

## CHAPTER 4

### CONCLUSIONS

#### 4.1 Synthesis of tungsten oxide by a hydrothermal method using ammonium metatungstate hydrate as a tungsten source

In this work, orthorhombic tungsten oxide ( $o\text{-WO}_3$ ) was synthesized by the 200 °C, 24 h hydrothermal reaction of ammonium metatungstate solutions containing different volumes of 1M HCl and hexadecyltrimethylammonium bromide (CTAB) cationic surfactant. In the HCl-free solution, the product was an amorphous phase. When 2.50 ml 1M HCl was added to the solution, both orthorhombic  $\text{WO}_3 \cdot 0.33\text{H}_2\text{O}$  and  $\text{WO}_3$  phases were detected. These products became pure orthorhombic  $\text{WO}_3$  in the 5.00 ml and 7.50 ml 1M HCl-added precursor solutions. In 7.50 ml 1M HCl-added solution, the product was  $o\text{-WO}_3$  microflowers, with microsquare layers growing out of their cores. These analyses showed that their phases and morphologies were controlled by the acidity of the solutions. FTIR and Raman vibrations of  $\text{W}=\text{O}$ ,  $\text{O}-\text{W}-\text{O}$ , and  $\text{W}-\text{O}-\text{W}$  stretching modes were detected, and showed typical crystalline  $\text{WO}_3$ . Their optical properties showed a maximum absorption at 275 nm in the UV region and a maximum emission peak at 375 nm.

#### **4.2 Synthesis of tungsten oxide by a hydrothermal method using sodium tungstate dihydrate as a tungsten source**

Tungsten oxide ( $\text{WO}_3$ ) nanostructures with different morphologies were synthesized by hydrothermal reactions of sodium tungstate solutions containing different volumes of 3M HCl and ammonium sulphate as a capping reagent. A various factors influencing on the final morphologies of  $\text{WO}_3$  such as acidity, reaction temperature and time were studied. The XRD patterns revealed pure phase hexagonal  $\text{WO}_3$  (h- $\text{WO}_3$ ) by comparing with its JSPDS database. Their morphologies were observed by SEM that shows nanoparticles, nanorods and nanowires, controlled by various factors. Hexagonal  $\text{WO}_3$  nanowires with a diameter of 20-30 nm and lengths of up to several micrometers were successfully synthesized by a hydrothermal reaction at 200 °C for 48 h in a solution containing 5.00 ml 3M HCl-added precursor solution. FTIR and Raman vibrations of W=O, O-W-O, and W-O-W stretching modes were detected, and showed typical crystalline  $\text{WO}_3$ . Their optical properties showed a maximum absorption at 275 nm in the UV region.