1.0μm Gate-Length GaAs MHEMT Devices and SPDT Switch MMICs*

Xu Jingbo[1,†], Li Ming[1], Zhang Haiying[1], Wang Wenxin[2], Yin Junjian[1], Liu Liang[1], Li Xiao[1], Zhang Jian[1], and Ye Tianchun[1]

(1 *Institute of Microelectronics, Chinese Academy of Sciences, Beijing* 100029, *China*)
(2 *Institute of Physics, Chinese Academy of Sciences, Beijing* 100080, *China*)

Abstract: 1.0μm gate-length GaAs-based MHEMTs have been fabricated by MBE epitaxial material and contact-mode lithography technology. Pt/Ti/Pt/Au and Ti/Pt/Au were evaporated to form gate metals. Excellent DC and RF performances have been obtained, and the transconductance, maximum saturation drain current density, threshold voltage, current cut-off frequency, and maximum oscillation frequency of Pt/Ti/Pt/Au and Ti/Pt/Au MHEMTs were 502(503) mS/mm, 382(530) mA/mm, 0.1(−0.5) V, 13.4(14.8) GHz, and 17.0(17.5) GHz, respectively. DC-10GHz single-pole double-throw (SPDT) switch MMICs have been designed and fabricated by Ti/Pt/Au MHEMTs. Insertion loss, isolation, input, and output return losses of SPDT chips were better than 2.93, 23.34, and 20dB.

Key words: MHEMT; Pt/Ti/Pt/Au; Ti/Pt/Au; SPDT; MMIC
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1 Introduction

Lattice matched InP-based HEMTs have performance advantages over GaAs-based PHEMTs due to their high electron velocity and 2-DEG density[1]. However, InP substrates are brittle, small, and expensive, and it is difficult to fabricate InP-based HEMTs at a high production level. GaAs-based MHEMTs were grown on semi-insulating GaAs substrates using a grading In content metamorphic buffer (M-buffer). MHEMTs have advantages of both InP-based HEMTs and GaAs substrates. Recently, GaAs-based MHEMTs by MBE material have emerged as an attractive, low cost alternative to InP-based HEMTs for high performance, low noise, and power applications[2~5].

1.0μm gate-length GaAs-based MHEMTs have been fabricated and excellent DC and RF performances have been achieved. Pt/Ti/Pt/Au and Ti/Pt/Au were evaporated to form both gate metals. G_m, J_{DSS}, V_T, f_T, and f_{max} of Pt/Ti/Pt/Au and Ti/Pt/Au MHEMTs are 502(503) mS/mm, 382(530) mA/mm, 0.1(−0.5) V, 13.4(14.8) GHz, and 17.0(17.5) GHz, respectively. In addition, DC-10GHz SPDT switch MMICs have been designed and fabricated by Ti/Pt/Au MHEMTs. Insertion loss, isolation, and return loss of SPDT switches were better than 2.93, 23.34, and 20dB. This is very helpful for the further investigation of MHEMT devices and MMICs.

2 Device fabrication

The epitaxial wafers grown on semi-insulting GaAs substrates by MBE technology were provided by the Institute of Physics, Chinese Academy of Sciences. The structure is composed of a 300nm GaAs layer, a 1000nm In composition grading M-buffer, an 18nm InGaAs channel (In composition is 0.6), a 4nm InAlAs spacer, a planar doping layer, an 18nm InAlAs Schottcky barrier layer, and a 20nm n^+ InGaAs cap layer.

The source and drain electrodes of GaAs-based MHEMTs were fabricated by conventional evaporation and lift-off processes. After annealing, a typical ratio ohmic contact resistance of $4\times10^{-7}\ \Omega\cdot cm^2$ was obtained. Mesa-isolation was completed by wet-etching. Contact-mode lithography technology was used to obtain a 1.0μm gate pattern. Citric acid-H_2O_2 solution was used for the gate recess process. Pt/Ti/Pt/Au and Ti/Pt/Au were evaporated to form the gate metal, respectively. The first and second metal lines were Ti/Au. The picture of the MHEMT device is shown in Fig. 1.

