Nearly-ideal Molybdenum Schottky contacts on AlGaN/GaN heterostructures

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Gallium Nitride (GaN) stands out as a promising material for next-generation high-power electronic devices due to its wide bandgap of 3.4 eV and high critical breakdown electric field of 3.3 MV/cm [1]. Additionally, the development of AlGaN/GaN hetero-epitaxial structures benefits from the coexistence of spontaneous and piezoelectric polarization [2], which leads to the formation of a quantum-confined two-dimensional electron gas (2DEG) with high sheet carrier density and electron mobility [3]. These properties make high electron mobility transistors (HEMTs) based on such heterostructures highly attractive for advanced high-power and high-frequency applications.

In HEMTs, Schottky contacts are critical for modulating the amount of charge of the 2DEG underneath the gate contact. The electrical behavior of Schottky contacts is ideally explained by the Thermionic Emission (TE) model, exhibiting temperature-independent parameters like the Schottky barrier height (Φ_B) and a unitary ideality factor (n) [4]. However, in AlGaN/GaN heterostructures, deviations from ideality are particularly significant, often with ideality factors exceeding 2 [5], [6]. Furthermore multiple mechanisms are often employed to rationalize the overall conduction mechanism [5], [6]. Such strong deviations from ideality indicate the complexity of conduction mechanisms in these systems and highlight the need for detailed studies to understand these behaviors.

Commonly used Schottky contacts for AlGaN/GaN heterostructures employ Ni/Au bilayers. On the other hand, also other unconventional metallization, such as W, TiN, WC, Cu, Fe, or Al have been explored [7]. Molybdenum (Mo), as a refractory metal with a high melting point (2600 °C), exhibits favorable properties such as thermal stability, mechanical strength, good adhesion to AlGaN/GaN surfaces, and low oxidation tendency below 500 °C. Despite its potential as a cost-effective "Au-free" alternative, the application of Mo Schottky contacts in GaN-based electronics deserve further investigation.

This study investigated Mo Schottky contacts on AlGaN/GaN heterostructures using current-voltage-temperature (I-V-T) measurements (see Fig. 1). The results, displayed in Fig.2, indicate near-ideal TE behavior, with an ideality factor of ~1.26 at 25 °C and minimal changes over the temperature range of 25–150 °C. The barrier height increased slightly from 0.85 eV to 0.89 eV, while the ideality factor decreased from 1.26 to 1.20. These findings suggest a minimal contribution from tunneling mechanisms. To address deviations from ideal TE behavior, the inhomogeneity of the Schottky barrier was analyzed using Tung's model [8]. This model provides insights into the observed temperature dependence of the Schottky barrier and ideality factor, attributing the deviations to localized low-barrier regions embedded within the overall barrier [9],[10]. Furthermore, introducing the inhomogeneities contribution to the Richardsons' equation, it was possible to extract a value of the Richardsons' constant that is close to the one commonly used for AlGaN/GaN heterostructures (32 A cm^{-2} K^{-2}). Moreover, according to the Tung's model it was possible to model the I-V curves acquired at the different temperature by considering 10 different patches (see Fig.4).
These results expand the understanding of conduction mechanisms in AlGaN/GaN heterostructures and highlight Mo as a promising material for GaN-based electronics.

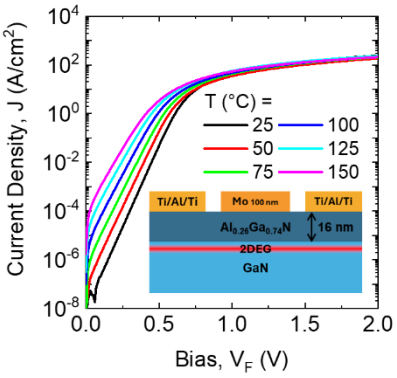

Figure 1 Experimental J-V curves of the Mo/AlGaN/GaN diodes

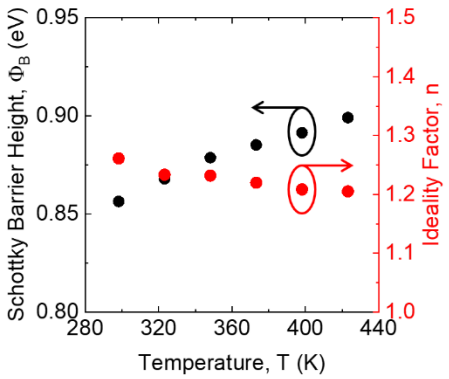

Figure 2 Thermal dependence of the barrier height and ideality factor

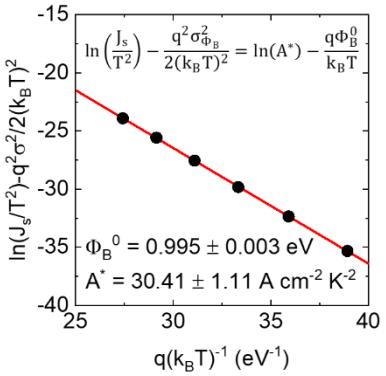

Figure 3 Richardsons' plot including the inhomogeneities contribution, extraction of a constant A* = 30.41 A cm^{-2} K^{-2}

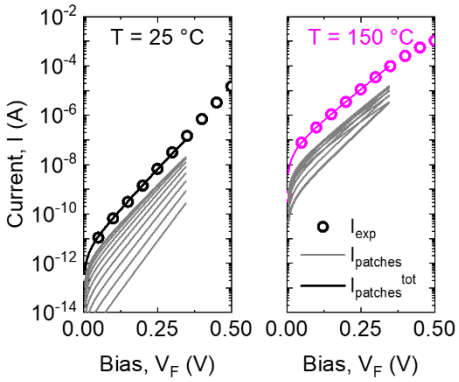

Figure 4 Rationalization of the conduction mechanism considering 10 different patches according to Tung's model

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