MOCVD 8 inches GaAs HBT Manufacture Evaluation

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Keywords: 8-inch GaAs, HBT, MOCVD, Epitaxy

Abstract

The 6-inch GaAs process is currently the mainstream for production of microwave IC product. To enhance the production output and reduce the manufacturing cost, we examined an 8-inch GaAs epitaxial process and evaluated the growth feasibility of an HBT structure on an Aixtron 2800 G4 MOCVD with 8-inch compatible parts. We also studied the epitaxial growth method in which the group V top to bottom gas flow ratio of the triple injector was adjusted in order to improve the uniformity. The beta and turn on voltage within wafer uniformity could be improved from 2.12 % to 0.74 % and 6 mV to 4.3 mV respectively, and reduced turn on voltage from 1.0744 V to 1.0728 V. Using top to bottom gas flow ratio optimization, 8-inch HBT epitaxial wafers were able to achieve the same level of performance as 6-inch HBT production epitaxial wafers.

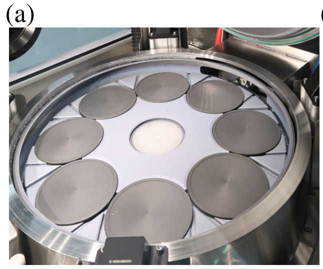
I. INTRODUCTION

The current microwave IC products are mainly fabricated with 6-inch GaAs process. In order to enhance manufacturing capability, mass production output and reduce the manufacturing cost, increasing the wafer size is one of the solutions. The Aixtron 2800 G4 MOCVD that we grew the epitaxy in production is suitable for 6-inch wafers. With limited changes and costs for 8-inch wafer compatibility, the reactor's parts were designed to accomplish 8-inch epitaxial wafer growth. Besides, the uniformity is an important factor to determine the performance of the epitaxial process. The changes of temperature, gas flow and individual satellite rotation could better maintain the uniformity from past experience [1]. In addition, changing the group V ratio of top to bottom gas flow had potential to improve the uniformity in triple injector design [2].

II. EXPERIMENTAL

The susceptor design of Aixtron G4 MOCVD was modified from 8 x 6" to 5 x 8". To perform better heat efficiency, 8-inch and 6-inch susceptor's outer edge was aligned (shown as Fig. 1(a) and (b)). The HBT device was fabricated in 75 um x 75 um large device and measured the turn on voltage and beta at Ic=2 A/cm^2 and 1 kA/cm^2. Besides, to ensure the HBT device characteristics, the calibration process of p-GaAs layer, n-GaAs layer and especially InGaP layer which was critical to HBT device were needed. It showed the difference in photoluminescence (PL) wavelength, growth rate and Indium composition which was caused by temperature and flow field changes in the reactor from InGaP bulk material growth. After the calibration process, the layers' characteristics of 8-inch configuration were aligned with 6-inch configuration (shown as Fig. 2).

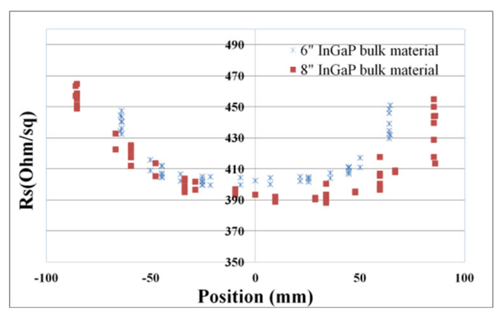
(a)



(b)

Fig. 1. Configuration of (a) 6-inch setup (b) 8-inch setup

(a)



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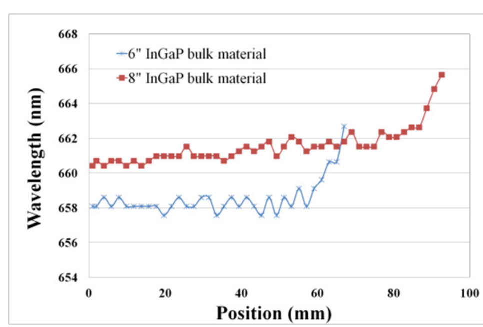

(c)

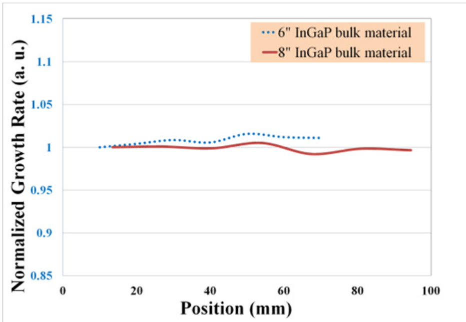

Fig. 2. (a) Sheet resistance (Rs) (b) PL wavelength and (c) growth rate profile of 8-inch InGaP bulk material matched with the 6-inch InGaP bulk material.

III. RESULTS AND DISCUSSION

At initial test, on 8-inch epitaxial wafer, the uniformity was naturally worse than 6-inch wafer and the most characteristics can be tuned appropriately by total gas flow and temperature. However, the improvement of uniformity of beta and turn on voltage of 8-inch epitaxial wafer were limited that it still got worse performance compared with the typical 6-inch mass production epitaxial wafer.

