Chapter 7

Conclusions

ZnO nanowires were grown on Si(100) and Si(111) substrates by thermal evaporation method in a conventional and modified set-up. FESEM images showed the size of undoped ZnO nanowires were sensitive to the substrate temperature and orientation of the substrates as well as the vapor concentration in the set-up. A surface effect in term of nanowires diameters has been suggested as an explanation for the observed shift in the peak position (381nm → 375nm) of the UV emissions. In addition, a relationship between UV and DLE emission intensities and aspect ratio of the nanowires was obtained. Furthermore, PL results of the nanowires were grown by a modified set-up showed improved optical properties by emitting only UV emission of the nanowires that produced by the modified set-up.

Besides the growth of undoped ZnO nanowires, we investigated the effect of doping materials (Mg, Al, In, Sn, and S) on morphological and optical properties of doped ZnO nanowires and nanobelts. Two methods were used to produce Mg-doped ZnO nanowires. Firstly, a sintering method with gold catalyst was used to prepare the source material; secondly, a modified set-up was used to grow of Mg-doped ZnO nanowires. Our studies have shown that the nanowires produced by second method were better than the first method. Furthermore, gold effect catalyst on Mg-doped ZnO nanowires was investigated and was observed that gold catalyst have a significant role during growth process of Mg-doped ZnO nanowires. It was also shown from field emission study that the $Zn_xMg_{1-x}O$ nanowires grown with thinner gold catalyst are excellent field emitters. This superior field emission property is attributed to their sharp tips and high aspect ratio.

Ultra thin film AlN was used as a source material for Al-doped ZnO nanowires. Studies have indicated that Al diffused from AlN thin film into ZnO nanowires. Auger spectroscopy studies have shown that the existence of Al has caused Auger electron energies of Zn and O shifted to higher energies.

In this work In was also used as dopant in ZnO nanowires. The sintering method was also used to prepare of the source material for In-doped ZnO. EDX and Auger studies have indicated that the nanowires were grown with heterostructure of ZnO/ZnInO. The nanowires growth process study has shown that In has taken as a self-catalytic role during growth process of the nanowires. Furthermore, the PL results have shown that the optical band-gap of ZnO nanowires was increased by 0.09 eV due to In-doping.

The final part of our research was a comparative study on the optical properties of S- and Sn-doped ZnO nanobelts as a cation and an anion dopant, respectively. S- and Sn-doped ZnO nanobelts have shown a significant different in the optical properties. The S-doped ZnO nanobelts exhibited only DLE in the visible region (blue, green, and yellow emissions) without any peaks in the UV region. On the other hand, the PL result of the Sn-doped ZnO nanobelts has two emission bands, one related to the UV emission with a strong peak at 376 nm, and another related to the green emission with a weaker peak. The UV peak of the Sn-doped ZnO nanobelts has blue-shifted by about 6 nm in comparison to that of the undoped ZnO nanobelts. A weak UV peak appeared at 383 nm for the S-doped ZnO nanobelts, and the UV peak of the Sn-doped ZnO nanobelts was more blue-shifted after annealing at air ambient. Studies have shown that the optical properties of the S-doped ZnO nanobelts were more greatly affected by annealing than that of the Sn-doped ZnO nanobelts.

Future work should focus on various aspect of growing *p*-type ZnO nanostructures. These will include the type of dopants used as well as the doping

technique. The ability to produce not only *n*-type but also *p*-type ZnO is very crucial in terms of electronic devices fabrications. Similar study on other metal oxide such as nickel oxide can provide insight on the deeper understanding of such materials.