Crystal Growth of Nd:YAG for 1.06 μm Lasers

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

Nd:YAG crystals were grown by Horizontal Bridgman method. The effects of sliding rate (growth rate) of Molybdenum container, growth atmosphere and concentration of Neodymium ions on crystal qualities were investigated. The size of the crystals grown was up to 150-200 mm in length, 70 mm in width and 25-35 mm in thickness. Crystals grown under the optimum conditions were violet, transparent and could not be observed any macroscopic defects. Under the polarizing microscopic observations with crossed polar, striations, {211} facets and inclusions were detected. With the grown crystals, prototypes of laser rods for 1.06 μm laser application were manufactured and then characterized. As a result, we can get high quality of Nd:YAG laser rods with <111> and <110> axis, 63 mm in length and 6.3 mm in diameter.

1. Introduction

Yttrium aluminum garnet (YAG) crystals are popular laser materials in the world can be expressed with the chemical formula of $Y_3Al_5O_{12}$. Crystal System of YAG is cubic (a=12.001A); 4/m bar 3 2/m[1]. Garnet structure has three different crystallographic sites; dodeca-, octa- and tetra-hedral sites. Because there are high freedoms for substitution of cations with other cations, a lots of garnet compounds more than 400 were founded in nature and synthesized artificially. Among them YAG crystals shows high mechanical strength, chemical and thermal stability. When Neodymium ions are doped in YAG crystal matrix, it shows small coefficient of birefringence depending on temperature and high emission cross section with the sharp lasing wavelength of 1.06 μm. And also it has congruent melting nature. Because of these useful properties, Nd:YAG crystals are used as high power diode pumped solid-state lasers[2] and high power lasers for material processing applications such as welding, drilling, trimming, marking of metals, ceramics, wood, cloths and polymers[3].

In this study, we tried to set-up the technologies for large crystal growth of Nd:YAG by horizontal Bridgman(HB) method, the optimum growth conditions for high quality crystals and fabrication of laser rods for 1.06 μm laser applications.

2. Experiments

99.99% of Al_2O_3, Y_2O_3 and Nd_2O_3 powders were used for this experiment as a starting material. After the pre-melting of the powder, it was crushed as granules of Nd:YAG. 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, and concentration of Neodymium ions, 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 and microscopic defects characterization by polarizing microscope were carried out.

Grown crystals are cut and polished along the growth direction. After the fabrication of laser rods, laser oscillation for the measurements of lasing threshold and slope efficiency were performed.

3. Results and Discussions

One of grown crystals is shown at Fig. 1. Grown crystals were sized up to 150-200 mm in length, 70 mm in width and 25-35 mm in thickness (weight; 1300-1800 g). Grown crystals were pale violet and transparent.

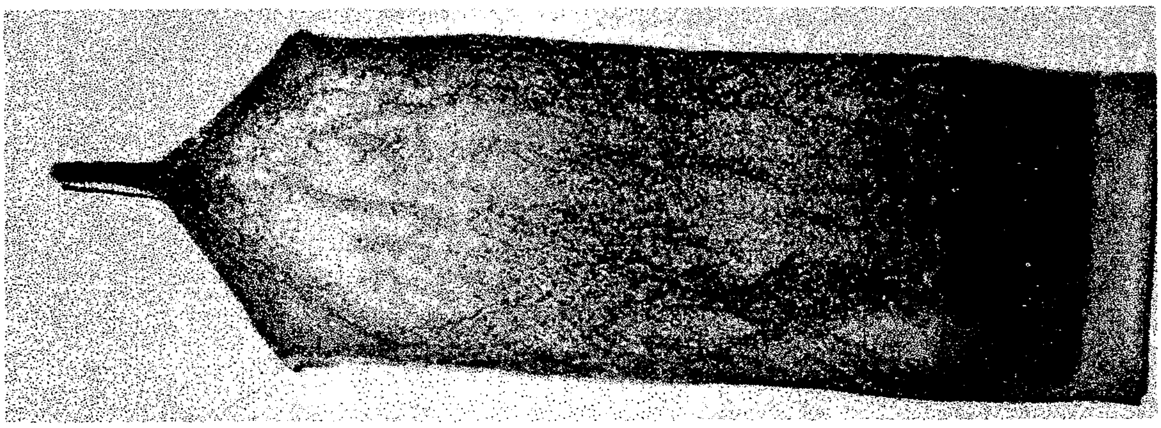

Fig. 1. Example of grown Nd:YAG crystal.

