

## CHAPTER V

### CONCLUSIONS AND FUTURE DIRECTION

#### 5.1 Conclusions

NR vulcanizates filled with silica were prepared by using alkyltriethoxysilanes (VTOS, ETOS, and BTOS) and TEOS as precursors to generate the silica *in situ*. The silanes were mixed and directly added into the concentrated latex having 60% DRC and 0.7% NH<sub>3</sub>. Each mixture was heated at 50°C for 5 days to complete the sol-gel process of the silanes. Conversion of the silanes to silica in the NR matrix was about 92% for TEOS, but decreased when the alkyl group of the alkyltriethoxysilanes increased in size. The conversion was decreased in such an order- TEOS > VTOS > ETOS > BTOS. The *in situ* generated silica particles from TEOS alone and alkyltriethoxysilanes/TEOS were well dispersed in the NR matrix without noticeable agglomeration, as was observed in the mechanically mixed silica-filled vulcanizate. The size of the *in situ* silica particle in the vulcanizate observed by TEM is approximately 40 nm, and not depending on the silane types.

The tensile modulus, tensile strength, and tear strength of the vulcanizates were affected by both the method for preparing the composites and the silanes types. The mechanical properties of the *in situ* silica-filled NR vulcanizates are higher than NR vulcanizate filled with silica powder (Hisil-255). Furthermore, these three mechanical properties of the *in situ* silica-filled NR vulcanizates could be increased by increasing the amount of VTOS in the VTOS/TEOS formulation from 5 to 20% of the total silanes. Cure characteristic and swelling in toluene gave evidences leading to the conclusion that the vinyl group (from VTOS) must probably participate in the sulfur vulcanization.

## 5.2 Future Direction

- Explore the use of other ratios of VTOS and TEOS in the sol-gel process to prepare the composites with the aim to find the best formulation to enhance the mechanical properties.
- Investigate in more detail on the effect of alkyl structure on the mechanical properties and cure behavior of the vulcanizates by preparing silica-rubber composite having the same amount of total silica in all samples.



ศูนย์วิจัยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย