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Enhancement of Breakdown Voltages in InP-based HEMTs with Tri-Layer Channel Structure

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【 Introduction 】 Recently, InP-based high-electron-mobility transistor (HEMT) devices exhibited good high-speed performances [1-3].

However, the breakdown properties of such devices were degraded due to the aggressive scaling of the gate length. In this work, we report on a novel channel structure that allows a significant increase in breakdown values for short-gate-length HEMTs without degrading their high-speed operation.

【Device Structure】Our novel tri-layer channel (TLC) structure is based on 9-nm $In_{0.8}Ga_{0.2}As/In_{0.53}Ga_{0.47}As/InP$ channel layers. Compared to the $In_{0.8}Ga_{0.2}As/In_{0.53}Ga_{0.47}As$ composite channel (CC) structure, it features a series of channel layers with smaller bandgap step difference, pushing channel carriers farther from the gate at higher electric fields, and thus reducing both: the thermionic field emission effect, which degrades the off-state breakdown; and the impact ionization, which degrades the on-state breakdown.

【Results】Using the gate drain-current injection technique [4], the obtained off-state breakdown bias (BV_{DS}) for the 70-nm-gate-length TLC HEMT was 4.8 V compared to 2.3 V for a formally developed 70-nm-gate-length high-speed pseudomorphic $In_{0.8}Ga_{0.2}As/In_{0.53}Ga_{0.47}As$ CC HEMT (Fig. 1), which represents an increase of more than 200%.

The TLC HEMT was also investigated using the gate-current extraction method [5], and it exhibited an on-state breakdown bias of 4 V compared to 1.2 V for the CC device, which represents a 350% performance increase.

Moreover, devices based on this new structure exhibited a better transconductance (g_m) and drain conductance (g_D), giving a 57% higher g_m/g_D gain compared with the CC HEMT, without any degradation in RF performance (Table I).

Employing our new TLC HEMTs in integrated circuits, such as amplifiers, will double their power density and their voltage swing.

【Summary】A novel structure with higher DC and RF performance has been investigated. An improvement of more than 200% in breakdown values was obtained for 70-nm-gate-length devices.

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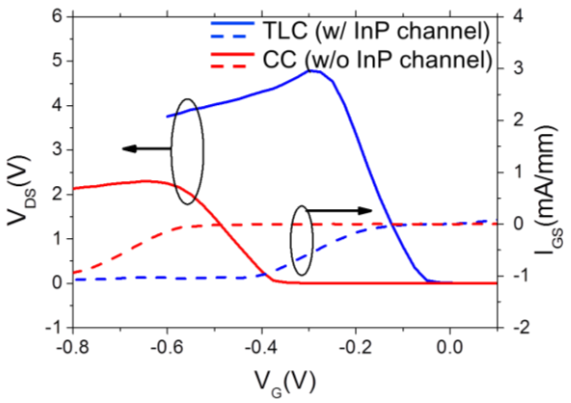

Fig. 1 Off-state breakdown values for HEMT devices with L_G=70nm.

Table I. Summary of the fabricated HEMTs

Structure	g_m (S/mm)	g_D (S/mm)	f_T (GHz)	f_{MAX} (GHz)
TLC	2.1	0.28	305	650
CC	1.7	0.40	300	800