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† Corresponding author. Email: xu.jing.bo@ime.ac.cn
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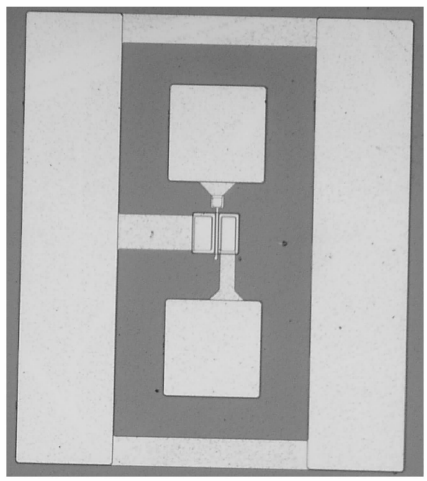

Fig.1　1.0μm gate-length MHEMT device

3　Results and analysis

Both MHEMT devices exhibit excellent DC and RF performances. The results of the Pt/Ti/Pt/Au MHEMT (1.0μm gate length, 30μm gate width) are shown in Fig. 2. V_T, g_m, J_{DSS}, f_T, and f_{max} are 0.1V, 502mS/mm (V_{DS} = 1V, V_{GS} = 0.35V), 382mA/mm, 13.4GHz, and 17.0GHz, respectively. The results of the Ti/Pt/Au MHEMT (1.0μm gate length, 20μm gate width) are shown in Fig. 3. V_T, g_m, J_{DSS}, f_T, and f_{max} are −0.5V, 503mS/mm (V_{DS} = 1V, V_{GS} = −0.2V), 530mA/mm, 14.8GHz, and 17.5GHz, respectively.

Because Pt-based buried-gate metals were chosen, during the process of annealing, Pt-InAlAs reaction occured and Pt sunk into the InAlAs layer to reduce the distance between gate and channel, and the V_T of the Pt/Ti/Pt/Au MHEMT increased positively while the V_T of the Ti/Pt/Au MHEMT remained negative. Due to different characteristics of Pt/Ti/Pt/Au and Ti/Pt/Au during annealing, positive and negative threshold voltages have been achieved, respectively.

Nine-stage ring oscillators have been designed and fabricated by 1.0μm gate-length Pt/Ti/Pt/Au and Ti/Pt/Au MHEMTs. Oscillators contain nine-stage DCFL inverters and a three-stage DCFL inverter output buffer. When the supply voltage is 1.2V, the oscillation frequency is 777.6MHz, and the gate delay time is 71.4ps. The testing results of the ring oscillators are shown in Fig. 4.

DC-10GHz SPDT switch MMICs have been designed and fabricated by Ti/Pt/Au MHEMTs. The topology of the SPDT switch was a series-shunt structure, containing 6 MHEMTs (1.0μm gate length, 4 × 50μm gate width), and the chip size is 1.0mm × 1.0mm. The results of SPDT switches on-wafer testing are shown in Fig. 5. Insertion loss, isolation, input, and output return losses are better than 2.93, 23.34, and 20dB.

