The Study on Characteristic of Nitride Semiconductor Electron Devices Using micro-Raman Spectroscopy

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This thesis for a doctorate is to characterize nitride semiconductor electron devices using micro-Raman spectroscopy and electro-thermal simulation. AlGaN/GaN HFETs (heterostructure field effect transistors) have been targeted for high power, high frequency and high temperature electronic devices for mobile communication systems, radars and power electronics. In order to realize these features, much effort must be paid to solve various problems, for example the thermal management, reliability and degradation from self heating effect and high electric field concentration.

First, we develop the way of direct measurement technique because the analysis of temperature distribution in devices is important to examine intrinsic device performance and to avoid the overheating. We use GaN E_2(high) phonon peak position for high temperature resolution measurement with actually operating device. This micro-Raman system demonstrates the highest performance in the world for these purposes.

Next, we use this micro-Raman system for 2D temperature distribution and device simulation on different structure of AlGaN/GaN HFETs. These device temperatures depend on thermal conductivity of substrate and power density. The maximum temperatures appeared around the gate edge on the drain side seem to correspond to high electric field regions. The thermal conductivity of substrate and exhaust heat technique are important to high power operation.

At last, we study HFET operated around breakdown voltage to understand much further high power operation using our analysis techniques. We propose a conduction mechanism under operating around breakdown bias by the detailed temperature measurement and device simulation. The model predicts some degradation of transconductance and pinch-off characteristics under operating around breakdown bias.

The subjects of high power operation and reliability of AlGaN/GaN HFETs become increasingly important. These results obtained in this study will provide academic and technical expertise regarding the development of AlGaN/GaN HFETs and related fields.