AlNGaN HEMT T- gate Optimal Design

zhangxiaowei[1,2], Jiakejin[1], Wangyuangang[2], Fengzhihong[2], Zhaozhengping[2]
[1]Hebei University of Technology, College of information engineering, Tianjin, 300130
[2]China Electronics Technology Group 13 Institute, Key Laboratory of special integrated circuit, shijiazhuang,050000
[a] Zhangxiaowei0323@126.com

***Abstract*—The GaN HEMT is widely used in high-frequency aspects, use the T-gate to reduce gate resistance is one of the most effective methods to improve the the device maximum oscillation frequency (fmax). But f_{max} is very sensitive to T-gate size, improper selection may reduce f_{max}, Therefore, in order to reduce the cost of production, it is necessary to select appropriate simulation T-gate size. We have worked out AlGaN/GaN HEMT with gate length of 0.17μm and f_{max} values 110GHz. Accuracy of the simulation model is verified by experiment. Then detailed simulates the impact of the T-gate size and we obtain ptimized T-gate size range.**

Keywords- frequency characteristics; GaN HEMT ; T-gate size; Simulation model

I. INTRODUCTION

GaN HEMT performs superiority in the aspect of high frequency and power performance, and is widely used in the microwave and power applications, it is also one of research hotspots. As to high frequencies, the most direct and effective method is reducing gate length. APA Optics Corporation Khan et al proposed AlGaN/GaN HEMT with 0.25 μm gate length, 11GHz cut-off frequency (f_T) and 35GHz maximum oscillation frequency (f_{max}) in 1994, from then on scholars shrink the gate length to improve the AlGaN/GaN HEM frequency continuous. In 2000, Micovic et al of HRL reduced gate length to 50nm, and its f_T and f_{max} reached 110GHz and 140 GHz respectively. In 2010, Chung et al used T-gate and MBE technologies achieve AlGaN/GaN HEMT with f_{max} values 300GHz. However, with the narrowing of gate length, the short channel effect is more and more obvious, and it impact threshold value, frequency, and other characteristics of HEMT. In order to further improve f_{max} of HEM, select a suitable T-gate size is a effective way. But if the T-gate size selection improper, it cannot improve device f_{max}, even counterproductive, So in HEMT design process, to clear the influence degree of size of the T-gate to devices $f_{max,}$ so as to select a appropriate T-gate size. In this paper, combine with existing the tapeout parameters and results, we conduct optimized design simulation of the T-gate.

II. COMPARISON OF EXPERIMENTAL AND SIMULATION RESULTS OF ALGAN/GAN HEMT

On the barrier layer of 20nm$Al_{0.25}$GaN, to work out AlGaN/GaN HEMT with 170nm gate length and 400nm gate cap width, the device contains AlGaN back barrier, and the substrate uses sapphire, its f_T and f_{max} reached 50GHz and 110GHz respectively, as is shown in Figure 1. In a same size, the experimental and test data comparison shown in Table 1, there exist few difference between them, and verify the accuracy of our model. The models we used include: polarization model, low field mobility University of Bologna model, high field mobility Canali model, band gap model, complex model, thermal electron emission model and so on.

Table 1 Test results and experimental results of AlGaN/GaN HEMT

AlGaN/GaN HEMT	f_T(GHz)	f_{max}(GHz)
Test result	51	111
Experimental result	54	116

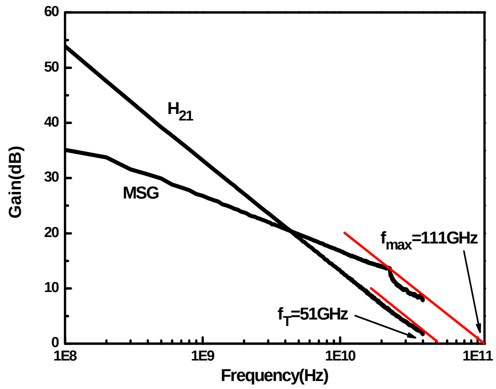
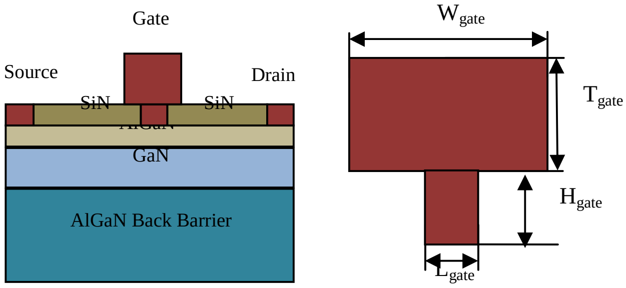


