

## CHAPTER VIII

### CONCLUSIONS AND RECOMMENDATIONS

#### 8.1 Conclusions

SBA-15 was successfully synthesized via a simple room temperature sol-gel process using silatrane, an inexpensive and conveniently prepared silica as the silica precursor and nonionic triblock copolymer (EO<sub>20</sub>PO<sub>70</sub>EO<sub>20</sub>) as a template under acid condition. The method is straightforward and can be conducted at room temperature without the need for hydrothermal treatment as conventionally required. The crystallographic, morphological and physical properties of SBA-15 obtained by this simple process are comparable to mesoporous silica prepared by the more complex microwave-assisted hydrothermal method. The metal substituted SBA-15 mesoporous materials (Ti-, Fe- and Mo-SBA-15) were also synthesized through the simple room temperature sol-gel process. DRUV results provide evidence that there is the upper limit of metal incorporation into SBA-15 framework. The SBA-15 framework can accommodate up to 7 mol% Ti, 10 mol% Fe and 1 mol% Mo without perturbing mesopore order. The catalysts maintained a *p6mm* hexagonal mesostructure, high surface areas (670-729 m<sup>2</sup>/g), large pore diameters (5.4-6.8 nm) and volumes (0.83-1.04 cm<sup>3</sup>/g). Systematic variations of acidity, aging temperature, aging time, and Ti loading lead to an optimized Ti-SBA-15 product.

Crystallochemical incorporation of Ti<sup>4+</sup>, Fe<sup>3+</sup> and Mo<sup>6+</sup> substitution for Si<sup>4+</sup> in the mesopores via sol-gel process proves superior catalytic performance to post-synthesis method by incipient wet impregnation under identical reaction condition. These materials were used as a catalyst in the catalytic activity of styrene epoxidation with H<sub>2</sub>O<sub>2</sub>. All Ti-, Fe- and Mo-SBA-15 demonstrate good activity and selectivity in this reaction. The only products obtained are styrene oxide and benzaldehyde. The selectivity of styrene oxide reached 34.2%, 34.5% and 39.9% at a styrene conversion of 25.8%, 10.3% and 7.7% for 7 mol% Ti-SBA-15, 10 mol% Fe-SBA-15 and 1 mol% Mo-SBA-15, respectively. This research demonstrates that M-SBA-15 (M = Ti, Fe and Mo) heterocatalysts can be synthesized by a low cost and energy efficient process that will allow to scale-up for possible industrially application.

## 8.2 Recommendations

1. The incorporation of two or three types of metals into SBA-15 framework should be studied to explore the potential in synergistic effect.
2. Other techniques to fabricate SBA-15 and metal substituted-SBA-15 should be studied, such as electrospinning technique, film etc.
3. Upscale of SBA-15 synthesis should be studied to explore the possibility to bring it to the industry.
4. Other applications should be studied, such as adsorption, separation etc.