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論　文　内　容　要　旨

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学位論文題目	Investigation on Integrated AlGaN/GaN Ion-Sensitive Field-Effect Transistors（集積化AlGaN／GaNイオン感応性電界効果トランジスタに関する研究）		

内容要旨

AlGaN/GaN heterostructure ion-sensitive field-effect transistors (ISFETs) can provide high sensitivity and fast response due to the high electron mobility and high electron density providing by the two-dimensional electron gas (2DEG) generated at the AlGaN/GaN heterostructure interface. My research mainly focuses on the investigation of the integrated AlGaN/GaN ISFETs for pH sensing.

To achieve high performance on AlGaN/GaN ISFET pH sensor, we fabricated sensors with different Al composition (25%, and 35%). We compared the characteristics of the sensors with 25% and 35% Al composition. The pH sensor with Al composition (35%) in the barrier layer with a 16 nm transition layer of 25% Al composition shows better surface sensitivity (S_V) of 56.01 mV/pH, which is higher than that of the sensor with 25% Al composition (53.94 mA/pH), but worse current sensitivity S_A (-0.09544 mA/pH Vs -0.10166 mA/pH). In addition, threshold voltage increases from approximately -1.6 V to approximately -0.8 V when measured in alkaline solution for 5 times, along with a decreasing output current. High-resolution SEM photos show that there are high density hexagonal pits with the size of approximately 100 nm on the device surface, presenting the etching effect along the dislocations during alkaline sensing. The X-ray photoelectron spectroscopy (XPS) demonstrates that the intensity of the Ga3d and Al2p spectra decreases after pH sensing measurement, implying the variation of chemical component occurs in the upper AlGaN thin layer. Many voids with a size of approximately 100 nm were observed from the transmission electron microscope (TEM) pictures, which are comparable with that of the scanning electron microscope (SEM). Combining with the energy dispersive X-ray spectroscopy (EDX), the degradation in electrical performance can be attributed to the transformation of AlGaN into oxide as well as the followed alkaline solution dissolve.

To avoid the reaction of surface Al with solution, a 3 nm GaN cap layer was added. To reduce the barrier layer thickness, a recessed gate with a length of 2 μm and a depth of about 14 nm was formed. The current sensitivity of the AlGaN/GaN ISFET pH sensors has been improved by 61%, from 52.25 to 84.39 μA/pH, by the recessed-gate structure and ammoniate water treatment.

A pH meter system based on the GaN pH sensor was constructed and evaluated. GaN-based ISFET can measure the pH value of the solutions with similar circuit, whether in the linear region or the saturation region. The measurement is stable and repeatable. The small current in the linear region can make the measurement stable and fast, but the resolution is a bit low. High resolution can be obtained in the saturation region, but the measurement is unstable due to excessive current.

The Schottky barrier diode (SBD) based on GaN can be used for temperature sensing, and the temperature sensitivity can be improved by different structure design. A recessed anode AlGaN/GaN SBD is suitable to integrate with GaN-based power device for temperature sensor application. The temperature dependent forward voltage at a fixed current shows good linearity, resulting in a sensitivity of approximately 1.0 mV/K. The p-NiO guard ring can suppress the electric field at the anode/GaN interface and field crowding at the anode edge effectively, which enhances the breakdown voltage to approximately -250 V. Using the same material, we can design an integrated device sensor based on GaN to measure temperature and pH simultaneously, which will solve the measurement deviation of pH sensor at different temperatures.