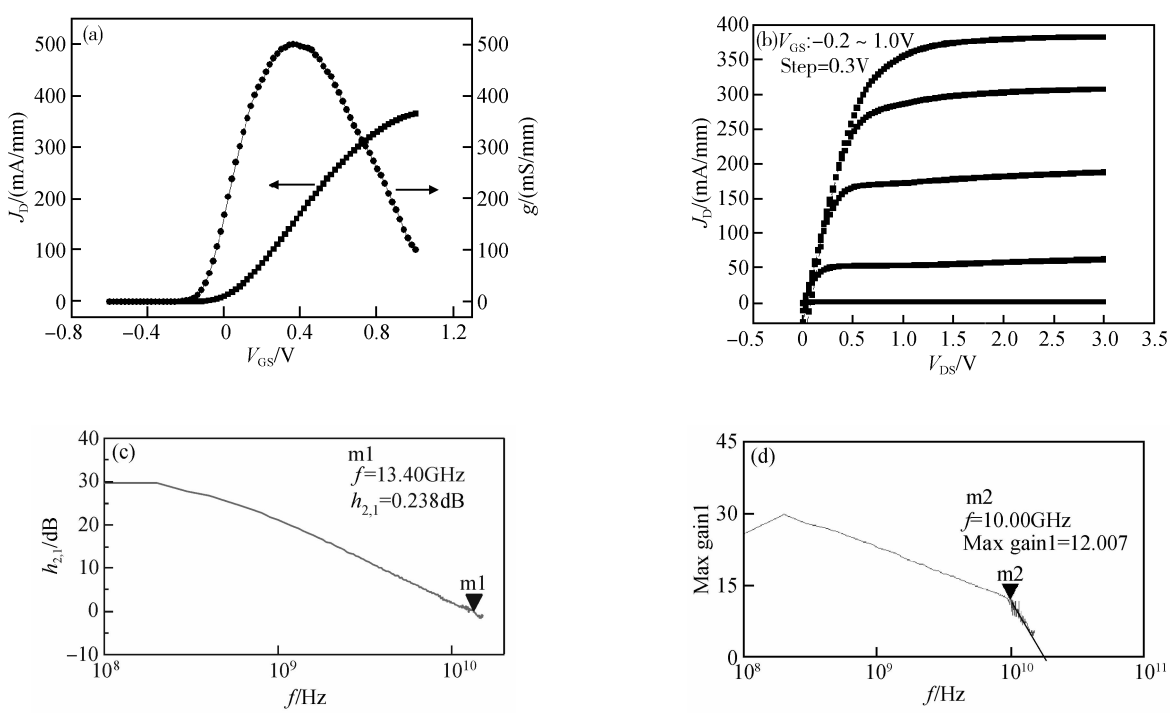

Fig.2　DC and RF characteristics of Pt/Ti/Pt/Au MHEMT

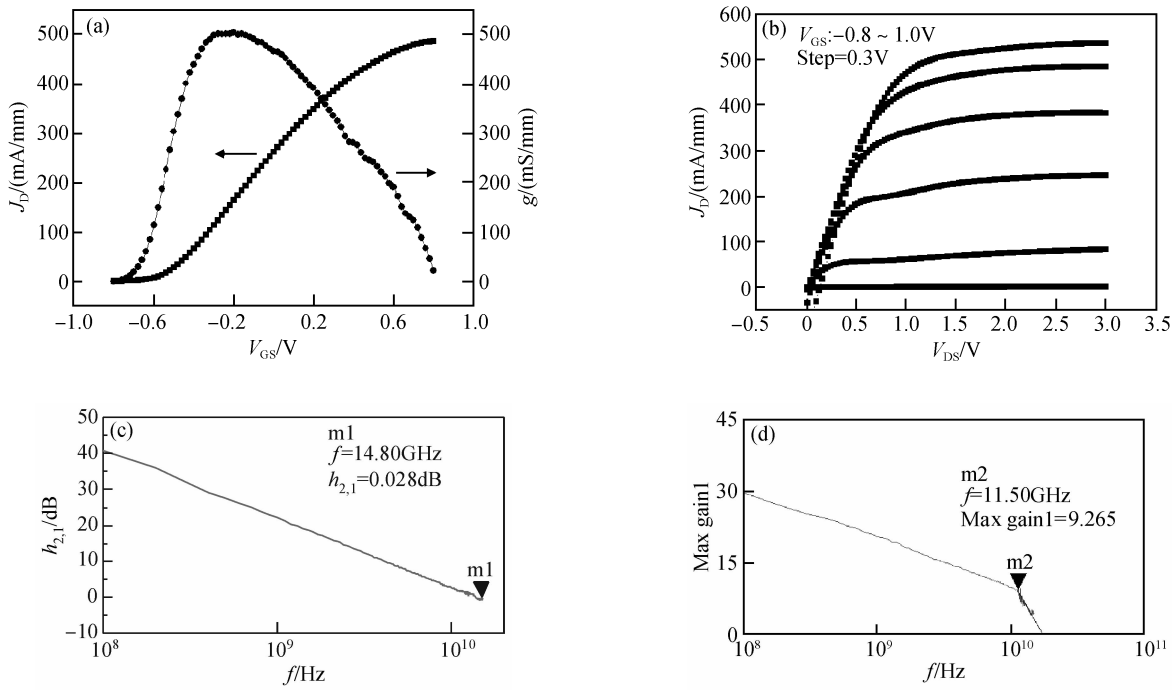

Fig. 3 DC and RF characteristics