CHAPTER V

CONCLUSIONS AND SUGGESTION

5.1 Conclusions

In this work, a procedure for preparing silica-reinforced natural rubber films by latex dipping process was introduced. Only one heating step at 80°C was carried out to complete the drying, vulcanization, and silica formation in the rubber matrix. The *in situ* generated silica was produced as common silica having silanol groups on the silica surface and alkylated/vinylated silica with alkyl/vinyl groups on its surface. Different types of alkylalkoxysilanes- TEOS, VTOS, ETOS, and MPS, were used as precursors for silica formation. All silanes (less than 30 phr) were mixed into the latex compound containing vulcanization agents without any use of additional surfactants. After mixing, the latex mixture had to be maturated for 1-2 days to let the silane precursor to begin its sol-gel process at room temperature so that the degree of conversion from the alkoxysilane to silica would be more efficient.

The conversions of silane to silica from highest to lowest are TEOS (77.1%), VTOS (65.2%), MPS (18.7%), and ETOS (5.9%), depending on the size and polarity of the alkyl group in the silane. The mixtures of TEOS and alkyltrialkoxysilanes were required to generate the alkylated silica in order to produce the films with higher silica content than the amount in single silane system. By TEM, the *in situ* silica particles were observed around the NR particle. The size of silica particle was less than 100 nm, but it did not depend on the silane types. The SEM images and EDX analysis confirmed that the *in situ* silica particles were fairly dispersed inside the rubber matrix.

The results of mechanical properties indicated that samples containing *in situ* silica obtained from mixed TEOS-VTOS always possessed high tensile modulus. These results lead us to believe that vinyl groups in the *in situ* generated silica (from vinyltriethoxysilane) probably take part in the sulfur vulcanization process. For tension set, it was found that all dipped films samples had low tension set values

(<10%) and did not significantly different from one another. The resilience properties of rubber remained in all samples.

Thermal properties of the dipped films were measured by TGA. The degradation of all samples took place in two steps. The first step obtained from rubber decomposition is in the temperature range of 300-450°C. The second step of degradation was between 450-600°C, which related to the degradation of sulfur vulcanizates. The inclusion of silica in the dipped films did not enhance its thermal stability but only increased the char residue at 800°C.

5.2 Future directions

Since VTOS was found to be the alkoxysilane with the most reinforcement efficiency. Investigation should be carried out in more detail on the effect of the vinyl group on silica particle in terms of mechanical properties. The ratios of TEOS mixed with VTOS in the sol-gel process to prepare the composites must be explored with the aim to find the best formulation to enhance the mechanical properties of the dipped NR films.