

Crystal growth and wafer processing of 6" Indium Phosphide substrate

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I. Introduction

The recent fiber telecommunication system progress and 5G wireless communications are creating demand for ultra-high speed digital devices, such as HBTs or HEMTs for ICs. These devices are fabricated on semi-insulating Fe-doped InP substrates. As performance of these devices is improved and the chip size is increased, the market expects higher quality and larger diameter substrates (6-inch) to improve device performance and reduce production costs. With the growth of larger diameter InP crystals, the increase of dislocation densities becomes critical. Though a boat growth method is the most appropriate for achieving low dislocation density, the boat growth of InP is difficult because of twinning issues. Therefore a <111>-growth orientation have been previously adopted to prevent twinning [1]. However, this type of orientation is not suitable for the production of (100) substrates.

Table1 shows a comparison of InP crystals by VCZ(Vapor pressure controlled Czochralski), VGF(Vertical Gradient Freezing) and VB(Vertical Boat) methods, respectively.

We focused on the improvement of lot size and succeeded in developing a long VB grown InP single crystal ingot. Long crystal ingot means more wafers can be obtained from one ingot. Doping concentration of impurities changes from the seed

side to the tail side because of segregation phenomenon. Therefore the longer ingot makes smaller variation in doping concentration among wafers from one ingot.

We are reducing the furnace cost gradually through the simplification of the structure. In addition, productivity per furnace is gradually increasing through larger lot sizes and yield improvement.

Table1. Comparison of InP crystals by VCZ, VGF and VB methods

		VCZ	VGF	VB
Quality	Electrical property variation between wafer in the same ingot(*1)	Good	Good	Very Good
	Residual strain	High	Low	Low
	Breakage, Slip	Good	Very Good	Very Good
Productivity	Lot size	Good	Good	Very Good
	Furnace price	High	High	Low

(*1)Resistivity, Carrier concentration, and mobility

SEI has succeeded in developing 6-inch Fe-doped InP substrates that are higher in quality and that can be manufactured at competitive costs using VB technique.

II. Crystal growth and wafer processing

The equipment for VB single crystal growth techniques is schematically drawn in Figure.1. A single crystal is grown in a vertical boat by solidifying the melt from a seed crystal with <100>-growth orientation placed at the bottom of the

vertical boat. InP single crystal can be grown under small axial temperature gradient of between 5-20 degree C/cm near the solid-liquid interface.

This makes it possible to grow InP crystals with much lower dislocation density and more reproducibility than VCZ method.

The wafer processing was performed under a double side polish (DSP) and single side polish (SSP) that is almost of the same concept as 6-inch GaAs wafer processing.

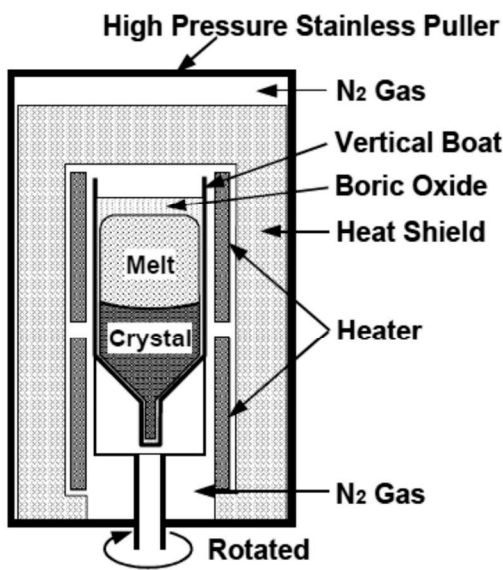


Figure 1. VB equipment for InP single crystal growth techniques

III. Results

Figure 2 shows EPD (Etch Pit Density) distribution of 4-inch and 6-inch Fe-doped InP substrates. The 4-inch VB substrates exhibit much lower EPD than conventional VCZ substrates [3]. The 6-inch VB substrates are of the same level of EPD as that of 4-inch VB substrates.

Figure 3 (a) shows the correlation between Fe concentration (determined by GDMS) and electrical resistivity. Since activation of Fe and the concentration of residual impurities influence electrical resistivity, we can know the degree of the activation of Fe and the concentration of residual

impurities from this correlation. The data of 4-inch and 6-inch substrates are plotted on the same line and we can control the electrical properties of 6-inch substrates as well as 4-inch substrates. Figure 3 (b) shows the radial distribution of electrical resistivity for 4-inch and 6-inch substrates. The uniformity of 6-inch substrates is as good as that of 4-inch substrates, which means that the shape of solid-liquid interface of VB stays flat even for growth of 6-inch single crystals.

Figure 4 shows the comparison of warp and total thickness variation (TTV) between 4-inch and 6-inch substrates. The TTV and warp of 6-inch substrates is as good as that of 4-inch substrates. Using a similar type of GaAs 6-inch polishing tool, the total cost of 6-inch InP substrates processing can be minimized even for larger scale production.

