CHAPTER IX
CONCLUSIONS

9.1 Conclusions

The success of the admicellar polymerization of PPy/PTh coated latex particles was investigated by using FTIR, SEM, TEM, and TGA. This technique is efficient, % yield in the range between ~83-91%. The %yield and reaction times of admicelled rubber were decreased along with the PPy and PTh (monomer) concentration increased. At lower amount of pyrrole, it takes longer reaction times (35-30 hrs) to synthesis than PTh at beginning. However, the reaction of Pyrrole monomer seems to be faster at higher conversion than Thiophene. The reason can cause by the change in band structure of PPy and PTh subsequent to doping. The TEM and SEM micrographs revealed the even coating of monomer over latex particles and they showed core-shell structure of monomer and NR. It also confirmed the faster polymerization at higher amounts of monomer. SEM result can confirm the presence of polypyrrole in natural rubber. PPy are presented as a grained texture, coaser cauliflower. However, PTh demonstrated spong-like, porous structure and globular structure whereas NR exhibited the smooth surface without any coating. As the result of TGA, the admicelled rubbers began to lose weight at higher temperature compare to that of NR and they also showed the shift of major decomposition of pure PPy and pure PTh to higher temperature. The DTG curves also demonstrated the increase of char yields of the admicelled rubbers. The higher amount of PPy and PTh, can consequently slower the samples degraded temperature from 373.6°C (NR) to 374.4°C (800mM PPy) and 378.7°C (800mM PTh). Furthermore, coating with PTh (20-800mM) can enhance the peak temperature of admicelled rubber, a little more than PPy. However, the end temperature, PTh (20-800mM) has a little lower than PPy. Moreover, the residual content of PPy is significantly higher than PTh. These demonstrate that char yields of admicelled rubber increased with related to content of monomers added. The mechanical properties from tensile testing showed the increased of tensile strength and young modulus of the admicelled rubbers. This indicated the higher stiffness of the admicelled rubbers compared to natural rubber. Since the PPy and PTh behaved like a hard and brittle material, the stiffness of the

materials increased as PPy or PTh content increased. The effect of conductivity measurement revealed that the addition of polypyrrole at the same condition, 9V ,25°C, pH ~3, which allowed more adsorption and adsolubilization leading to homogeneous coating of monomer(PPy,PTh) over rubber surface. However, too much voltage is not good to stabilized leading to the contamination in admicellar rubber due to corrosion copper. The electrical conductivity as high as $3.19x10^{-4}$S/cm(800mM PPy) and $8.26x10^{-6}$ S/cm(800mM PTh) could be obtained. They promoted an increase of ninth to eleventh orders of magnitude on the conductivity of NR, ranging from 10^{-15} to 10^{-6} S/cm. The electrical conductivity as high as $3.19x10^{-4}$S/cm(800mM PPy) and $8.26x10^{-6}$ S/cm(800mM PTh) could be obtained by using electrochemical polymerization technique. They promoted an increase of ninth to eleventh orders of magnitude on the conductivity of NR, ranging from 10^{-15} to 10^{-6} S/cm. Therefore, as monomer(PPy,PTH) content increased the conductivity was also increased because the coating of monomer was more perfectly at higher concentration as supported by TEM and SEM micrographs and the resulting of TGA. The higher number of polymer chains was obtained when content is high to abstract electron from pyrrole and enhance free radical polymerization, resulting in higher conductivity and higher in their density.

In chapter 7, the reaction time to polymerization of iodine doped can enhance the faster than undoped. The % yield and reaction times of admicelled rubber were decreased along with the increased monomer concentration. The morphology of Iodine doped on molecule show a lot of pinholes in the material after polymerization, this can caused by hydrogen gas occurred whereas natural rubber sheet morphology exhibited the smooth surface. FTIR spectra for Iodine doping and those polymer samples corresponding to a new band attributable to the C-I stretching at 495 cm^{-1}. It can be seen from the TGA curve that 10% weight loss in the range of 100-250°C is due to the evaporation of physically absorbed water and some surfactant. I_2 doped can enhance the decomposition temperature to the molecule stats at around 357 to 368.3°C, which it higher than that of the undoped molecule (369.4 to 378.7°C). Moreover, a significant improvement of the conductivity, the iodine-doped natural rubber latex was estimated about one order (from $7.18x10^{-15}$ to $7.25x10^{-14}$) of magnitude higher than of undoped. In addition, the mechanical properties from

Lloyd UTM testing indicated the iodine doped has higher tensile strength (1.486 ± 0.536 MPa) and stiffness than natural rubber (0.515 ± 0.415 MPa) and undoped (1.338 ± 0.089 MPa). Although, Iodine doping can increased orientation to the molecule and conductivity, it gives lower elongation to the molecule.

In chapter 8, the conductivity of thin stretched admicelled rubber flims at different distance in low strain region was studied. It demonstrated that the conductivity increased with low strain due to the improvement of alignment of polypyrrole and polythiophene but the conductivity decreased significantly when continuing to stretch the film to larger strain, because the particle contacts and the path ways of charge carrier were disconnected.

9.2 Further suggestion

The recommendations for the future work were described below.

1) The admicelled of pyrrole and thiophene monomer should be measured dielectric constant of materials by using impedance/gain-phase analyzer (Hewlett Packard., model 4164A, in parallel capacitance (C_p) mode, with frequency from 1 kHz to 10 MHz at room temperature). The cole-cole plot should be determined to see homogenous of the material and how much of the energy loss.
2) To determined the Ferroelectric properties, the polarization and electric field characteristics (Hysteresis loop) should be measured by RT66A: standardized.
3) The effect of applied voltages on conductivity of stretching rubber should be studied.