Grown crystals were identified with garnet structure by X-ray diffraction method. Growth directions that determined by Laue method from growth normal wafers were analyzed <111> and <110>. It was found that depending on the sliding rates and concentration of Neodymium ions in melt densities of defects drastically changes. Among the several kinds of growth atmosphere, vacuum atmosphere was mostly recommended. Under the polarizer, cracks and inclusions were observed when they grow with high growth rate more than 1.1 mm/hr and/or with high concentration of 1.5 atomic% in raw materials. When it grows with optimum growth rate (less than 1 mm/hr), vertical solid-liquid interface and optimum concentration of Neodymium ions (less than 1.5 atomic% in raw materials), grown crystals did not shown any defects except microscopic defects, such as striations and {211} facets.

Spectroscopic properties such as absorption and fluorescence were identified with previous measured. It was measured that lasing wavelength was 1064 ± 5 nm, FWHM

45A and lifetime 0.2 msec. Fabricated laser rods for 1.06 μm laser purposes are shown at Fig. 2. The dimensions of laser rods were 6.3 in diameter and 63 mm in length. With the 75% of output mirror and without AR coating on the surfaces of rods, it was measured that lasing threshold was 3.67J and slope efficiency was 0.5%.

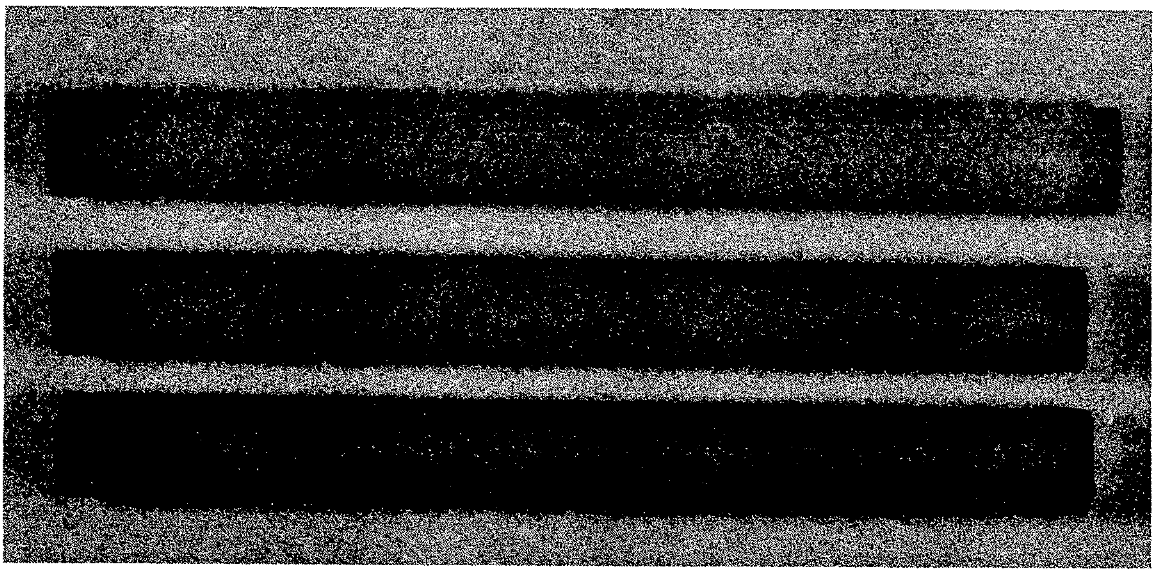

Fig. 2. Prototypes of laser rods manufactured for 1.06 μm laser.

4. Conclusions

By HB method, we can develop the technologies and know-how on growth of large Nd:YAG crystals and fabrication of laser rods for 1.06 μm laser. For the growth of Nd:YAG growth rate of 1.1 mm/hr and 1.5 atomic% of raw materials were used. Also we can prepare the prototypes of laser rods with the high quality and with the size of 6.3 mm in diameter and 63 mm in length. Laser action with fabricated laser rod from the grown crystals was obtained.

References

1. H.S.Yoder and M.L.Keith, Am.Miner., 36, 519 (1951)
2. U.Stamm et.al., Proc. SPIE-Int. Soc. Opt. Eng., 2991, 194-200 (1997)
3. I.P.Tuersley and I.R.Pashby, Proc. SPIE-Int. Soc. Opt. Eng., 2993, 138-145 (1997)