1.48 dB-Noise Figure E-mode Recessed-Gate GaN MOSHEMT by Neutralized Ion Beam Etching for LNA Applications

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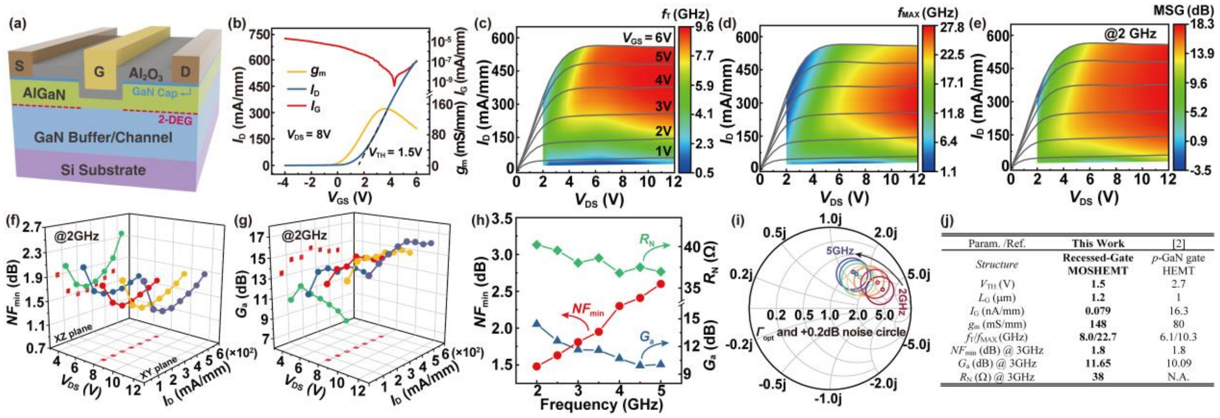
Enhancement-mode (E-mode) GaN-based devices are increasingly receving research interest for RF applications due to their inherent failure-safe characteristics and compatability with single-polarity bias design. Among various E-mode GaN transistors, recessed-gate MOSHEMT holds the promise of low gate leakage current with an isolated gate and high g_m due to reduced gate-to-channel distance. However, conventional Cl-based inductively coupled plasma reactive ion etching (ICP-RIE) may generate plasma-associated damage as well as defects, resulting in increased leakage current and deteriorated noise figure. In this work, for the first time, noise performance of recessed-gate MOSHEMTs, featuring a low-damage neutralized ion beam etching and normally-off operations[1], are explicitly invesigted for low noise amplifier (LNA) applications.

With a gate length of 1.2 µm, the fabricated device showed a positive voltage threshold (V_{TH}) of 1.5 V, a large saturation drain current of 599 mA/mm, a maximum transconductance of 148 mS/mm, and a working-state gate leakage currents (I_G) of 78.7 pA/mm at a drain current (I_D) of 200 mA/mm (Fig.1(b)). As V_{DS} increased, this device illustrated an improvement in small-signal cutoff frequencies (f_T/f_{MAX}), and achieved a maximum f_T/f_{MAX} of 9.6/27.8 GHz at V_{DS} of 12 V and V_{GS} of approximately 3.5 V (Fig.1(c) & (d)). Meanwhile, this device possessed high maximun stable gain (MSG) of 18.3 dB at 2 GHz and V_{DS} of 12 V (Fig.1(e)). As LNA, this device achieved a NF_{min} of 1.48 dB and an G_a of 14.43 dB at a I_D of 200 mA/mm, a V_{DS} of 8 V, and a frequency of 2 GHz (Fig.1(f) & (g)). As frequency rised from 2 to 5 GHz, NF_{min} was increased from 1.48 to 2.60 dB, G_a decreased from 14.43 to 10.04 dB, R_N decreased from 40 to 37 Ω (Fig.1(h)), and the optimum noise impedance (Γ_{opt}) changed from 0.69∠19.8° to 0.53∠57.67° (Fig.1(i)).

A comparison between the recessed-gate MOSHEMT and previous work is displayed in Fig. 1(j). With similar L_G, the recessed-gate MOSHEMT exhibits comparable NF_{min} and G_a to the *p*-GaN gate HEMT at 3 GHz, while achieving higher f_T / f_{MAX}. This improved performance is attributed to lower level of I_G and higher g_m. This work demonstrate great promise of low NF_{min} E-mode recessed-gate GaN MOSHEMT for receiver front end.



Param. /Ref.	This Work	[2]
Structure	**Recessed-Gate MOSHEMT**	*p*-GaN gate HEMT
V_{TH} (V)	**1.5**	2.7
L_G (µm)	**1.2**	1
I_G (nA/mm)	**0.079**	16.3
g_m (mS/mm)	**148**	80
f_T/f_{MAX} (GHz)	**8.0/22.7**	6.1/10.3
NF_{min} (dB) @ 3GHz	**1.8**	1.8
G_a (dB) @ 3GHz	**11.65**	10.09
R_N (Ω) @ 3GHz	**38**	N.A.

Fig. 1: (a) Structure schematic of recessed-gate MOSHEMT. **(b)** DC transfer characteristics. Contour charts of **(c)** f_T, **(d)** f_{MAX}, and **(e)** MSG at different DC bias. Dependence of **(f)** NF_{min} and **(g)** G_a on DC bias at 2 GHz. Frequency dependence of **(h)** noise parameters, **(i)** Γ_{opt}, and +0.2 dB noise circle at I_D of 200 mA/mm and V_{DS} of 8V. **(j)** Comparison of noise performance of E-mode device between recessed-gate MOSHEMT and *p*-GaN gate HEMT.

References:

[1] X. Zou *et al.*, *IEEE Electron Device Lett.*, vol. 45, iss. 6, pp. 968–971, 2024.
[2] X. Zou *et al.*, *IEEE Electron Device Letter.*, vol. 44, no. 9, pp. 1412–1415, 2023.