CHAPTER V

DISCUSSION AND CONCLUSION

Discussion

1. Fire-retardancy Evaluation

Limiting Oxygen Index (LOI)

In Figure 4-1, the values of LOI are plotted versus concentration of zinc hydroxystannate (ZHS), zinc stannate (ZS), antimony trioxide (Sb_2O_3) and ammonium sulphate (AS) fire retardants. The LOI values of plasticized PVC (hard film) blended with fire retardants increase rapidly with increase concentration of fire retardants. Fire retardants at concentration 3-4 phc is the optimum concentration of blended fire retardant. In comparison of ZHS, ZS, Sb_2O_3 and AS systems, the flame retardancy by adding ZHS and ZS up to 10 phc is observed to be higher than that by adding Sb_2O_3 which can increase small fire retardancy effect as the concentration more than 4 phc. AS is less effective as compared with the others which can consider not to be fire-retardant additive.

Figure 4-2 shows LOI curves for soft film and highly soft film blended with fire retardant. The LOI curves are similar to Figure 4-1, but it is less effective of fire retardancy and Sb_2O_3 increase small fire retardancy effect when the concentration is more than 4 phc.

Figure 4-3 shows the similar behavior of fire retardancy but Sb_2O_3 system consider to be more effective in any concentration.

The fire-retardancy evaluation (LOI comparison) show that zinc hydroxystannate (ZHS) and zinc stannate (ZS) consider to be more effective fire retardant for low plasticizer content PVC compound and during burning can observed the char formation on polymer surface which assume to operate by condensed-phase mechanism and should be study more in mode of retardation.

Antimony trioxide (Sb_2O_3) consider to be more effective fire retardant for high plasticizer content PVC compound

Ammonium sulphate (AS) consider not to be fire-retardant additive because of low price so it should be study as synergistically efficient fire retardants and HCL toxicant removing additive by forming NH_4Cl

Burning Rate

The burning rate is defined as the horizontal burning rate of material used in occupant compartment of road vehicles, and of tractors and small machinery for agriculture and forestry, after exposure to a small flame. This burning characteristic is related to the LOI value of the materials.

Table 4-4 show the burning rate of hard film containing ZHS, ZS, Sb_2O_3 and AS fire retardant. The hard film containing no fire retardant show the burning rate 133 mm/min., by adding 1 phc of ZHS, ZS, Sb_2O_3 and is observed to be self-extinguished which relate to the LOI value as shown in Table 4-1 that the hard film containing no fire retardant show the LOI value less than 25, this illustrate that the hard film containing no fire retardant is flammable material. The hard film containing ZHS, ZS and Sb_2O_3 fire retardant more than 1 phc is observed to be self-extinguished

and show the LOI value more than 26.9. The hard film containing AS fire retardant up to 10 phc show the LOI value less than 26.9 this illustrate that AS cannot be used as fire retardant .

Table 4-5 shows the similar behavior of relationship of burning rate data and LOI as Table 4-4

Table 4-6 shows the similar behavior of relationship but highly soft film containing 3 phc of ZHS, ZS and Sb_2O_3 , LOI value 23.0, 22.7, and 24.4 respectively, consider to be self-extinguished but the highly soft film containing AS fire retardant at the concentration up to 10 phc consider to be flammable materials.

2. Evolved Gas Analysis

Figure 4-4 shows pyrogram of hard film containing no fire retardant The main pyrolyzed products eluted at retention time about 2.82, 3.41, 4.0 min. Fukatsu reported that the peak at retention time about 2.80 is the hydrocarbon peak.(12)

Figure 4-5 shows pyrogram of soft film containing no fire retardant. The main pyrolyzed products eluted at retention time shift to 2.65, 3.17, 3.8 min.

Figure 4-6 shows pyrogram of highly soft film containing no fire retardant. The main pyrolyzed products eluted at retention time shift to 2.68, 3.21, 3.85.

Figure 4-7 shows pyrogram of hard film containing 1 phc of ZHS dipping in pure benzene, the main peak which changed in increasing of peak area % is the peak at retention time 3.40. This result shows that the peak at retention time 3.40 is the benzene peak.

Figure 4-8 shows pyrogram of hard film containing 1 phc of ZHS dipping in pure toluene, the main peak which changed in increasing of peak area % is the peak at retention time 4.00. This result shows that the peak at retention time 4.00 is the toluene peak.

Figure 4-8 shows pyrogram of hard film containing 1 phc of ZHS the area % of hydrocarbon, benzene and toluene peak are shown in Table 4-7 for comparison with ZS, Sb_2O_3 and AS fire retardant at the concentration 0 phc, 1 phc, 4 phc and 10 phc. Figure 4-13 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the hydrocarbon peak area % of hard film pyrolysis.

Figure 4-14 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the hydrocarbon peak area % of soft film pyrolysis.

Figure 4-15 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the hydrocarbon peak area % of highly soft film pyrolysis.

As illustrated by these data, the hydrocarbon degradation products evolved from pyrolysis of hard film containing ZHS fire retarant is more than hydrocarbon evolved from pyrolysis of hard film containing no fire retardant.

This behavior is different from pyrolysis of soft film containing fire retardant which the evolved hydrocarbon is less than the hydrocarbon evolved from pyrolysis of soft film containing no fire retardant.