Figure 1 Test figure of frequency characteristics

III. SIMULATION AND OPTIMIZATION OF ALGAN/GAN HEMT T-GATE SIZE

The structure of AlGaN/GaN HEMT sees at figure 2. Figure 2(b) shows the amplification of the gate. W_{gate} and T_{gate} is the dimension of the gate head and the thickness respectively. L_{gate} is the gate length and H_{gate} is the height of gate root.



(a) (b)

Figure 2 AlGaN/GaN HEMT:

(a)Device structure (b) The structure of T-gate

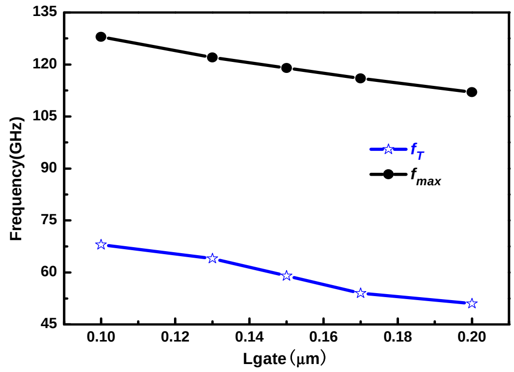


Figure 3 The relationship between AlGaN/GaN HEMT gate length and f_T/f_{max}

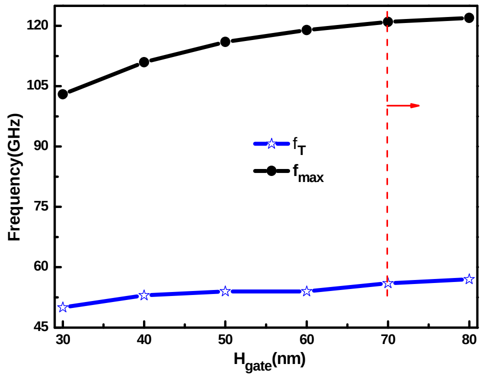


Figure 4 the relationship between AlGaN/GaN HEMT gate root height and f_T/f_{max}

1 Optimization of AlGaN/GaN HEMT gate length (L_{gate}) and gate root height (H_{gate})

The relationship of AlGaN/GaN HEMT gate length and frequency is shown in figure 3. We can see that f_T and f_{max} increase steadily in pace with the decrease of gate length L_{gate}(L_{gate}>100nm). When L_{gate} is larger than 100nm, the ratio of gate length and the thickness potential barrier is bigger than 5, the device short channel effect is not obvious. The gate source capacitance and gate-drain capacitance decrease steadily with the decrease of gate length. We can see that the decrease of gate source capacitance C_{gs} and gate-drain capacitance C_{gd}, f_T and f_{max} will increase steadily from the posture (1) and posture (2). Therefore, we should decrease gate length under permission of technology when design AlGaN/GaN HEMT.

$$f_T \approx \frac{g_m}{2\pi(C_{gs}+C_{gd})} \quad (1)$$

$$f_{max} \approx \frac{f_T}{2\sqrt{(R_i+R_s+R_g)g_{ds}+(2\pi f_T)R_g C_{gd}}} \quad (2)$$

As shown in figure 4, we can see the influence to f_T/f_{max} from AlGaN/GaN HEMT gate root height H_{gate}. The gate source capacitance and gate-drain capacitance decrease steadily with the increase of gate root height, the change touch off the decrease of f_T and f_{max}. However, the increasing trend of f_{max} become slow down gradually and reach a saturation value reached saturation. On one hand, the reduction of C_{gs} and C_{gd} decrease steadily with the increase of gate root height. On the other hand, with the decrease of gate capacitance, the degree of influence of parasitic capacitance to f_{max} increase, the resistance becomes bottleneck to bind up the f_{max}. f_{max} reach a saturation value reached saturation when H_{gate} exceed 70nm.