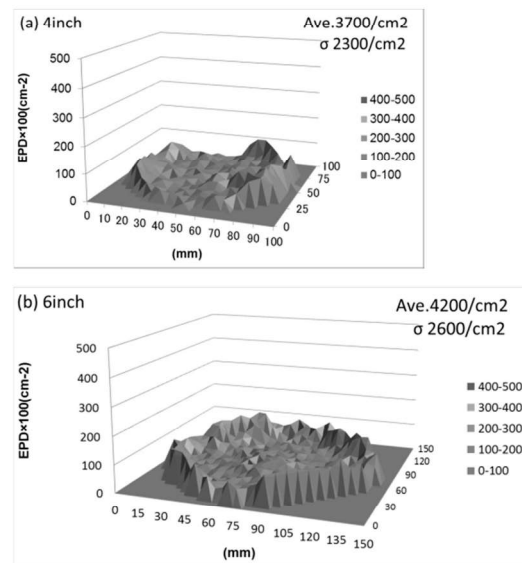


Figure 2 EPD distribution of (a) 4-inch VB and (b) 6-inch VB

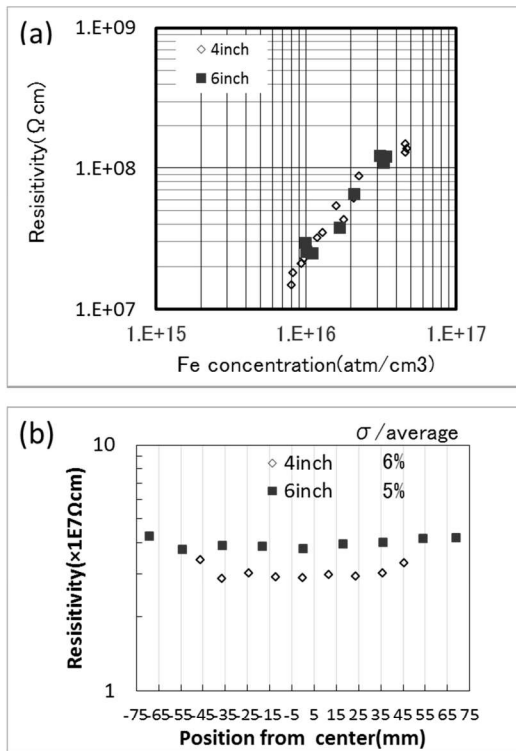


Figure 3 (a) Correlation between Fe concentration determined by GDMS and electrical resistivity. (b) Distribution of electrical resistivity of 6-inch and 4-inch substrates.

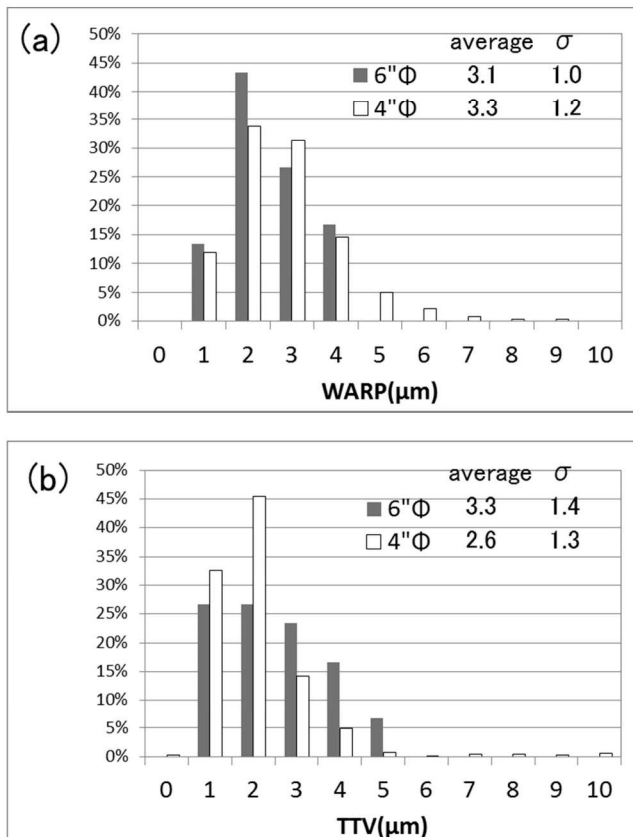


Figure 4 Warp and TTV histogram for 4-inch and 6-inch InP substrates

IV. Summary

The market requires a mass production of 6-inch InP substrates with high quality and reasonable price. To respond to this market requirement, we have focused on the cost effective manufacturing by reducing both direct production cost and indirect investment cost. The optimization of crystal growth furnace and polishing process makes it possible to respond to this market requirement effectively.

VI. References

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