

# **Materials Characterizations and Process Development of WN<sub>x</sub> T-gate AlGa<sub>N</sub>/Ga<sub>N</sub> High Electron Mobility Transistor for High Temperature Applications**

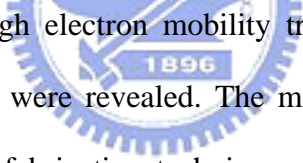
Student: Chao-Yi Fang

Advisor: Prof. Edward Yi Chang

Prof. Ming Shein Feng

Department of Material Science and Engineering  
National Chiao Tung University

## **ABSTRACT**



AlGa<sub>N</sub>/Ga<sub>N</sub> HEMTs (high electron mobility transistor) with WN<sub>x</sub> T-gate for high temperature applications were revealed. The materials growth of AlGa<sub>N</sub>/Ga<sub>N</sub> HEMT structures and device fabrication techniques were developed, especially for high temperature applications including metallization and etch techniques. This dissertation starts with the epitaxy of the Ga<sub>N</sub>. The recrystallization process was optimized by the ramping rate. The PL of the Ga<sub>N</sub> at low temperatures was discussed in details that showed the fine structure of the valence band. The 2DEG related intersubband emissions of the AlGa<sub>N</sub>/Ga<sub>N</sub> heterostructures were observed at low temperatures. The effects of the Al compositions and spacer thickness on the energy levels of the subbands in the triangular well of the Al<sub>x</sub>Ga<sub>1-x</sub>N/Ga<sub>N</sub> heterostructures were discussed. The ICP (Inductively coupled plasma) and PEC (photo-enhanced chemical) etch were also investigated in this dissertation. Schottky diodes characteristics were as indexes in optimizing the parameters. By applying the hybrid

ICP and PEC etch, it is possible to minimize the surface damages after etch. The hybrid etch technique was then applied to fabricate the HEMTs in this dissertation. The metallizations, the Ohmic electrode and the Schottky electrode, for high temperature applications were also studied. The  $\text{TiWN}_x$  and  $\text{WN}_x$  were used as Schottky contact materials. The materials analysis showed that the Ti atoms in  $\text{TiWN}_x$  were easy to diffuse into the GaN. As a result, the  $\text{WN}_x$  was the better choice in fabricating Schottky electrode. The thermal stability of the Ti/Al/Pt/Au Ohmic contact and the  $\text{WN}_x$  Schottky contact to GaN were proven to be working well at high temperatures. Using the etch techniques and the metallization techniques developed here, the  $\text{WN}_x$  T-gate HEMTs were carried out. According to the DC characteristics at high temperatures, the  $\text{WN}_x$  T-gate AlGaN/GaN HEMTs showed high thermal stabilities that were very suitable for high temperature applications.

