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A 0.25 μm Gate AlGaN/GaN HEMT for X-band Using RELACS Process

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1. Introduction

An AlGaN/GaN high electron mobility transistors (HEMTs) are strong candidates for future high power, high efficiency applications. The main difficulty for their GaN-based application is the drain current collapse. The current collapse raises the reduction of the high-frequency current compared with its static value. To resolve the drain current-collapse, we applied a Cat-CVD (catalytic chemical vapor deposition) technology to AlGaN/GaN HEMTs. As a result, we have reported high power and high efficiency amplifiers at C-band [1, 2].

In this work, we report a 0.25 μm gate AlGaN/GaN HEMT amplifier for X-band frequency range. Although E-beam lithography is used as a conventional method to form short gate length less than 0.25 μm, the E-beam lithographic process is difficult to realize low cost mass production. Therefore we developed a new gate process that can be simply formed short gate length and is suited to mass production. The developed device for X-band is formed by the new gate process on the basis of well established C-band AlGaN/GaN device technology.

2. Device Structure and Fabrication

Fig. 1 is a schematic of fabricated HEMT. An undoped AlGaN/GaN heterostructure was grown on a 4H SiC substrate by MOVPE. Si ions were implanted into source and drain regions, and subsequently implanted Si ions were activated by rapid thermal annealing [3]. Source and drain electrodes were formed by Ti/Nb/Pt. Device was isolated by Ar ion implantation. We used SiN film deposited by the Cat-CVD after NH_3 treatment for surface passivation layer. By using micro-lithographic process, called RELACS (Resolution Enhancement Lithography Assisted by Chemical Shrink) process [4, 5], and inductively coupled plasma (ICP) etching process, a 0.25 μm gate length was formed (Fig. 2). The RELACS process is good for mass production compared with the E-beam one, because conventional i-line lithographic process can be used. Finally a T-shaped Ni/Au Schottky gate electrode was formed by a lift-off technique.

3. Device Characteristics

The DC characteristics of a 100 μm gate width were measured. Fig.3 shows comparison of the DC I-V characteristics and the pulsed I-V characteristics at Vdq = 30 V and Vgq = -5 V. The device exhibited a maximum drain current of 1.0 A/mm and good channel pinch-off characteristics at the Vg = -3 V for 0.25 μm gate length. The device exhibited good pulse response. The ratio of pulsed maximum drain current to the DC one is more than 90 % due to the Cat-CVD method.

Fig.4 shows gate length dependence of transconductance at Vd =30 V. The transconductance increased by 20 % from 190 mS/mm of the 0.75 μm gate length to 235 mS/mm of the developed 0.25 μm gate length.

Fig.5 shows the large signal characteristics of a 500 μm periphery under CW operating conditions. The device shows a 75.8 % drain efficiency (DE) (69.5 % power added efficiency (PAE)), a linear gain of 14.4 dB and an output power (Pout) of 32.9 dBm (3.9 W/mm) in X-band at 30 V drain voltage.

4. Conclusion

We have developed a high efficiency AlGaN/GaN HEMT optimized for X-band operation, applying the RELACS process for short gate length and the Cat-CVD technique for depositing SiN surface passivation layer. A 75.8 % drain efficiency is achieved in X-band at 30 V drain voltage.

References

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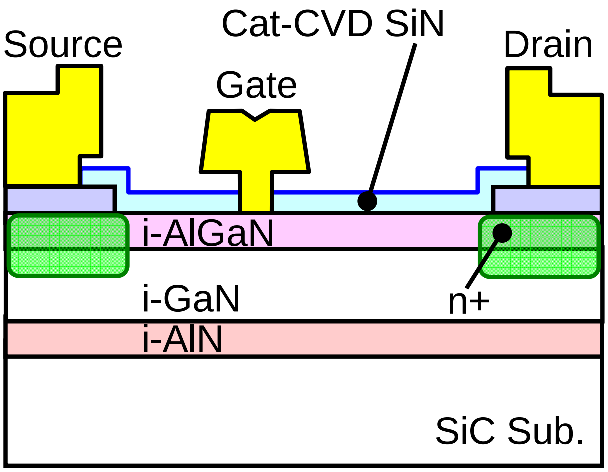

Fig.1 Schematic cross-section of fabricated AlGaN/GaN HEMT with the SiN film deposited by Cat-CVD and Si ion implantation.

