Thin Solid Films 628 (2017) 31–35

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

The effects of tetramethylammonium hydroxide treatment on the performance of recessed-gate AlGaN/GaN high electron mobility transistors

Jae-Won Do [a,*], Hyun-Wook Jung [a], Min Jeong Shin [a], Ho-Kyun Ahn [a], Haecheon Kim [a], Ryun-Hwi Kim [b], Kyu Jun Cho [a], Sung-Jae Chang [a], Byoung-Gue Min [a], Hyung Sup Yoon [a], Ji-Heon Kim [c], Jin-Mo Yang [c], Jung-Hee Lee [b], Jong-Won Lim [a]

[a] *Electronics and Telecommunications Research Institute (ETRI), 218 Gajeong-ro, Yuseong-gu, Daejeon 34129, Republic of Korea*
[b] *School of Electronics Engineering, Kyungpook National University, Daegu 41566, Republic of Korea*
[c] *Agency for Defense Development, Daejeon 34186, Republic of Korea*

ARTICLE INFO

Article history:
Received 26 October 2016
Received in revised form 16 February 2017
Accepted 22 February 2017
Available online 24 February 2017

Keywords:
Alumium gallium nitride
Gallium nitride
High electron mobility transistors
Surface treatment
Tetramethylammonium hydroxide
Gate recess

ABSTRACT

AlGaN/GaN high electron mobility transistors (HEMTs) are fabricated using a gate recess process and a surface treatment with tetramethylammonium hydroxide (TMAH) prior to gate metal deposition. Electrical characterizations show improved extrinsic transconductance and saturation current, as well as more uniform off-state behavior with reduced off-current by a factor of 3.5 and gate leakage current by a factor of 4.2 in the devices with TMAH treatment. The analyses based on atomic force microscopy, transmission electron microscopy, and X-ray photoelectron spectroscopy show that the TMAH treatment effectively reduces the roughness of the recess-etched AlGaN surface and removes the native oxide layer on the AlGaN surface, suggesting a simple and viable route towards the fabrication of gate-recessed HEMTs based on AlGaN/GaN heterostructure with improved controllability and uniformity.

1. Introduction

The high electron mobility transistors (HEMTs) based on AlGaN/GaN heterostructures have attracted much attention for high-power and high-frequency applications due to their high mobility of two-dimensional electron gas (2DEG) and high intrinsic breakdown voltage [1–4]. Enhancement-mode HEMTs are of special interest as the normally-off operation enables simple design of driving circuits and reduces power loss during switching, especially for applications in digital circuits [5,6]. Recessed-gate approach is one of the effective methods to realize the enhancement-mode AlGaN/GaN HEMTs because the threshold voltage (V_{th}) and the extrinsic transconductance (g_m) can be easily optimized on a wafer scale using conventional lithography and dry etching techniques [4,5,7,8]. However, the dry etching step to etch AlGaN layer usually results in a roughened and damaged surface, which can cause unreliable device operation and degraded device performance.

On the other hand, TMAH is well known to anisotropically etch GaN-based materials and effectively remove the plasma damages and the oxides on the surface of GaN-based materials [7,9–13]. Recent studies [12,13] by Im et al. used this anisotropic etching property of TMAH to fabricate MOSFETs based on GaN nano-structures using top-down approaches, and a recent work [7] by Joglekar et al. also treated the sidewall facets of AlGaN/GaN heterostructure with TMAH to investigate its effects on the regrown ohmic contacts. However, TMAH treatment has not been used on the etched AlGaN surface in a HEMT structure nor its removal of the oxide has been extensively verified through multiple characterizations.

In this work, TMAH is used to treat the recess-etched AlGaN surface to improve the device performance by enhancing the morphology and modifying the composition of the interface between the gate metal and the recess-etched AlGaN layer in a HEMT structure. Electrical measurements show that the devices with TMAH treatment exhibit more uniform off-state behavior with lower off current and gate leakage current, higher extrinsic transconductance, and higher saturation current. Characterizations by atomic force microscopy (AFM), X-ray photoelectron spectroscopy (XPS), and transmission electron microscopy (TEM) also show that the TMAH treatment renders more uniform AlGaN surface and removes the oxide layer, suggesting a simple and viable solution towards the fabrication of recess-etched AlGaN/GaN HEMT devices with enhanced controllability and uniformity.

* Corresponding author.
E-mail address: jdo@etri.re.kr (J.-W. Do).

http://dx.doi.org/10.1016/j.tsf.2017.02.053
0040-6090/