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Richard Meunier, Alphonse Torres, Matthew Charles, Erwan Morvan, Marc Plissonnier, Frédéric Morancho

To cite this version:

HAL Id: hal-01054216
https://hal.science/hal-01054216
Submitted on 5 Aug 2014

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**AlGaN/GaN MIS-HEMT Gate Structure**

Improvement Using Al₂O₃ Deposited by PEALD

R. Meunier¹, A. Torres¹, M. Charles², E. Morvan³, M. Pliissonnier¹, F. Moranco²

¹CEA-Leti, LC2E, 17 Rue des Martyrs, 38054 Grenoble Cedex 9, France
²LAAS-CNRS, 7 Avenue du Colonel Roche, 31400 Toulouse, France

AlGaN/GaN heterostructures are very promising for the elaboration of high-power and high frequency devices because of their excellent electrical properties such as a high breakdown voltage, a high electron saturation velocity and a high mobility of the 2D electron gas. The Metal Insulator Semiconductor (MIS) gate structure with the introduction of high dielectric constant (high-k) materials as a gate dielectric represents one of the most promising ways to achieve viable power electronic devices [1,2]. Among various insulators commonly used in the world of microelectronics, Al₂O₃ is mostly used for its deposition simplicity and has already lead to obtaining very good results, though it often needs post deposition treatments and surface pre-conditioning [3].

This work is focused on the capacitance/voltage (C(V)) and current/voltage/gate-voltage (Iₜ(Vₜ)/I(Vₜ)) measurements analysis for two different atomic layer deposition (ALD) techniques. In both cases, tri-methyl aluminum (TMA) was used as a precursor, but in one case water is used as oxidizer while oxygen plasma is used in the other. MESA etching isolation and ohmic contacts using Ti/Al annealed at 900°C were realized before a 10nm Al₂O₃ deposition, and a Cr/Au gate was used. The C(V) measurement were carried out on 400µm diameter diodes and Id(Vg) measurements were performed on 1mm width circular transistors with a 100µm gate length.

As we can see in Fig.1, two distinct behaviors appeared depending on the oxidation process used during the ALD. The one using H₂O showed a stepped C(V) curve while the one using oxygen plasma led to a smooth and steep non-stepped on/off transition. The threshold voltage (Vₜh) was also increased from ~9V to ~5V. In the latter case, the same sharp behavior and steady capacitance below Vₜh was also obtained for frequencies as low as 1kHz, while the H₂O samples led to negative capacitance below 50kHz.

Regarding Iₜ(Vₜ) measurements, we see in Fig.2 the same increase in Vₜh as before, as well as a drastic gate leakage current (Iₗₕ) reduction for the plasma oxidized sample. We were thus able to obtain a threshold slope of 80mA/decades between the on and off state.

Those trapped charges can be associated to the carbon contamination of the AlGaN surface. The improvement of the results between the two deposition techniques may come from a better carbon removal at the surface during the first cycles of plasma assisted ALD. This was confirmed through XPS analysis. If we look at Fig.3, we can see the carbon level using PEALD is lower than the one for thermal ALD for samples with the same thickness of high-k deposited. Comparing to the AlGaN reference, the carbon level is slightly higher after high-k deposition due to a residue of CH₃ inside the Al₂O₃ coming from the TMA precursor. As for the stepped behavior in the C(V) curves, it can be associated to a detachment at the gate perimeter as shown on fig.4. XPS analysis of thick Al₂O₃ layers has also shown that CH₃ removal is more efficient using PEALD.

In this study, we have shown that using O₂-plasma instead of water during the oxidation steps of the Al₂O₃ ALD deposition drastically improves our device performances (threshold voltage and gate leakage current). Furthermore, these good results can be easily achieved without any specific surface preparation or post-deposition treatments.

**References**


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**Fig. 1:** C(V) measurements for MIS diodes with 10nm Al₂O₃ deposited by thermal and plasma enhanced ALD

**Fig. 2:** Iₜ(Vₜ) measurements for circular transistors with 10nm Al₂O₃ deposited by thermal and plasma enhanced ALD

**Fig. 3:** C1s XPS spectra for different thicknesses of Al₂O₃ deposited by thermal and Plasma Enhanced ALD on AlGaN

**Fig. 4:** TEM image of the gate detachment at the gate periphery for thermal ALD