Forward conduction mechanism at W-based Schottky contacts on AlGaN/GaN heterostructures

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Gallium Nitride (GaN) is considered to be a suitable material for the next generation of high power electronic devices considering the high bandgap (3.4 eV) and high critical breakdown electric field (3.3 MV/cm) [1]. Furthermore, the fabrication of AlGaN/GaN epitaxial heterostructures, due to the compresence of spontaneous and piezoelectric polarization [2], leads to the formation of a quantum confined two-dimensional electron gas (2DEG) characterized by a high electron mobility of about 2000 $cm^2V^{-1}s^{-1}$ [3]. For these reasons, high electron mobility transistors (HEMTs) based on heterostructures are captivating devices for the next generation of high-frequency applications.

The Schottky contact plays a significant role in HEMTs, modulating the amount of charge of the 2DEG channel, i.e. the channel current. The conduction mechanism at Schottky metal/semiconductor interfaces is an extremely important topic for AlGaN/GaN HEMTs. Typically, this current is rationalized by the Thermionic Emission (TE) model, and it depends on the bias applied to the contact and the energetic value of the barrier at the interface, defined as Schottky Barrier Height (SBH). In particular, the SBH represent a fundamental parameter in HEMTs technology, since it has practical repercussions on devices' performances (turn-on voltage [4], threshold voltage [5], subthreshold swing [6], and overall reliability [7]). However, the presence of the 2DEG at the AlGaN/GaN interface, as well as active participation of defects inside the semiconductor, can lead to the co-presence of other mechanisms that have to be taken in consideration for a correct interpretation of the leakage current [8-10].

In this work, we have studied the current mechanisms at the interface of a W-based Schottky metal on AlGaN/GaN heterostructures by measuring the electrical properties (I-V) of Schottky Barrier Diodes at different temperatures. In Fig. 1 is reported the semilog plot of the forward current density-voltage (J-V) characteristics of the Schottky diodes measured at temperatures that range from 25°C to 150°C. The electrical behavior of the measured J-V curves displays the presence of a knee (around 1 V at room temperature) that becomes less evident by increasing the measurement temperature. The TE model itself is not able to completely explain the behavior of the acquired J-V curves. Indeed, the first linear region of the curve (0.2 – 0.5 V) has been fitted employing the tunneling model. From the slope of these curves, it is possible to extrapolate the value of E_0 [8] defined as a tunneling parameter. Then, from the thermal dependence of E_0 it was possible to estimate a value of E_{00} = 75 meV, which represents the characteristic tunneling energy, as reported in Fig. 2.

In the second linear region (0.7 – 1.2 V) the TE model has been adopted to describe the behavior of the J-V curves. Here, from the fit of the experimental curves it was possible to extrapolate the SBH and the ideality factor. These values are extracted for each curve at different temperature (Fig. 3), and by increasing the temperature from 25°C to 150°C, there's a decrease of the ideality factor from 2.59 to 1.97, and an increase of SBH, from 0.77 to 0.93 eV.

The thermal dependence of the SBH and the ideality factor is symptomatic of an inhomogeneous contact, in fact from the analysis of the experimental data the diode is made of different regions each that contribute to the total current with a particular conduction mechanism. Indeed, considering both Tunneling and TE model, it was possible to fit the entire experimental curves. In Fig. 4 the J-V curves acquired at 25°C and 150°C has been displayed as an example. In particular, it can be seen that at low bias (<1 V) the tunneling mechanism has the highest contribution to the total current density, while at high bias (>1 V) the TE mechanism prevails.

Increasing the temperature makes the TE model to be the most predominant mechanism over a wider range of applied bias even at bias lower than 1 V.

These results highlight the inhomogeneity nature of the Schottky contact on AlGaN/GaN heterostructures, and the prevalence of the Tunneling or TE model indicated by the evident knee in the experimental J-V curves depending on the temperature and the applied bias.

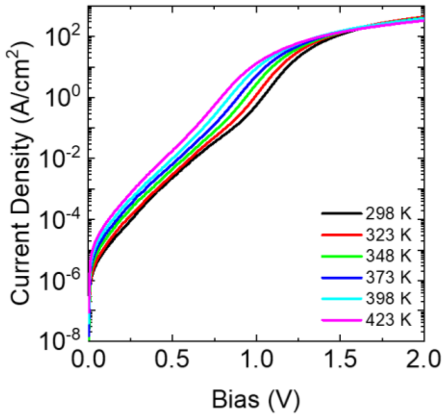

Fig 1. Experimental J-V curves measured at different temperatures.

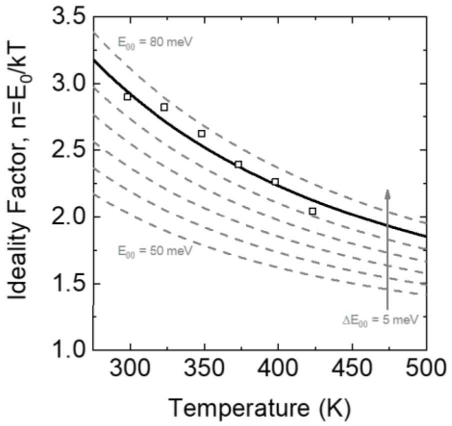

Fig 2. Temperature dependence of the ideality factor and simulation of ideality factors for arbitrary E_{00} values.

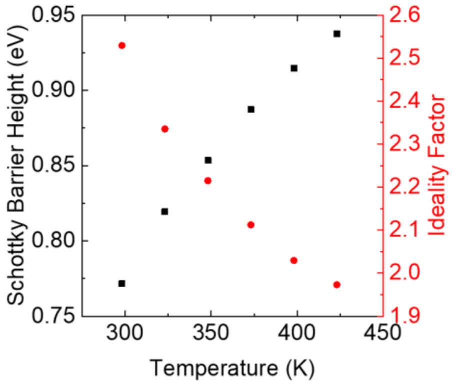

Fig 3. Temperature dependence of the ideality factor and the Schottky Barrier Height from TE mode.

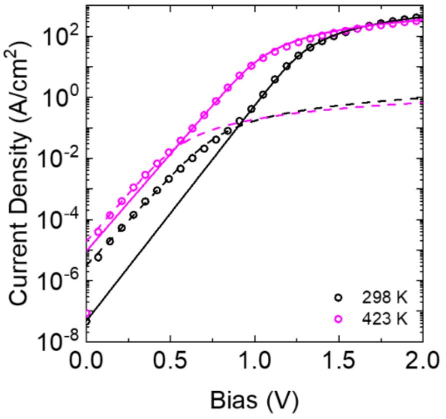

Fig 4. Experimental and fitted J-V curves according to the Tunneling model (dashed lines) and the TE model (solid lines) at 25°C and 150°C.

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