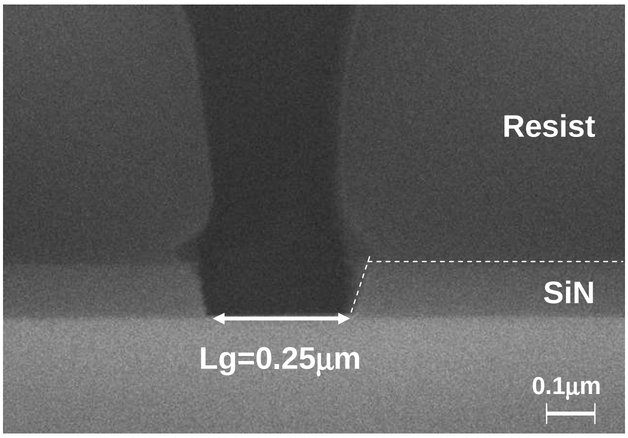

Fig.2 Cross-section of SEM image of 0.25 μm gate fabrication.

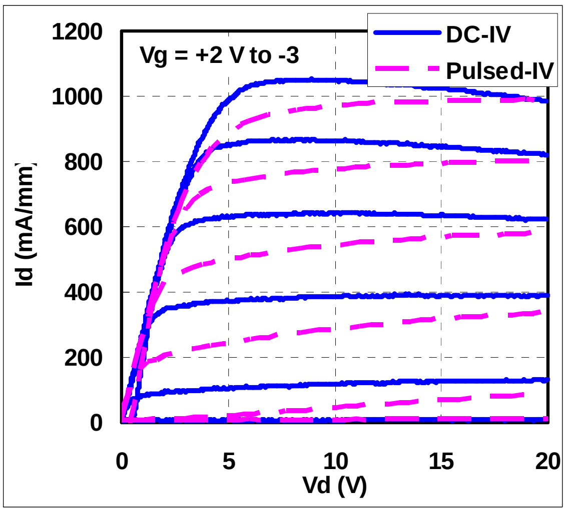

Fig.3 I-V characteristics measured under DC and pulse operation of a 100 μm device.

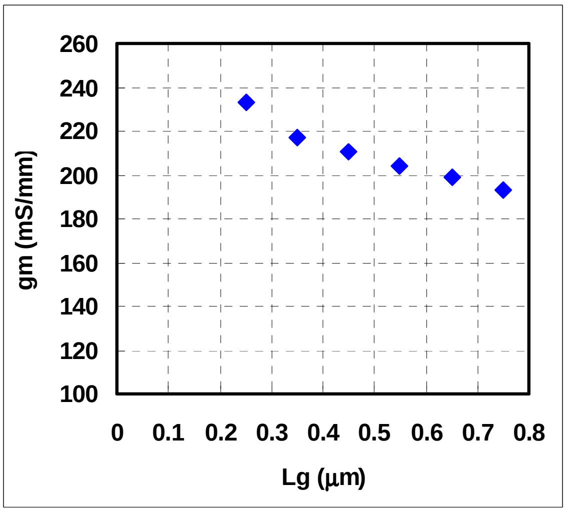

Fig.4 Gate length dependence on transconductance at 30 V drain voltage.

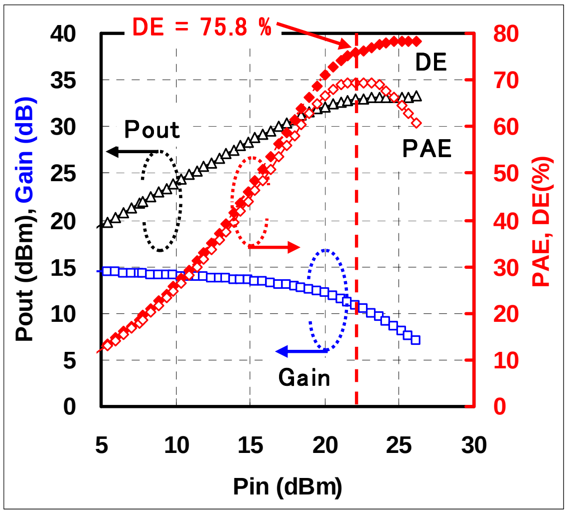

Fig.5 Output power (Pout), gain, drain efficiency (DE) and power-added efficiency (PAE) of a 500 μm device as a function of input power (Pin) at 30 V drain voltage in X-band.