# CHAPTER VI

# CONCLUSION AND RECOMMENDATION

## 6.1 Conclusions

ZnS nanoparticles with distinguishable morphology could be synthesized in quaternary W/O microemulsion systems using various types of cosurfactant. The main purpose of this research is to investigate the effect of cosurfactant types, reactant concentration, anions, and temperature. According to abovementioned experimental results, it can be concluded as follows:

### 6.1.1 Effect of types of cosurfactants

From the experimental result, it could be clearly shown that the size and the morphology of the ZnS nanoparticles are dependent upon the types of cosurfactant and the reactant concentration as well as the molar ratio of water to surfactant ($w_o$). Cosurfactant with large molecular size could provide higher possibility to synthesize ZnS nanoparticles with higher aspect ratio, like nanorod or nanotube. With relatively high reactant concentration, some certain amount of ZnS nanorod and nanotubes could be successfully synthesized. With n-hexanol at $w_o = 15$, and reactant concentration of 0.1 mol/dm$^3$, ZnS nanoparticles with the morphology of hollow tubes could repeatedly synthesized. However, with lower reactant concentration, spherical ZnS quantum dots or ellipsoidal nanoparticles became predominantly obtained regardless of types of cosurfactant or $w_o$.

### 6.1.2 Effect of types of anions

In this part, with addition of anions such as $Cl^-$ or $Br^-$ into the microemulsion, the higher population of ZnS nanorods and nanoneedles were obtained. From these results, it could be obviously shown that adding some amount of anions can have more effect on the morphology of the nanoparticles synthesized in the microemulsion with n-butanol as a cosurfactant. When employing this alcohol, the interesting ZnS nanorods with agglomeration of nanoneedles could be synthesized at high $w_o$ (15 or 20).

### 6.1.3 Effect of temperature

The reaction temperature can greatly affect the morphology and size of the resulting nanoparticles. The interesting morphologies of ZnS nanoparticles such as nanowires with very small diameter were also obtained when n- hexanol was employed as a cosurfactant and with aging temperature of 10 $^{o}$C. Some amount of nanotubes were also found when n-butanol was used as a cosurfactant at $w_o$=11 and the reaction temperature of 60 $^{o}$C. Moreover, very uniform spherical nanoparticles could be synthesized under some certain conditions. However, the study on this parameter needs more experimental investigation in the future.

## 6.2 Recommendation for future work

From the experimental results in this work, the desired products such as ZnS nanorods and nanotubes were found with some amount of spherical and amorphous nanoparticles. In several cases, these morphologies were found with less quantities compared with amorphous or nanospheres. How to get more nanoparticles with high aspect ratio especially for nanotubes when using W/O microemulsion method to synthesize should be more comprehensively studied. Such interesting products with distinguishable morphologies could be found while few reports in synthesizing nanotubes by using liquid phase reaction have been existed. However, there is one reference reporting about synthesizing ZnS nanotubes by using O/W microemulsion[6]. In their experiment, they used $CS_2$ as oil phase and sulphur source and they could get some amount of ZnS nanotubes. So we think this is one of good methods to produce the other sulphur compound-nanotubes. However, there are many problems in this method, one is about $CS_2$. This reagent is very toxic, serious health hazard and extremely flammable. Moreover, if you think to prepare other compound nanotubes, this method is so difficult.

As mentioned above, this research shows that it is possible to synthesize nanotubes and other interesting morphologies by using W/O microemulsion technique. However, some parameters should be studied in the future as follows:

1. Concentration of cosurfactants
2. Concentration of anions
3. Temperature
4. Mixing procedure