MOCVD-Grown 0.25-μm MESFET's Using Tertiary Butyl Arsine as the Arsenic Source

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Abstract—**High-performance 0.25-μm-gate MESFET's on MOCVD-grown epitaxial structure have been fabricated using tertiary butyl arsine (TBA) as the arsenic source. DC characterizations show that the extrinsic peak transconductance is 508 mS / mm. From on-wafer *S*-parameter measurements, the MESFET's show a current-gain cutoff frequency of 55 GHz and the maximum-available-gain cutoff frequency of 93 GHz. These results represent the best results reported for MOCVD-grown MESFET's using a TBA source, and compare favorably with the previously reported f_t of 40 GHz for MBE-grown MESFET's.**

I. Introduction

One critical issue of employing MOCVD in the large volume production of device-quality epitaxial layers on GaAs substrates is the hazard associated with arsine, which is currently used as the arsenic source. Alternate arsenic sources for use in the MOCVD growth of GaAs is hence an active area of research [1]. For any alternative, safer arsenic source to be a viable substitute for arsine, it is important that the quality of the epitaxial layers be equal to or better than those obtained with arsine. Several alternative arsenic sources, mainly in the form of alkyl compound, have been examined for growing GaAs by MOCVD [2]. Recently, using trimethyl gallium (TMG) and a new arsenic source, namely, tertiary butyl arsine (TBA), high-quality GaAs epitaxial layers for photovoltaic applications have been grown [3]. TBA, a liquid phase organometallic arsenic compound, is a promising alternate arsenic source due to a lower vapor pressure, and thus is safer to handle than arsine. These TBA grown layers exhibited electrical characteristics comparable to those grown with arsine in the same reactor. In this letter we report on the characteristics of 0.25-μm MESFET devices grown by MOCVD with TBA and TMG.

II. Epitaxial Growth and Device Fabrication

The MESFET structure studied in this report was grown in an EMCORE GS-3200 reactor at a pressure of 60 torr. Semi-insulating 2-in GaAs (100) substrates oriented 2° off toward (110) were used. The growth temperature was 690°C. The TBA and TMG bubblers were maintained at 0°C and −5°C, respectively. The mole fractions of TBA and TMG during epitaxial growth were kept at 1.3×10^{-3} and 1.2×10^{-4}, respectively, corresponding to a V/III molar ratio of 11. The intrinsic layers grown under the described condition were found to be p-type with a carrier concentration of 5×10^{15} cm^{-3}, and with a 77 K Hall mobility of 4800 cm^2/V/s. Diethyl tellurium was used as the source of n-type doping.

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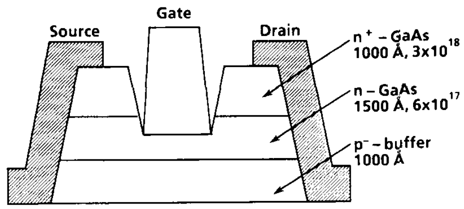

Fig. 1. MESFET device structure.

Fig. 1 shows the device structure investigated in this work. A 100-nm buffer layer with unintentional p^- doping was first grown on the semi-insulating GaAs substrate, followed by the 150-nm n-channel layer with a doping level of 6×10^{17} cm^{-3}. An n^+ layer with a thickness of 100 nm and a carrier concentration of 3×10^{18} cm^{-3} was grown on the channel layer to provide good electrical contacts to the channel region.

MESFET devices were fabricated by first mesa etching into the buffer layer for device isolation. Ohmic contacts were defined by optical lithography, and AuGe/Ni/Au metallization was E-beam evaporated and alloyed by rapid thermal annealing at 450°C. Half-micrometer gates were defined by contact lithography and the lift-off process using 600 nm of Ti/Pt/Au metallization. Quarter-micrometer gates were defined by direct write e-beam lithography using the single-layer PMMA resist process and the same gate metallization. NH_4OH-based pH-controlled gate recess etching was used to control the threshold voltage before the gate metallization.

III. DC and Microwave Characteristics

The typical peak extrinsic transconductance of a 0.5×100 μm MESFET device is 360 mS/mm with a threshold voltage of −1.6 V. Fig. 2(a) and (b) shows the I-V characteristics and transconductance, respectively, versus gate voltage of a 0.25×100-μm device. The peak extrinsic transconductance is 508 mS/mm at a drain voltage of 1.5 V, and the pinch-off voltage is approximately −1.8 V. The source resistance of the device, determined from end resistance measurement, is 0.5 $\Omega \cdot$ mm. The intrinsic transconductance of the 0.25-μm device, corrected for the source resistance, is 680 mS/mm.