2 Optimization of AlGaN/GaN HEMT gate width (W_{gate}) and gate head thickness T_{gate}

Maintain the 170nm gate length and 50nm gate root height that have tapped out to study the influence to f_T/f_{max} from W_{gate}. The relationship between AlGaN/GaN HEMT gate width and f_T/f_{max} is shown in figure 5. C_{gs} and C_{gd} decrease steadily with the decrease of Wgate. The change results in the decrease of f_T. The posture (2) shows that the decrease of gate capacitance enforces f_{max} increase. However, with the increase of gate width, gate resistance increase as well. The change will enforces f_{max} decrease. Therefore, with the decrease of gate width, f_{max} will increase first and will decrease later. It has an excellent value range: 250—300nm.

Maintain the 170nm gate length, the 400nm gate width and 50nm gate root height to study the influence to f_T/f_{max} from T_{gate}, as shown in figure 5. With the increase of Tgate, the gate resistance decreases, however the gate capacitance is essentially the same, so f_T practically constant, f_{max} is increased gradually. However, f_{max} gradually become saturated. The reason is as follows: as it shows by the formula (2) in case of f_T constant, (R_i + R_s + R_g) g_{ds} and 2 $f_T R_g C_{gd}$ would affect f_{max}. With the decreasing of gate resistance, 2 fTRgCgd continues to decrease, while (R_i + R_s + R_g) g_{ds} will become saturated. (R_i +R_s+R_g) become the major factor impact on f_{max} as the increasingly proportion. f_{max} tends to saturation when the gate head thickness T_{gate} beyond 500nm.

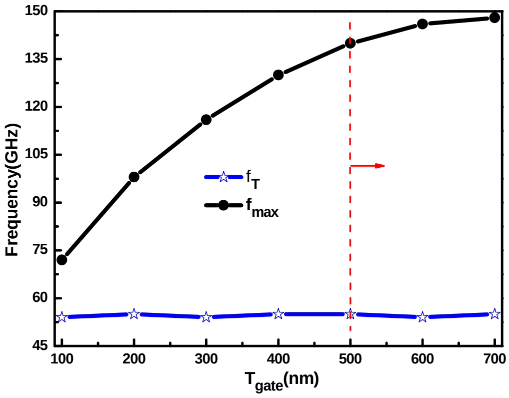


Figure 5 The relationship between AlGaN/GaN HEMT gate width and f_T/f_{max}

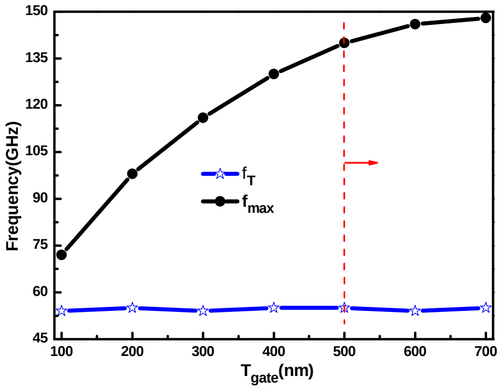


Figure 6 The relationship between AlGaN/GaN HEMT gate head thickness and f_T/f_{max}

IV. Conclusion

The accuracy of the simulation model of this article has been verified through experiment firstly, then simulation shows the influences on f_T/f_{max} of the T-gate sizes, provided a reference for the experiment. After Simulation, it comes to conclusions that: the width of the gate head affects R_g, C_{gs} and C_{gd}, the influence on the f_{max} exists an optimal range: 250-350nm. As the gate root height and gate head thickness increase, fm_{ax} increases but gradually become saturated. As gate length (>100nm) decrease, f_{max} monotonically increasing, According to the process conditions, reduce the gate length as far as possible.

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