of Ti/Pt/Au MHEMT

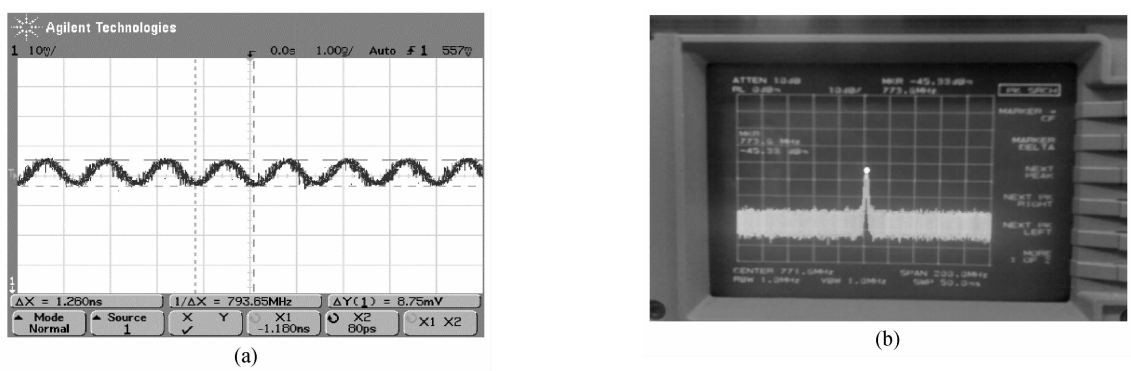

Fig. 4 Output wave of nine-stage ring oscillator (a) and result of spectrum analyzer test (b)

