Crystal Growth of Sapphire for GaN Substrates

Y.M. YU*, S.J. Jeoung, J.C. Koh, B.H. Ryu
Korea Research Institute of Chemical Technology
(P.O.Box 107, Yusong, Taejon, 305-600, Korea)

Abstract

Sapphire crystals were grown by Horizontal Bridgman method. The effects of sliding rate (growth rate) of Molybdenum container, growth atmosphere, temperature gradient and orientation of seed on crystal qualities were investigated. The size of the crystals grown was up to 150-200 mm in length, 90 mm in width and 25-35 mm in thickness. Crystals grown under the optimum conditions were colorless, transparent and could not be observed any macroscopic defects, such as bubbles, cracks, twins and mosaic structure. With the grown crystals, prototypes of sapphire substrate for blue diode of GaN were manufactured and then roughness of surface and orientations of wafers were characterized. As a result, we can get high quality of sapphire wafers with c-axis, 1.5 inches in diameters and 0.33mm in thickness.

1. *Introduction*

Sapphire crystals are expressed with the chemical formula of Al_2O_3 and be called with Corundum as a mineral name. Crystal System of sapphire is trigonal (a=4.758A, c=12.991A); bar 3 2/m[1]. It is the second hardest natural mineral known to science. The hardness of corundum can be partially attributed to the strong and short oxygen-aluminum bonds. These bonds pull the oxygen and aluminum atoms close together, making the crystal not only hard but also quite dense and chemically stable for a mineral made up of two relatively light elements. Because of high chemical and mechanical stability and small mismatch in lattice parameters with GaN, sapphire crystals are used as a substrate materials for GaN blue light emitting diode[2].

In this study, we tried to set-up the technologies for large crystal growth of sapphire by horizontal Bridgman(HB) method, the optimum growth conditions for high quality crystals and fabrication of substrate materials for the devices of GaN blue diode.

2. Experiments

99.99% of Al_2O_3 powder was used for this experiments as a starting material. After the pre-melting of the powder, it was crushed as granules of corundum. Granules were charged in Molybdenum container and then melted by tungsten heaters in growth chamber of HB apparatus. Molybdenum plates as heat shields were used for control of temperature gradient at growth zone.

The effects of sliding rate (growth rate) of Molybdenum container, growth atmosphere, temperature gradient and orientation of seed, as experimental variables, on crystal qualities were studied for the optimum condition of crystal growth.

For characterization of grown crystals, structural identification by XRD method, confirm of growth orientations by Laue method, macroscopic defects observation by polarizer, microscopic defects characterization by polarizing microscope, and measurement of the density of etch-pits were carried out.

Grown crystals are cut and polished with the precise orientation of c axis. After the fabrication of substrates, roughness of surface and orientation of substrate were evaluated for decision of quality of substrate.

3. Results and Discussions

One example of grown crystal is shown at Fig. 1. Grown crystals were sized up to 150-200 mm in length, 90 mm in width and 25-35 mm in thickness (weight; 1800-2000 g). Grown crystals were completely colorless and transparent.

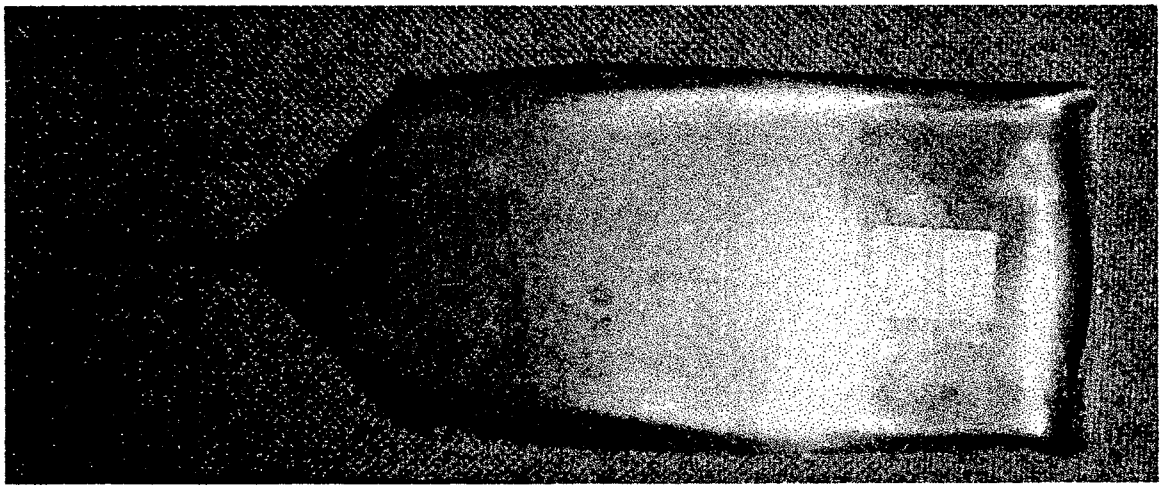

Fig. 1. Example of grown sapphire crystal.

