This paper reports the first implementation of HBT technology on 100 mm OMVPE-grown epitaxial wafers. The electrical characteristics of large area HBT devices with an emitter size of $67 \times 67 \, \mu m^2$ are used to measure the uniformity of the epitaxial material. The variations of current gain and $V_{be}$ turn-on voltage for such devices are less than 3% and 1%, respectively, across a wafer. This indicates that the characteristic uniformity of epitaxial films grown on 100 mm wafers is comparable with films grown on 3-inch wafers. Process induced variation in the device characteristics is measured on small area devices with an emitter size of $1.4 \times 3 \, \mu m^2$. The across wafer variations of current gain and $V_{be}$ turn-on voltage for these devices are less than 10% and 1%. Circuit yield sufficient for production ramp-up has been demonstrated for gain blocks, pre-scalers, 14-bit digital-to-analog converters and 8-bit analog-to-digital converters. The success over this array of products demonstrates that the OMVPE-grown 100 mm epitaxial wafers and the HBT fabrication process developed are well suited for a production environment.

INTRODUCTION

The production of digital and analog ICs using AlGaAs/GaAs HBT technology has matured rapidly over the past two years addressing the demand for applications with performance in excess of 3 GHz. Currently, IC production with this technology has been limited to 3-inch wafers. Although the cost benefits of transferring the process to 100 mm wafers are readily apparent, suitable epitaxial material on these larger wafers has not been available in sufficient quality and quantity. Now that stable MESFET and HEMT processes are established using 100 mm wafers in Rockwell’s GaAs FAB, a successful scale-up depends solely on the epitaxial materials and on the adaptation of critical processes unique to the HBT technology.

The first implementation of HBT technology on 100 mm wafers was achieved on carbon-doped HBT epitaxial wafers grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact. The carbon-doped HBT epitaxial wafers were grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact. The carbon-doped HBT epitaxial wafers were grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact. The carbon-doped HBT epitaxial wafers were grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact. The carbon-doped HBT epitaxial wafers were grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact. The carbon-doped HBT epitaxial wafers were grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact. The carbon-doped HBT epitaxial wafers were grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact. The carbon-doped HBT epitaxial wafers were grown to specification using low-pressure OMVPE. The typical HBT structure used for digital applications is shown in Table I. An $n^+$-InGaAs cap layer is used for a non-alloyed Ohmic contact.
RESULTS AND DISCUSSION

The material properties of the epitaxial material were measured using standard TLM test patterns and large area HBT devices. The TLM test patterns were used to extract the sheet resistance and specific contact resistance for the emitter, base and collector layers. Figures 2 and 3 contain boxplots for the sheet resistance and specific contact resistance of these layers, for a batch of 9 wafers. The emitter, base and collector layers have mean sheet resistance of ~ 50, 300 and 12 Ω/µm² and specific contact resistance of ~ 3 x 10⁻⁷, 4 x 10⁻⁶ and 1 x 10⁻⁶ Ω·cm², respectively. The boxplot results indicate that the uniformity and the reproducibility of OMVPE-grown HBT wafers are better than 5%. Current gain and turn-on voltage were extracted from large area HBT devices. Figures 4 and 5 show the boxplots of current gain at 1 mA and V_{be} turn-on voltage at 100 µA, respectively, for HBT devices with an emitter size of 67 x 67 µm². These results indicate that the variation of V_{be} turn-on voltage across a wafer is less than 10 mV, while the variation of current gain is less than 5%.

The process induced variation in the device characteristics is measured using small area HBT devices. Figures 6 and 7 show the boxplots of current gain at 1 mA and V_{be} turn-on voltage at 100 µA, respectively, for HBT devices with an emitter size of 1.4 x 3 µm². With the device structure specified in Table I, a typical current gain of 70 and a V_{be} turn-on voltage of 1.27 V can be achieved. It is apparent from the boxplot results that the current gain and V_{be} turn-on voltage are less than 10% and 1%, respectively. It should be noted that the small area HBT devices were measured at a higher current density than the large area devices resulting in a higher current gain. Note also the lower current gain in the last four wafers in Figure 6. These wafers were split with an alternate passivation process and illustrate one process sensitivity.

The gain blocks fabricated on these wafers were designed to meet the following specifications: a DC gain of 10 dB and a 3-dB bandwidth of 10 GHz. A histogram of DC gain is illustrated in Figure 8 with bandwidth being represented by...
Figure 3. Boxplots of specific contact resistance for the emitter, base and collector layers.

Figure 4. Boxplots of current gain at 1 mA for HBTs with an emitter size of $67 \times 67 \, \mu m^2$.

Figure 5. Boxplots of $V_{be}$ turn-on voltage at 100 $\mu A$ for HBTs with an emitter size of $67 \times 67 \, \mu m^2$.

Figure 6. Boxplots of current gain at 1 mA for HBTs with an emitter size of $1.4 \times 3 \, \mu m^2$.

Figure 7. Boxplots of $V_{be}$ turn-on voltage at 100 $\mu A$ for HBTs with an emitter size of $1.4 \times 3 \, \mu m^2$.

Figure 8. Histogram of DC gain for gain blocks.
CONCLUSIONS

We have successfully fabricated digital and analog circuits implemented with AlGaAs/GaAs HBTs on OMVPE-grown 100 mm epitaxial wafers. A combination of uniform material characteristics and tight process control across a 100 mm wafer make this technology suitable for volume production. Currently HBTs are being used for manufacturing the gain blocks, prescalers, active mixers, logarithmic amplifiers, gate arrays, analog-to-digital converters and digital-to-analog converters.

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