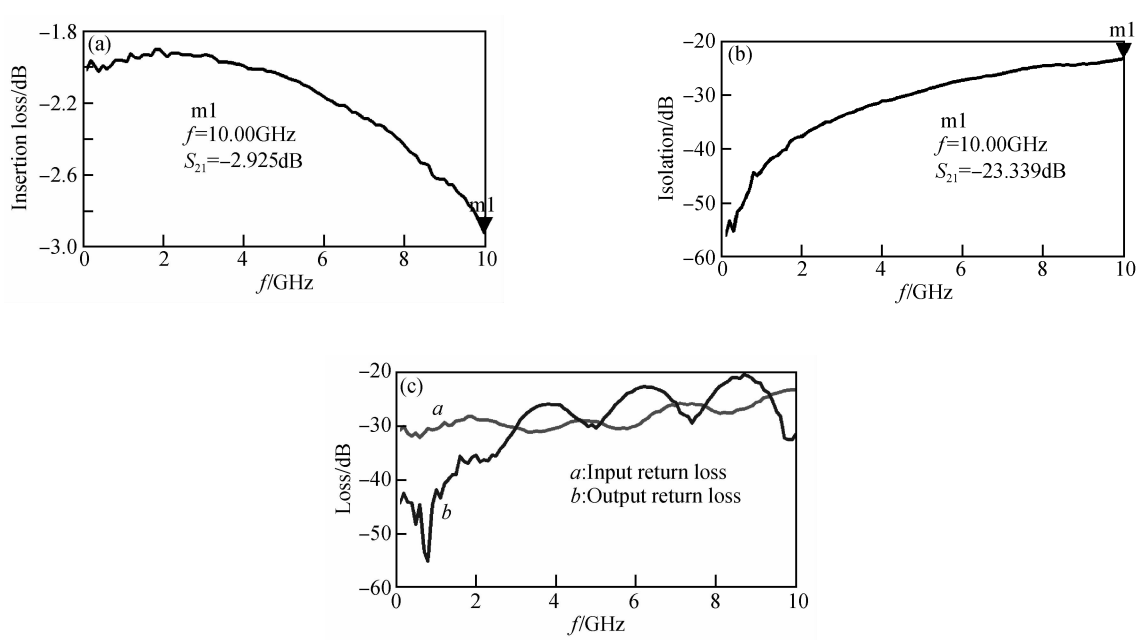

Fig. 5 Insertion loss, isolation, and return loss of SPDT switches

4 Conclusion

1.0μm gate-length GaAs-based MHEMT devices, nine-stage ring oscillator and DC-10GHz SPDT switch MMICs have been designed and fabricated by MBE epitaxial material and contact-mode photolithography technology. Pt/Ti/Pt/Au and Ti/Pt/Au were evaporated to form gate metal, respectively. G_m, J_{DSS}, V_T, f_T, and f_{max} of both MHEMTs are 502(503)mS/mm, 382(530)mA/mm, 0.1(−0.5)V, 13.4(14.8)GHz, and 17.0(17.5)GHz, respectively. When the supply voltage is 1.2V, the oscillation frequency and gate delay time of the nine-stage ring oscillators are 777.6MHz and 71.4ps. Insertion loss, isolation, input, and output return losses of the SPDT chips are better than 2.93, 23.34, and 20dB. Performances of both devices and circuits can be improved further by optimizing the material structure, switch model, the design of devices and circuits, as well as processing conditions.

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1.0μm 栅长 GaAs 基 MHEMT 器件及 SPDT 开关 MMIC*

徐静波[1,†]　黎　明[1]　张海英[1]　王文新[2]　尹军舰[1]　刘　亮[1]　李　潇[1]　张　健[1]　叶甜春[1]

(1 中国科学院微电子研究所，北京　100029)
(2 中国科学院物理研究所，北京　100080)

摘要：利用 MBE 外延材料和接触式光学光刻方式，成功制备出 1.0μm 栅长 GaAs 基 MHEMT 器件，分别蒸发 Pt/Ti/Pt/Au 和 Ti/Pt/Au 作为栅电极金属. 获得了优越的 DC 和 RF 性能，Pt/Ti/Pt/Au 和 Ti/Pt/Au MHEMT 器件的 g_m 为 502(503)mS/mm，J_{DSS} 为 382(530)mA/mm，V_T 为 0.1(−0.5)V，f_T 和 f_{max} 分别为 13.4(14.8)，17.0(17.5)GHz. 利用单片集成增强/耗尽型 GaAs 基 MHEMT 器件制备出九阶环型振荡器，直流电压为 1.2V 时，振荡频率达到 777.6MHz，门延迟时间为 71.4ps. 利用 Ti/Pt/Au MHEMT 器件设计并制备出了 DC-10GHz 单刀双掷(SPDT)开关 MMIC，其插入损耗、隔离度、输入输出回波损耗分别优于 2.93，23.34 和 20dB.

关键词：MHEMT；Pt/Ti/Pt/Au；Ti/Pt/Au；SPDT；MMIC
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† 通信作者. Email: xu.jing.bo@ime.ac.cn

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