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Research Article

Impact of the Gate Width of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT on Its Characteristics

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This paper presents impact of layout sizes of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT heterostructure high-mobility transistors (HEMTs) on SiC substrate on its characteristics that include the threshold voltage, the maximum transconductance, characteristic frequency, and the maximum oscillation frequency. The changing parameters include the gate finger number, the gate width per finger. The measurement results based on common-source devices demonstrate that the above parameters have different effects on the threshold voltage, maximum transconductance, and frequency characteristics.

1. Introduction

As the third typical semiconductor material, GaN has been widely investigated for several years due to their wide gap and high breakdown field. It will become an ideal candidate for high-power, high-frequency, and high-temperature electronic devices [1–4]. By the great development of the material quality and device processing techniques, AlGaN/GaN HEMT has been much improved in both DC and RF performances.

Performances of monolithic microwave integrated circuits (MMICs) are influenced by the characteristics of active devices. There are many papers about improving its DC and AC performances by changing material or structure of epitaxial layer of AlGaN/GaN HEMTs [5–8]. In recent years, a novel structure $Al_xGa_{1-x}N/Al_yGa_{1-y}N/GaN$ HEMT with low Al composite inserting layer $Al_yGa_{1-y}N$ has been reported [9–11] and MMICs based on AlGaN/GaN HEMT are designed by our group [12]. This paper will present the impact of layout sizes of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMTs based on SiC substrate on its characteristics.

2. Material Preparation and Device Fabrication

The layer structure of the device proposed in the study is grown on a SiC substrate. The epitaxial layer consists of an unintentionally doped 1.5 μm GaN buffer layer, 1 nm AlN spacer layer, 4 nm low Al component $Al_{0.04}Ga_{0.96}N$, and a 20 nm $Al_{0.27}Ga_{0.73}N$ barrier layer as shown in Figure 1. Epitaxial layer structure of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT is proposed and optimized by combining theory calculation and TCAD software; detail design process is given in our previous papers [13, 14].

An averaged electron mobility of 1800 $cm^2/(v\cdot s)$ and a sheet carrier density of $1.0 \times 10^{13}/cm^2$ are obtained by room temperature Hall measurement. The AlGaN/GaN HEMT fabrication commences with metalizing by high-vacuum evaporation in drain and source; the Ohmic contacts are formed by depositing the metal Ti/Al/Ti/Au and then rapid thermal annealing (RTA) at 870°C for 50 s in N_2 ambient. All these steps above result in a low ohmic contact resistance of 0.6 $\Omega\cdot$mm. Si_3N_4 film used for passivation is grown by

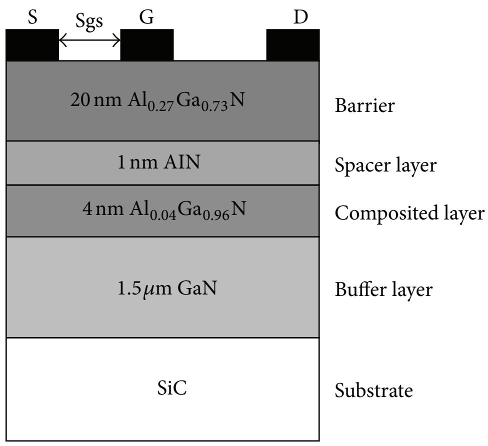

Figure 1: Cross section diagram of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT.

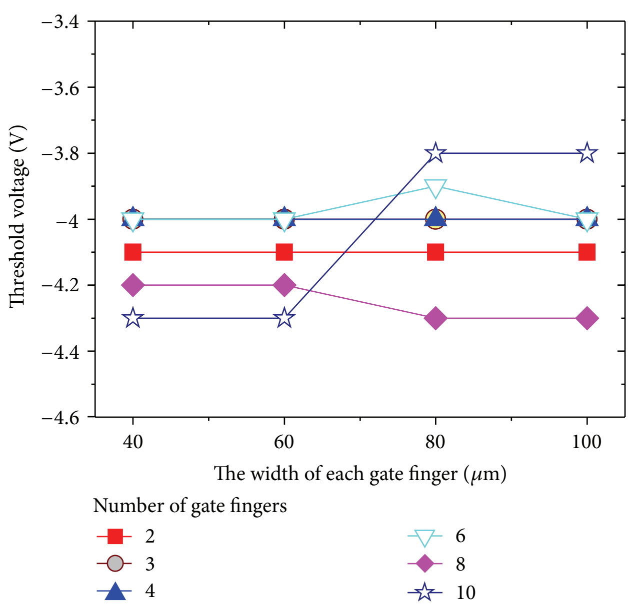

Figure 2: Threshold voltage versus the gate width.

PECVD. Then, the T-shaped Schottky gate is formed by Ni/Au evaporation and the subsequent lift-off process.

3. The Design of Layout and Analysis of Results

Layout of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT is designed including 24 types of samples with different gate fingers numbers and width of each finger. Total gate width of device is supposed to be $m \times n\,\mu$m ($m = 2, 3, 4, 6, 8$, and 10; $n = 40, 60, 80$, and 100), where "m" represents the finger numbers and "n" stands for width of each gate finger. The space between gate and source is 1 μm for all of devices.

