase. The crystallinity of composites is found to be higher than pure blend. In addition, the morphology of composites is more refined as compared to pure blend. The highest refinement in morphology is observed in the case of CB+IG and IFR filled blend. Thus, due to refinement in morphology, the formation of monoclinic $\alpha$-phase and trigonal $\beta$-phase PP phase and improvement in crystallinity result in highest improvement in tensile and impact properties of CB+IG and IFR filled blend. Thermal stability is highest for the CB+IG and IFR filled blend. CB+IG and IFR filled blend passed the V-0 rating of UL-94 and has LOI value of ~ 33. The improved thermal and flammability properties are due to improved dispersion of CB and IG in PP phase; and during degradation of CB+IG and IFR filled blend, organic and inorganic
protective layer form efficiently restrict the mass transport of volatile product to flame.

4. The influence of 2:1 ratio of APP:PER in addition with hybrid fillers on mechanical and thermal properties of PP/ABS blends in presence of dual compatibilizer was studied. TGA studies show the enhanced thermal stability of polymer is achieved by an addition of 2:1 ratio of APP:PER and hybrid fillers filled PP/ABS blends and its composites in presence of dual compatibilizer. The PP/ABS blends and its composites containing 2:1 ratio of APP:PER and hybrid fillers passed only V-0 rating of UL-94; it is due to the formation of inorganic protective layer form efficiently restrict the mass transport of volatile product to flame. The char studies of 2:1 ratio of APP:PER and hybrid fillers filled PP/ABS blends and its composites in presence of dual compatibilizer were carried out by heating the samples in a muffle furnace at different temperatures. It confirms that due to the formation of intumescent char, V-0 rating of UL-94 has obtained for 2:1 ratio of APP:PER and hybrid fillers filled PP/ABS blends and its composites in presence of dual compatibilizer. The tensile properties of 2:1 ratio of APP:PER and hybrid fillers filled PP/ABS blends and its composites in presence of dual compatibilizer are higher as compared to hybrid fillers filled PP/ABS blends and its composites in presence of dual compatibilizer, but impact properties are lower.

This work shows that addition of two fillers along with IFR in PP/ABS blends and its composites in presence of dual compatibilizers is helpful in achieving the V-0 rating of UL94. The optimization of APP:PER ratio and filler concentration in PP/ABS blends and its composites in presence of dual compatibilizers need to be studied further in view to make the system commercially attractive.