Intoduction

In previous works, we studied the selective and reversible response to anions of the undoped Gallium Nitride (0001) planar electrodes in aqueous solution using potentiometric measurements. In this work, we study the response of AlGaN/GaN ChemFETs to different potassium salts (KCl, KBr, KNO₃ and KSCN) in solution, which confirms the preferential anionic binding on the 6H-GaN surface, and leads to the development of new series of Anion-Selective CHEMFETs.

Results

ChemFETs were fabricated from AlGaN/GaN HEMT structure grown by plasma-assisted Molecular Beam Epitaxy. A 2µm GaN cap layer covered the AlGaN barrier to secure the electrochemical characteristics of the GaN surface for the ChemFET. The polarization discontinuity at an AlGaN/GaN heterojunction results in a net positive polarization charge at the interface. This phenomenon is compensated by the formation of a mobile two dimensional electron gas (2DEG) at the GaN side, thus forming the conductive channel of high electron mobility transistor (HEMT) devices. The 2DEG density was 1.2x10¹⁰ cm⁻² with mobility of approximately 900 cm²/Vs at 300K and 3,000cm²/Vs at 77K, according to Hall effect measurements. ChemFETs with gate-width W=100µm and gate-length Lg in the range of 10-100µm were processed on the same chip. Device mesas with a depth of 0.4µm were formed by Cl₂-based reactive ion etching. Source and drain ohmic contacts consisted of a Ti/Al/Ni/Au multilayer annealed at ~800°C. Finally, the ChemFETs metallic contacts were encapsulated by polyimide (Figure 1).

Firstly, we examined the pH response of ChemFETs in a 2√[N-morpholino] ethanesulfonic acid 0.1M buffered solution by gradually adding amounts of 0.1M KOH solution. Figure 3 shows the Iᵩᵩ₋Vᵩᵩ characteristics of an ChemFET with Lᵩᵩ=80µm for different pH values. The response of Iᵩᵩ to pH at Vᵩᵩ=10V was Iᵩᵩᵩᵩ/pH =4µA/pH and the average response of Vᵩᵩᵩᵩ was 5V/pH=50mV/pH. It is concluded that since Iᵩᵩᵩᵩ decreases with increasing pH, negatively charged species (OH⁻) are being adsorbed onto the active 6H-GaN (0001) surface.

The next step was to study the effect of different concentrations of KCl, KBr, KNO₃ or KSCN salts in water. Figure 4(a) shows the Iᵩᵩ₋Vᵩᵩ characteristics for a ChemFET sensor with Lᵩᵩ=80µm immersed in different concentration of KCl solutions. The average response of Iᵩᵩᵩᵩ to the concentration range of KCl between 10⁻¹⁰M and 1M was -15µA/decade, at Vᵩᵩᵩᵩ=2.5V.

Conclusions

The presented results reveal a clear response of AlGaN/GaN ChemFETs to pH and anions in aqueous solution. This should be taken into account in advancing the understanding of the principles of operation of the novel family of AlGaN/GaN ChemFET sensors. The results also demonstrate the capability of using AlGaN/GaN ChemFETs as the basis for developing a novel family of Chemical and Biochemical sensors.

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