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InGaAs MOSFETs with Regrown Source: DC and RF Performance

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1. Introduction

III-V metal-oxide-semiconductor field-effect transistors (MOSFETs) are currently being developed in various transistor architectures. The main motivation is to utilize the advantageous transport properties, like the high injection velocity and the large low-field mobility, to enhance the drive current as compared to conventional Si-based implementations. Although there are many reports on high-performance device realizations in various technologies, there is still a need to develop transistors that combine large drive currents with good off-state performance.

In this paper, we present efforts to reduce the on-resistance in III-V MOSFETs using regrown source and drain regions. These devices have been implemented in a gate-last process, where a dummy gate is used during the regrowth process. We will also demonstrate that these MOSFETs may be integrated with resonant tunneling diodes to form millimeter wave MMICs in the form of wavelet generators operating at 60 GHz and above. These wavelets may find application in the area of low-power wireless systems.

2. Experimental

InGaAs transistor channels were grown on AlInAs layers on InP substrates using MBE [1]. For the implementation of the wavelet generators, the epitaxial stack also included InGaAs-based double barrier heterostructures operating at 122 kA/cm^2 that were selectively removed by wet etching to access the InGaAs transistor channel. Dummy gates were processed using an HSQ-process where the gate areas were defined by electron beam lithography. Source and drain regions were selectively overgrown with n$^+$-InGaAs and InP layers using MOVPE, where the later layer acts as a mechanical support in the gate formation process. Here, {111}-side facets were developed to facilitate the gate formation. Gate dielectric consisting of an Al_2O_3/HfO_2 bilayer was deposited using ALD and the gate electrodes (Pd/Au) were defined using electron beam lithography. After selective wet etching of the InP-layer to form a T-gate, Ti/Pd/Au was evaporated to form self-aligned source and drain ohmic contacts. For the MMICs, resonant tunneling diodes with an area of 2.2x12 µm^2 were implemented in series with the MOSFETs and waveguides were used to implement the inductances required for the oscillator operation. MIM-capacitors were introduced as DC-current blocks that help to reduce the DC power consumption.

The transistors were characterized electrically in DC- and RF-mode operation [2]. Transistors with 140 nm L_g operated in Enhancement mode with a V_t of 0.06 V and showed a drive current of about 1.3 A/mm and a transconductance of 1.05 S/mm at V_d=0.5 V. The off-state characteristics showed a subthreshold swing of 100 mV/dec.. Reducing the gate length to 55 nm resulted in a higher drive current of 2.0 A/mm and a transconductance of 1.9 S/mm. These devices showed an f_t of 244 GHz and f_{max} of 292 GHz. These good values are, at least in part, attributed by the record low value for the on-resistance, 199 Ωµm, realized by the regrowth technology.

Wavelet generators operating at 70 GHz showed an output power of 7dBm. Pulses as short as 41 ps long were generated by switching the MOSFET transistor on and off. Using these conditions 1.9 pJ was required to generate each pulse. The highest measured pulse repetition rate was 15 Gpps limited by the signal generator used [3].

3. Conclusions

This paper presents the main processing steps to realize III-V MOSFETs with high drive currents and good off-state performance. The MOSFET has been used as a switch in an oscillator circuit and ultra-short wavelets have been generated.

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References

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