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論 文 内 容 要 旨

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学位論文題目	Development of GaN Diodes with NiN Electrodes for Power Electronics and Temperature Sensing Applications (NiN電極を有するパワーエレクトロニクス及び温度センシング用GaNダイオードの研究)		

Schottky barrier diode (SBD) is a critical device of antenna-rectifier (rectenna) circuit in the microwave wireless power transmission systems, which is widely used in electric vehicle power charging, energy harvesting systems, power source, and in-building wireless power distribution. Gallium nitride (GaN)-based materials exhibit many extraordinary features, including large bandgap, higher breakdown field, higher electron mobility and higher electron saturation velocity, accordingly GaN-SBDs have attracted much attention for improving the efficiency of microwave wireless power transmission system. However, the most common Ni anode is reported to form a Ni-N alloy (a mixture of Ni_3N, NiN and so on) after thermal treatment, resulting in the degradation of stability. This is required more stability materials to replace the Ni for the Schottky contact applicaion. Moreover, GaN-based electronic devices have shown the excellent thermal stability and strong temperature dependence, meaning that it can be a possible candidate for temperature sensing. In this thesis, we discussed the synthesis and application of nickel nitride (Ni_xN) for GaN electron devices application. Meanwhile, we also investigated the GaN based pn diodes and SBD diodes for temperature sensor application.

Ni_xN films were deposited by magnetron reactive sputtering under varying N_2 partial pressure ($P(N_2)$) conditions range from 0.005 to 0.184 Pa. With the increasing $P(N_2)$, the deposition rate decreases while the resistivity and root mean square roughness increased. X-ray diffraction (XRD) and X-ray photoelectron spectra (XPS) indicate that Ni_4N and Ni_3N phases dominate the films at low and medium $P(N_2)$, respectively. In addition, Ni_2N phase can be also obtained at high $P(N_2)$. The Ni/N ratio evaluated from the energy dispersive X-ray spectrum is consistent with the Ni_xN phases showed in the XRD spectra of different $P(N_2)$. Comparing with the GaN diodes with Ni anode, the Schottky barrier height and turn-on voltage of the Schottky barrier diodes with Ni_xN anode are increased with 0.03~0.18 eV and 0.03~0.15 V, respectively. Capacitance-voltage curves demonstrated that good interface quality with no obvious hysteresis is realized.

Especially, Ni_3N anode diodes obtained at medium $P(N_2)$ possess a high barrier height and a low reverse leakage current and are regarded as a promising anode material. The temperature-dependent current voltage characteristics demonstrate that the Ni_3N-SBDs have better thermal stability than that of Ni-SBDs, owing to the suppression of interface reaction between Ni and GaN. In addition, the thermal stability of GaN diode with Ni_3N anode is potential for temperature sensing application with the sensitivity of approximately 1.3 mV/K.

P-NiO/n-GaN pn diodes and TiN/GaN SBDs were investigated extensively by varying the device diameter and current level. For the NiO/GaN pn diode, it is demonstrated that the series resistance and ideality factor dominate the sensitivity at the fully-turn-on state. However, the series resistance weakly influenced the sensitivity of the TiN/GaN SBDs temperature sensor at the fully-turn-on state. After subtracting the component of series resistance, the sensitivity decreases and increases with the increased device diameters for the p-NiO/n-GaN pn diodes and TiN/GaN SBDs temperature sensors, respectively.

For both type temperature sensors, in the sub-threshold state, a good linear relationship between sensitivity and the corresponding current density have been observed for devices with different diameters. A low current density is corresponding to the high sensitivity. The NiO/GaN pn diodes and TiN/GaN SBD presenting good thermal stability and linearity from 25 to 200 °C are promising candidates for temperature sensing application.

We also investigated the NiN/GaN SBD for temperature sensor application. While in the sub-threshold region, a good linear relationship between sensitivity and the corresponding current density hav been observed for a 200μm diameter NiN/GaN SBD temperature sensor. Comparing whih TiN, Ni and NiN electrode GaN SBD temperature sensor, the NiN electrode device shows a near-ideal theoretical sensitivity of a GaN SBD temperature sensor which is calculated by the TE model from GaN based SBDs.

We fabricated NiN-gated AlGaN/GaN HFETs by magnetron reactive sputtering with a Ni target in an ambient Ar and N_2 mixture gas. Gete leakage current characteristics shows that the reverse leakage current of NiN-gated HFETs is approximately reduced by one order of magnitude and the ON/OFF drain current ratio increases two order of magnitudes comparing with the conventional Ni-gated HFETs. The temperature-dependent gate leakage current-voltage characteristics demonstrate that the NiN-gated HFETs have better thermal stability.