CHAPTER V

CONCLUSION

1. In this research, silicon containing flame retardant additives for ABS/montmorillonite nanocomposites was successfully prepared by using silica extracted from rice husk (RHS) and corn cob (CCS). The percentage yield for RHS and CCS extracted from rice husk ash and corn cob ash was approximately 20-21% and 1-2%, respectively. Obviously, the silica extracted from rice husk ash and corn cob ash had high purity of silicon content as 99.2% and 64%, respectively. RHS had the smallest particle size and highest BET specific surface area of 35.30 μm and 201m^2/g, respectively whereas those values of CCS were 114.80 μm and 44.49m^2/g, respectively.

2. ABS is an engineering thermoplastic that its disadvantage is its inherent flammability, therefore it is essential to improve its fire retardant properties. Organomontmorillonite clay (OMT) was incorporated to ABS for enhancing flame retardancy. Flammability test demonstrated that 5 wt% of OMT exhibited the best flame retardant properties for ABS.

3. 3-Aminopropyltrimethoxysilane (AMMO) and Vinyltrimethoxysilane (VTMO) were successfully grafted on silica surface. The morphological characteristics of unmodified and modified silica were studied. It was found that the particle size of AMMO and VTMO grafted silica was significantly smaller than that of ungrafted silica. Regarding TGA thermograms of AMMO grafted silica, it had higher grafting efficiency onto the silica surface than VTMO grafted silica.

4. Combination of OMT and modified silica as filler onto SAN matrix could enhance flame retardancy of ABS because synergistic effect between clay layer of OMT and modified silica acted as a good insulator during combustion of the nanocomposites. UL-94 and LOI tests shown that ABS/5%OMT/20%AMMO-g-RHS or CCS nanocomposites had better flame retardant properties than neat ABS. Thus, AMMO was an efficient surface-modifying agent for grafting on surface of silica.

5. Silatrane glycol was synthesized from silica (i.e., commercial silica, RHS, and CCS) by hydrolysis in one pot process using ethylene glycol as a solvent, triethanolamine as an alcoholic reactant, and triethylenetetramine as a catalyst. All the synthesized silatrane had smaller particle size and lower surface area than their silica counterparts, except for silatrane synthesized from CCS (CCSilatrane) that had smaller particle size and higher surface area than corn cob silica. Regarding XRD technique, all the synthesized silatrane showed higher crystallinity than its starting material. Considering the TGA thermograms of SSilatrane, RHSilatrane, and CCSilatrane, it was found that the percentage of weight residues at at 600^{o}C was 50.63%, 42.84%, and 54.85%, respectively. As a result of this high silicaceous char residues, the synthesized silatrane could thus be used as an efficient silicon containing flame retardant additive for improving fire retardant properties of ABS.

6. TEM images of ABS/OMT/AMMO-g-SiO_2/SSilatrane, ABS/OMT/AMMO-g-RHS/RHSilatrane, and ABS/OMT/AMMO-g-CCS/CCSilatrane nanocomposites showed partially exfoliated and intercalated structures which were in agreement with XRD patterns.

7. From TGA analysis, the char residues of ABS/OMT/AMMO-g-RHS/RHSilatrane and ABS/OMT/AMMO-g-CCS/CCSilatrane nanocomposites were found to be as high as 26.34% and 27.67%, respectively. This silicaceous char residue could act as a thermal insulator for ABS.

8. As a result of UL-94 HB test, it was shown that the burning rate of ABS/5%OMT/20%AMMO-g-SiO_2/10%SSilatrane, ABS/5%OMT/20%AMMO-g-RHS /10%RHSilatrane, and ABS/5%OMT/20%AMMO-g-CCS/10%CCSilatrane decreased approximately 73.22%, 66.18%, and 70.64%, respectively, when compared to that of neat ABS. On the other hand, the burning rate of ABS nanocomposites without silatrane namely ABS/5%OMT/20%AMMO-g-SiO_2, ABS/5%OMT/20%AMMO-g-RHS, and ABS/5%OMT/20%AMMO-g-CCS decreased only 69.04%, 66.11%, and 66.18%, respectively as compared to that of neat ABS. Hence, the synthesized silatrane could be an effective flame retardant additive for ABS.

9. Considering impact property, it was founded that ABS/OMT nanocomposites containing AMMO/VTMO grafted silica had lower impact strength than

neat ABS because of the rigidity of modified silica. In addition, ABS/OMT nanocomposites containing AMMO grafted silica showed higher impact strength than those of VTMO because of hydrogen bonding occurred from amino group in AMMO structure. Thus, AMMO was suitable for using as a surface-modifying agent for silica. With the addition of silatrane, it was found that ABS/5%OMT/20%AMMO-g-RHS/10%RHSilatrane had the highest impact strength value as compared to ABS/5%OMT/20%AMMO-g-CCS/10%CCSilatrane and ABS/5%OMT/20%AMMO-g-SiO_2/10%SSilatrane nanocomposites. This resulted from the difference in particle size and purity of silica.

10. Regarding the tensile properties, ABS/OMT/AMMO-g-silica showed the greater efficiency of tensile strength and Young's modulus value than neat ABS. This result was attributed to the hydrogen bonding between amino group in AMMO structure and nitrile group in styrene part of ABS. Furthermore, ABS/5%OMT/20%AMMO-g-SiO_2/10%SSilatrane, ABS/5%OMT/20%AMMO-g-RHS/ 10%RHSilatrane, and ABS/5%OMT/20%AMMO-g-CCS/10%CCSilatrane showed the higher tensile stregth and Young's modulus values as compared to neat ABS and ABS/OMT/AMMO-g-silica.

5.1 Expected Benefits

The obtained ABS/OMT/modified/silatrane silica nanocomposites are very environmentally resistant and have good potential to be used for automotive parts, household appliances, and construction materials. This can be of great advantage and expand automotive industry in Thailand. Additionally, the synthesized silatrane from agricultural wastes (rice husk and corn cob) as flame retardant additives is a new route for improving flame retardant properties in polymers or plastics. Furthermore, this research gives a guideline in improvement of flame retardant properties of other thermoplastics, i.e. LDPE, PP, PVC in the future.

5.2 Suggestion for Future Work

The manufacturer of ABS nanocomposites for automotive parts industry appears to be technically feasible. It is recommended that further work should be preform to control quality of silica extracted from rice husk silica and corn cob silica. Regarding

TGA analysis of rice husk silica and corn cob silica, it was found that the elements in corn cob had an influence on silane grafting on surface of silica. On the contrary, the rice husk silica could be grafted successfully with silane coupling agent because of high purity of silicon contents in rice husk silica. Furthermore, it was also found that the rice husk silica exhibited the greater grafting efficiency than that of commercial silica. Therefore, the control of high purity of silica was important to be considered.

Besides, regarding the efficiency of silatrane as flame retardant additive for ABS, it is recommended that higher loading of silatrane (>10 wt%) should be added into ABS/OMT nanocomposites to increase their flame retardant properties; while the possible reduction in any mechanical properties should also be taken into consideration as well