The hydrocarbon degradation product evolved from pyrolysis of highly soft film containing ZHS and ZS fire retardant is remarkable less in relative quantity.

Figure 4-16 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the benzene peak area % of hard film pyrolysis.

Figure 4-17 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the benzene peak area % of soft film pyrolysis.

Figure 4-18 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the benzene peak area % of highly soft film pyrolysis.

The benzene degradation product evolved from pyrolysis of hard film, soft film and highly soft film containing ZHS and ZS fire retardant remarkable reduce in relative quantity different from the film containing Sb_2O_3 and AS fire retardant which decrease in small relative quantity or increased in quantity and it has been reported (12) that the benzene yield is remarkable reduced in the favor of graphitic structures in degradation of PVC so ZHS and ZS fire retardant assume to operate by condensed-phase mechanism and should be study more in mode of retardation.

Figure 4-19 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the toluene peak area % of hard film pyrolysis.

Figure 4-20 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the toluene peak area % of soft film pyrolysis.

Figure 4-21 shows the relationship between concentration of ZHS, ZS, Sb_2O_3 and AS fire retardant and the toluene peak area % of highly soft film pyrolysis.

The toluene degradation product evolved from pyrolysis of hard film, soft film and highly soft film containing ZHS and ZS fire retardant increase in relative quantity different from the film containing Sb_2O_3 and AS fire retardant which decrease in small relative quantity so AS should be study as toluene toxicant removing additive.

3. Mechanical Properties Evaluation

Mechanical test of the hard film showed that, ZHS, ZS, Sb_2O_3 and AS fire retardant had little effect on tensile strength at break, elongation at break and tear strength (Table 4-16 and Table 4-17). Incorporation of ZHS, ZS, Sb_2O_3 and AS at level 1 phc, 2 phc, 3 phc, 4 phc, 5 phc and 10 phc decreased tensile strength at break of the hard film containing fire retardants in the range of 5-35 kg/cm^2 (MD direction) 5-35 kg/cm^2 (TD direction) for ZHS, 10-25 kg/cm^2 (MD direction) 10-40 kg/cm^2 (TD direction) for ZS, 5-30 kg/cm^2 (MD direction) 5-15 kg/cm^2 (TD direction) for Sb_2O_3 , 100-130 kg/cm^2 (MD direction) 100-125 kg/cm^2 (TD direction) for AS respectively

Elongation at break of the hard film containing fire retardants indicated that increasing the fire retardants content would decreased elongation at break. ZHS, ZS, Sb_2O_3 and AS at level 1 phc, 2 phc, 3 phc, 4 phc, 5 phc and 10 phc decreased elongation at break in the range of 12.5-62.5 % (MD direction) 0-25 % (TD direction) for ZHS, 12.5-25 % (MD direction) 0-12.5 % (TD direction) for ZS, 5-30 % (MD direction) 5-15% (TD direction) for Sb_2O_3 , 175-337.5 % (MD direction) 125-275 % (TD direction) for AS respectively

Tear strength of the hard film containing fire retardants indicated that increasing the fire retardants content would decreased tear strength.

ZHS, ZS, Sb_2O_3 and AS at level 1 phc, 2 phc, 3 phc, 4 phc, 5 phc and 10 phc decreased elongation at break in the range 0-0.2 kg/cm (MD direction) 0-0.1 kg/cm (TD direction) for ZHS, 0 kg/cm (MD direction) 0-0.1 kg/cm (TD direction) for ZS , 0.2-0.4 kg/cm (MD direction) 0-0.1 kg/cm (TD direction) for Sb_2O_3 , 0.6-0.9 kg/cm (MD direction) 0.4-0.6 kg/cm (TD direction) for AS respectively

Mechanical test of the soft film (Table 4-18 and Table 4-19) and highly soft film (Table 4-18 and Table 4-19) containing ZHS, ZS, Sb_2O_3 and AS fire retardant showed the similar behavior as the hard film containing fire retardant.

Conclusion

The study of effectiveness of Zinc Hydroxy Stannate ($ZnSn(OH)_6$), Zinc Stannate ($ZnSnO_3$), Antimony Trioxide (Sb_2O_3) and Ammonium Sulphate as fire retardants in plasticized polyvinyl chloride show that zinc hydroxy stannate and zinc stannate can be used as fire retardant that exhibit the similar effectiveness as Sb_2O_3 which is the industrial fire retardant. In addition, zinc hydroxy stannate and zinc stannate offer the advantages over antimony trioxide that they were non-toxic additives(13) and can reduce the toxic benzene evolved from burning of the polymer.

In this study found that ammonium sulphate cannot be used as fire retardants in plasticized polyvinyl chloride, zinc hydroxy stannate and zinc stannate show the similar fire retardancy as antimony trioxide in hard polyvinyl chloride film and soft polyvinyl chloride film but show the less fire retardancy in highly soft polyvinyl chloride film. Zinc hydroxy

stannate and zinc stannate had small effect on mechanical properties of plasticized polyvinyl chloride film

In conclusion zinc hydroxy stannate and zinc stannate can be used as industrial fire retardant that offer the advantages over antimony trioxide that they were non-toxic additives and can reduce the toxic benzene evolved from burning of the polymer which now cannot find for industrial uses.