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Improved Non-Ideal Effects in AlGaN/GaN-Based Ion-Sensitive Field-Effect Transistors

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Abstract : This work uses H2O2 oxidation technique to improve the pH sensitivity of the AlGaN/GaN-based ion-sensitive field-effect transistors (ISFETs). 10-nm-thick Al2O3 was grown on the surface of the AlGaN. It was found that the pH sensitivity was improved from 41.6 mV/pH to 55.2 mV/pH. Since the H2O2-grown Al2O3 was served as a passivation layer and the problem of Fermi-level pinning was suppressed for the ISFET with the H2O2 oxidation process. Hysteresis effect in the ISFET with the H2O2 treatment also became insignificant. The hysteresis effect was observed by dipping the ISFETs into different pH value solutions and comparing the voltage difference between the initial and final conditions. The hysteresis voltage (Vhys) of the ISFET with the H2O2 oxidation process was improved from 8.7 mV to 4.8 mV. The hysteresis effect is related to the buried binding sites which are related to the material defects like threading dislocations in the AlGaN/GaN heterostructure which was grown by the hetero-epitaxy technique. The H2O2-grown Al2O3 passivate these material defects and the Al2O3 has less material defects. The long-term stability of the ISFET is estimated by the drift effect measurement. The drift measurement was conducted by dipping the ISFETs into a specific pH value solution for 12 hours and the ISFETs were operating at a specific quiescent point. The drift rate is estimated by the drift voltage divided by the total measuring time. It was found that the drift rate of the ISFET was improved from 10.1 mV/hour to 1.91 mV/hour in the pH 7 solution, from 14.06 mV/hour to 6.38 mV/pH in the pH 2 solution, and from 12.8 mV/hour to 5.48 mV/hour in the pH 12 solution. The drift effect results from the capacitance variation in the electric double layer. The H2O2-grown Al2O3 provides an additional capacitance connection in series with the electric double layer. Therefore, the capacitance variation of the electric double layer became insignificant. Generally, the H2O2 oxidation process is a simple, fast, and cost-effective method for the AlGaN/GaN-based ISFET. Furthermore, the performance of the AlGaN/GaN ISFET was improved effectively and the non-ideal effects were suppressed.

Keywords : AlGaN/GaN, Al2O3, hysteresis effect, drift effect, reliability, passivation, pH sensors
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