

論 文 内 容 要 旨

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学位論文題目	Synthesis and Application of Oxide for Gallium Nitride Electron Devices (酸化物の合成と窒化ガリウム電子デバイスへの応用)		
<p>内容要旨</p> <p>Due to the superior material properties of GaN, AlGaN/GaN HFETs have become the subject of competing research. In the field of high temperature and high frequency, an urgent need is to reduce the leakage current. For MOSFETs, there is an urgent need to find materials with high K and high crystallization temperatures for their high temperature applications. In this thesis, we discussed the synthesis and application of oxide for GaN electron devices, and the details as follows:</p> <p>NiO is a natural p-type semiconductor with stable chemical properties. Firstly, we fabricated NiO films with different O₂/Ar ratios of 15%, 25%, 50%, and 65%. The NiO films with the face-centered cubic crystalline structure are analyzed by AFM, XRD, XPS, and UV-Vis transmittance spectra. An optimal oxygen ratio for growing NiO is obtained.</p> <p>And then we evaluated the effect of the substrate temperature on the properties of the NiO films using magnetron reactive sputtering. All NiO samples can be indexed as (111) oriented face-centered cubic crystalline. When the substrate temperature increased from 30 to 200 °C, the crystalline quality and stoichiometric of the NiO film were improved, resulting in higher bandgap value and resistivity. While further increasing the substrate temperature to 300 °C, the decomposition of NiO will cause the appearance of Ni metal in the film. The NiO film under 30 °C has a lowest resistivity.</p> <p>Next, we have investigated the electrical properties of the NiO/GaN heterojunction device in the temperature range 25-175 °C. The turn-on voltage of the NiO/GaN heterojunction diode is relatively higher, comparing with the Ni/GaN Schottky diode. The NiO/GaN diode shows the more smaller reverse leakage current with exhibiting a temperature-dependent turn-on voltage. The as-grown NiO exhibited cubic crystalline structure with a bandgap of 3.2 eV. The NiO/GaN diode exhibited a temperature-dependent turn-on voltage. The three types of current transport mechanism are found to be strongly related to the applied bias voltages and temperatures. On the other hand, the device exhibited considerably a stable behavior over the temperature range of 25-175 °C and will be favorable for wildly applying in high-temperature and high-power environments.</p> <p>Combining the material and electric results, the NiO film under 30 °C with lowest resistivity is used as the gate electrode for HFETs application. Compared with the</p>			

Ni/Au-gated device, the threshold voltage of the NiO-gated device have a positive shift of approximately 1V because of the p-type conductivity as well as the conduction band offsets between NiO and GaN. The band offset at the heterojunction interface can be measured by XPS employing a well-known Kraut's method. The corresponding valence and conduction band offset is calculated to be 1.25 and 1.42 eV using a band gap of 3.57 eV for the NiO film. For the normally-off AlGaIn/GaN HFETs, we fabricated NiO gate with recess structure, the threshold voltage for the Ni- and NiO-gated HFETs has a positive shift after recessing. Normally-off GaN HFETs can be obtained with a threshold voltage of closing to 0 V with the recessed-gate structure.

HfO₂ and HfO_xN_y with wide bandgap and high-k are extensive investigated as one of the most promising candidates. Finally, We fabricated TiN/HfO_xN_y/AlGaIn/GaN MOSHFETs with different oxygen flow rates in the reactive sputtering ambient. The composition of films changed from HfN to HfO₂ domination with the increasing oxygen flow rate and HfO_xN_y formed at a medium oxygen flow rate. Compared with HfO₂ MOSHFETs, the introduction of the HfO_xN_y dielectric results in a negative shifting threshold voltage and a lower leakage current. After post deposition annealing at different temperatures, the devices using HfO_xN_y dielectric show good thermal stability at 900 °C while obvious degradation are observed for the HfO₂ MOSHFETs at 600 °C. A possible mechanism is that the existence of Hf-N bond in bulk dielectric and N at the dielectric/GaN interface can help to improve the thermal stability.