With triple injector design, the ratio of the hydride gas flow through the top and bottom group V inlet can be used to improve layer thickness uniformity [2]. Fig. 3. showed that by increasing the top to bottom phosphine (PH_3) gas flow ratio from 1 to 3, the center and edge growth rates decreased by 3.58 % and 2.8 % respectively in 6-inch InGaP bulk material. With similar performance of Rs, PL wavelength and Indium composition among different ratio from 1 to 3 (shown as Table 1), Fig. 4 showed that the uniformity of turn on voltage could be improved by 1.56 mV (from range = 2.78 mV to range = 1.22 mV) and the mean value decreased by 1.52 mV in corresponding HBT device. The decrease of turn on voltage might be partially contributed to by the effect of reducing the InGaP growth rate on ordering which was investigated by reducing the gas flow rate of TMGa, TMIn and phosphine[3]. We also observed the effect of ordering that PL wavelength increased 3.4 nm on the InGaP bulk material and the 5 mV turn on voltage decreased on the corresponding HBT device when InGaP growth rate decreased by 28 % (shown as Table 2).

Table 1. The characteristics of InGaP material from top to bottom ratio from 1 to 3.

Ratio	RS (ohm/sq)	PL_WL (nm)	XRD In (%)	Growth Rate (Normalized)
1	239.2	666.5	48.5	1
2	277.7	666.4	48.5	0.98*
3	272.2	666.5	48.5	0.97*

*** Growth rate is normalized by the value at condition of ratio = 1**

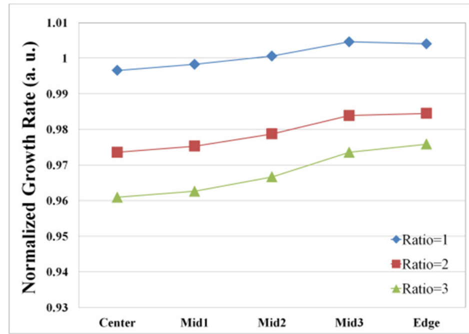

Fig. 3. The growth rate profile of InGaP bulk material at ratio of top to bottom flow R=1, 2, 3

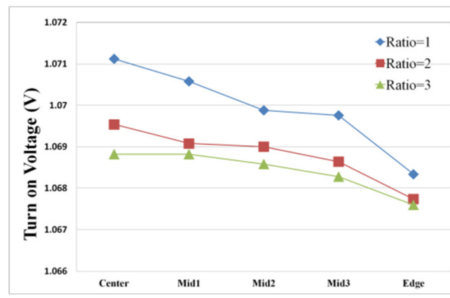

Fig. 4. The turn on voltage of corresponding 6-inch HBT device at ratio of top to bottom flow R=1, 2, 3

Table 2. The characteristics of InGaP bulk material and corresponding HBT device on standard growth rate and low growth rate.

	InGaP Bulk Material		HBT Device
Condition	**XRD_In(%)**	**PL_WL (nm)**	**Turn on Voltage (V)**
Standard	48.5	666.4	1.073
Low G/R	48.5	669.8	1.068

On 8-inch GaAs HBT device, turn on voltage and beta uniformity could be improved from 6 mV to 4.3 mV (shown as Fig. 5) and 2.12 % to 0.74 % (shown as Fig. 6) respectively. And reduced turn on voltage from 1.0744 V to 1.0728 V with optimized the process parameter.

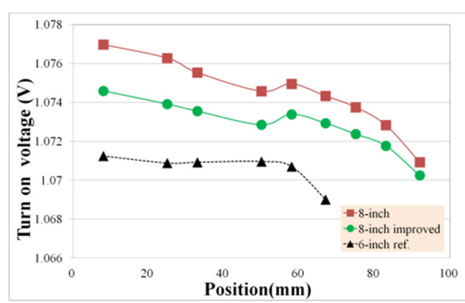

Fig. 5. The improvement of uniformity of turn on voltage with changing top to bottom ratio from 1 to 3.

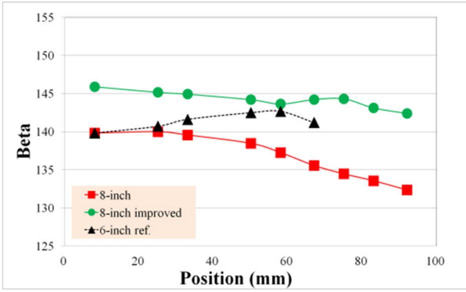

Fig. 6. The improvement of uniformity of beta with changing top to bottom ratio from 1 to 0.75.

IV. CONCLUSION

We made compatibility of 8-inch GaAs HBT manufacturing on an AIXTRON G4 MOCVD with re-designed reactor parts. And we investigated the techniques of top to bottom gas flow ratio to improve the beta and turn on voltage within wafer uniformity from 2.12 % to 0.74 % and 6 mV to 4.3 mV respectively, and reduced turn on voltage from 1.0744 V to 1.0728 V. The 8-inch HBT epitaxial wafers were able to achieve the same level of performance as typical 6-inch HBT epitaxial wafers.

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ACRONYMS

HBT: Heterojunction Bipolar Transistor
PL: Photoluminescence
RS: Sheet Resistance
G/R: Growth Rate