3.1. Threshold Voltage. Figure 2 presents that threshold voltage of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT changes with its gate width. The threshold voltages of the device

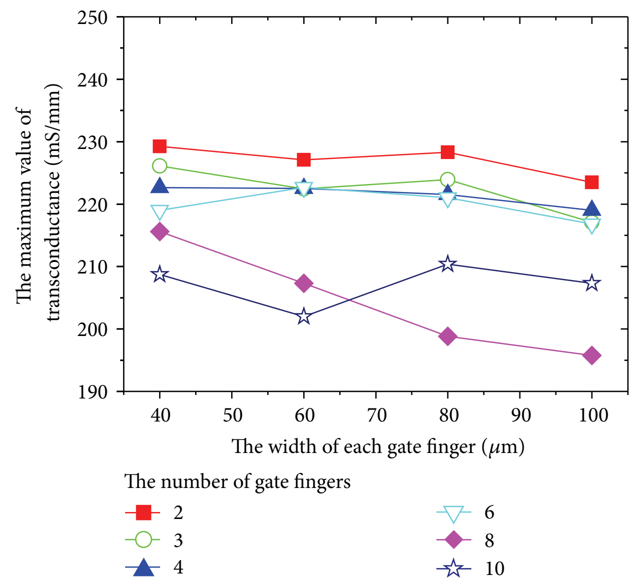

Figure 3: The maximum value of transconductance versus the gate width.

almost do not change with the width of each gate finger except gate finger number of 10 and change from −3.8 to −4.3 V with number of gate fingers.

3.2. Maximum Transconductance. Figure 3 presents that the maximum transconductance (Gm_{max}) of the GaN HEMTs changes with its gate width. The values of Gm_{max} reduce with the width of each gate finger. When the number of gate fingers is 8, downslope of the values of Gm_{max} is the largest of them with the width of each gate finger from 215 to 196 mS/mm.

3.3. Frequency Characteristics. S parameters are measured on line at the frequency from 500 MHz to 24 GHz. The current gain ($|h21|$) and the maximum available power gain (MAG) are calculated from measured S parameters as a function of frequency. The values of characteristic frequency (f_t) and the maximum oscillation frequency (f_{max}) are determined by extrapolation of the $|h21|$ and MAG data at −20 dB/decade. Figures 4 and 5 present that the characteristic frequency and the maximum oscillator frequency change with the gate width, respectively. Both of f_t and f_{max} reduce with increasing the gate width. Both of f_t and f_{max} are influenced larger by the number of gate fingers than by the width of each gate width.

4. Conclusion

A novel structure of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT with different sizes of layout is successfully designed and fabricated. After measurement, the performances of the threshold voltage, the maximum transconductance, characteristic frequency, and the maximum oscillation frequency with different gate widths of $Al_{0.27}Ga_{0.73}N/AlN/Al_{0.04}Ga_{0.96}N/GaN$ HEMT are analyzed carefully. It is

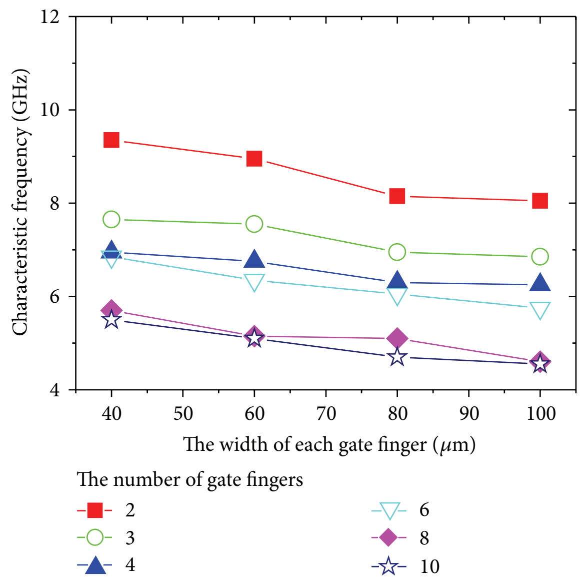

Figure 4: Characteristic frequency versus the gate width.

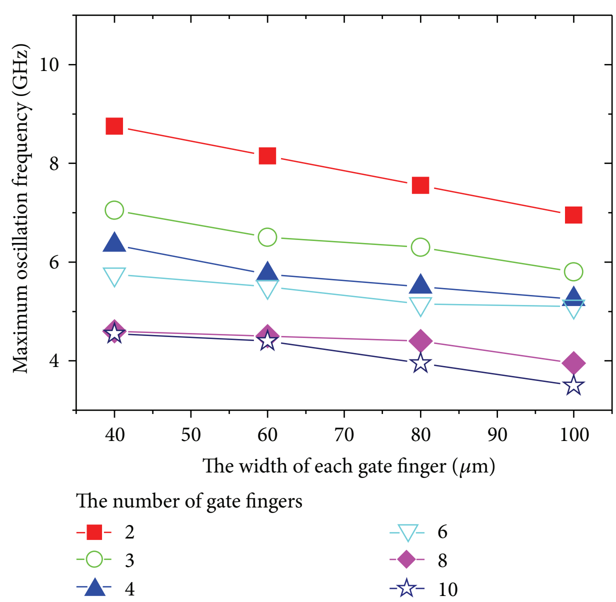

Figure 5: The maximum oscillation frequency versus the gate width.

significant for designing AlGaN/GaN HEMT with excellent performance.

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