Grown crystals were identified with corundum structure by X-ray diffraction method. Growth directions that determined by Laue method for growth normal wafers were analyzed <110> and <001>. It was found the low densities of defects occur when it grows under the smallest superheating along with <110> and <001> direction. And also it was recommended to use vacuum atmosphere. Under the polarizer, grown crystals show mosaic structure or mis-orientation when they grow with high growth rate or under the overheated status. When it grows with optimum growth rate (less than 8 mm/hr), vertical solid-liquid interface and optimum power of tungsten heater, grown crystals did not shown any defects, such as birefringence phases, mosaic structure, striations, secondary phases, inclusion and facets. Average density of etch-pits was analyzed at 7.8 x $10^3/cm^2$.

Fabricated wafers for substrate purposes are shown at Fig. 2. The dimension of

wafer is 1.5 inches in diameter and 0.33 mm in thickness. It was characterized that exact orientation was <001>$\pm$0.2° and RMS was 19A. RMS can be improved by control of abrasives and chemical polishing.

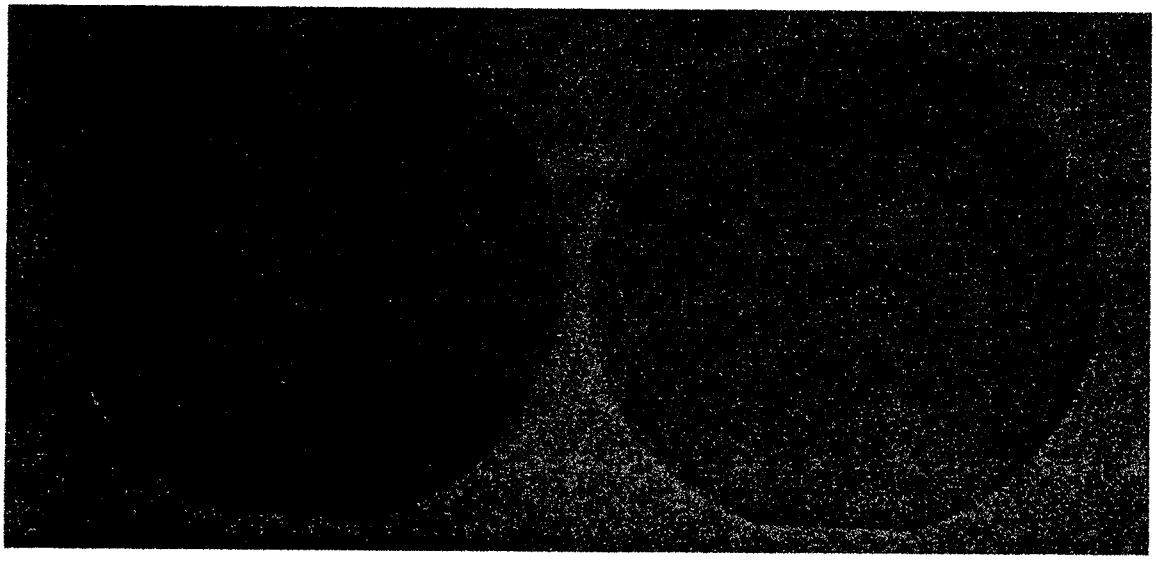

Fig. 2. Prototypes of sapphire wafer manufactured for substrate of GaN LED.

4. Conclusions

By HB method, we can develop the technologies and know-how on growth of large sapphire crystals and fabrication of wafer for GaN LED substrate. For the growth of sapphire high growth rate of 8 mm/hr and Molybdenum container and heat shields, Tungsten heater and vacuum atmosphere were used. Also we can get the prototype of wafers for GaN LED substrates with the high quality than 19A RMS and <001>$\pm$0.2° and with the size of 1.5 inches in diameter and 0.33 mm in thickness.

References

1. W.H.Bragg and W.L.Bragg, X-ray and Crystal Structure, G.Bell and Sons, London, pp.169 (1916)
2. M.A.Khan et.al., Mater. Sci. Eng., B, B43(1-3), 265-268 (English) 1997