

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORKS

Base on the experimental results, it has been demonstrated that the sparking process shows an important role in structural, optical, electrical and photocatalytic properties of ZnO and ZnO-TiO₂ coupled nanoparticle thin films. The following conclusions have been reached.

5.1 ZnO nanoparticle thin films

- (1) The anode tips were more eroded than the cathodes because the anodes were bombarded by the electrons and produced metallic ions as result more anode erosions.
- (2) The average sizes of the nanoparticles tended to increase with increasing the sparking voltage because of a high specific surface energy is governed by the associated energy stored in such a system. Since the electric energy stored in a capacitor is $E = \frac{1}{2} CV^2$, sparking at higher voltage supports the lower average sizes of the nanoparticles.
- (3) The particle sizes sparked from the sharp tips are smaller than the dull tips because “angle of the cone” and “radius of curvature” of the sharp tips were smaller than the dull tips so they have higher field enhance factor. Therefore, the local electric fields of the sharp tips were higher

than the dull tips so the tips transferred higher energy and produced the smaller nanoparticles.

- (4) The root mean square roughness of the thin films decreased with increasing the annealing temperature, whereas the average nanoparticle sizes increased. That was because the nanoparticles collapsed and merged with the others during the annealing process.
- (5) The film thickness could be controlled by the sparking number with the ratio of approximately 1 nm/spark.
- (6) The as-deposited films were mainly amorphous which were transformed to polycrystalline ZnO by the annealing treatments.
- (7) The optical transmittances in the visible region dropped with increasing the annealing temperature to the minimum transmittance at 600 °C.
- (8) The IL spectra of the films consisted of two emission bands, the green and orange-red emissions. The green emissions centered at 483 nm for the samples annealed at temperature ≤ 600 °C, but centered at 520 nm for the annealed sample at 800 °C. In contrast, the orange-red peaks centered at 650 nm for all samples.

5.2 ZnO-TiO₂ coupled nanoparticle thin film

- (1) The film thickness could be controlled by the sparking number with the ratio of 0.7 nm/spark.
- (2) The films consisted of ZnO, α -Zn₂TiO₄, Zn₂TiO₄, anatase and rutile TiO₂ (arranged from maximum to minimum amounts, respectively).

- (3) The films showed very high optical transmittance in visible region and a sharp drop in UV region at around 390 nm.
- (4) The IL spectra of the films consisted of two emission bands, the UV emission centered at 382 nm and green emissions centered at 518 nm.
- (5) The ZnO and TiO₂ films were better photocatalytic than the ZnO-TiO₂ coupled films, due to ZnO-TiO₂ coupled films consists of a lot of zinc titante component, non-photocatalyst materials.

5.3 Sparking ZnO using square wave pulse

- (1) The ZnO films were plated shape.
- (2) The film thickness could be controlled by the sparking time with the ratio of 17 nm/minute.
- (3) The ZnO films deposited on zinc substrates showed rectifier behavior when using silver paint as electrical contacts. This result confirms the sparking ZnO is n-type semiconductor.

5.4 Suggestion for further works

There are some interesting questions about sparking process of ZnO. Thus, it is anticipated that this could be partly filled by the following suggestions for further work.

- (1) Sparking process is a very simple method to deposit nanoparticle thin films from various metals therefore metal or metal oxide nanoparticle thin films, depend on oxidation conditions, should be fabricated. This

technique may be used to produce thin films for various applications such as, indium tin oxide for transparent oxide film and ferrite oxide films for magnetic application.

- (2) Further work on the doping ZnO to p-type semiconductor, because p-type ZnO are widely used in optoelectronic applications. Nitrogen is one of the most favorite dopant p-type ZnO so it is possible to dope nitrogen by sparking ZnO in nitrogen and oxygen containing atmosphere, such as nitrous oxide (N_2O) and the mixture of oxygen (O_2) and ammonia (NH_3).
- (3) The photocatalytic activity of the ZnO-TiO₂ coupled films should be improved by minimizing zinc titanate component in the films.
- (4) The sparking ZnO films using the discharge of capacitor and the square wave pulses produced the different surface morphology films. Therefore, it is interesting to study effects of sparking frequencies, duty cycles and wave forms on the morphology of the films.