The microwave characteristics were extracted from the

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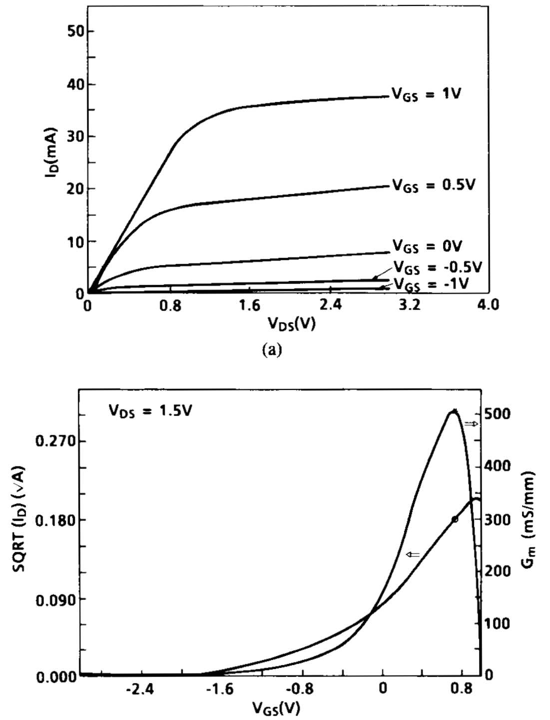

Fig. 2. (a) DC output characteristics of a 0.25×100-μm^2 MESFET. V_{gs} starts at 1 V with a step of -0.5 V. (b) Square root of the drain current and the transconductance G_m (mS/mm) as a function of gate voltage (0.25×100 μm^2). V_{ds} is 1.5 V.

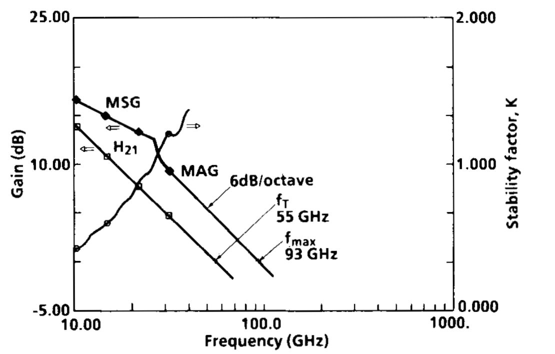

Fig. 3. Current gain (H_{21}), maximum stable gain (MSG), and maximum available gain (MAG), and the K factor (stability factor) as a function of frequency (0.25×100 μm^2).

on-wafer probing of S parameters up to 40 GHz using Cascade Microtech microwave probes and an HP 8510 network analyzer. For half-micrometer devices, the current-gain cutoff frequency f_t is measured to be 24 GHz and the maximum frequency of oscillation f_{max} is estimated to be 55 GHz under a bias condition of 2.5-V drain voltage and -0.5-V gate voltage. Fig. 3 shows the current gain (H_{21}), the maximum stable gain (MSG), and the maximum available gain (MAG) as a function of frequency for 0.25-μm MESFET's under a drain bias of 2 V and 70% of the I_{dss}. The stability factor k is also shown in the same figure. The k factor is larger than 1 for frequency above 30 GHz, which indicates that the device is unconditionally stable. The extrapolation of the current gain and the power gain using the -6-dB/octave line yields an f_t of 55 GHz and an f_{max} of 93 GHz. The maximum available gain at 31 GHz is 9 dB. These characteristics represent the best results reported for MOCVD-grown MESFET's using TBA source [4], and are comparable to the characteristics of MOCVD-grown MESFET devices using arsine source and silane doping in our laboratory. The current-gain cutoff frequency of 55 GHz also compares favorably with the f_t of 40 GHz reported for the MBE-grown MESFET structure [5].

IV. Summary

In summary, we have demonstrated an f_t of 55 GHz and an f_{max} of 93 GHz for 0.25-μm MESFET's using MOCVD-grown epitaxial substrates with TBA as the arsenic source. The characteristics of these devices are comparable to the MBE-grown MESFET structure or MOCVD-grown structure using arsine. These results demonstrate that tertiary butyl arsine is a viable alternate arsenic source to satisfy the safety criteria in high volume production of the epitaxial growth of GaAs device structures.

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