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# THE EFFECT OF THERMAL TO THE DIAMETER OF Nd:YAG CRYSTAL DURING GROWTH PROCESS

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## ABSTRACT

The Nd:YAG crystal grown in a pure argon atmosphere using Czochralski method with ADC (Automatic Diameter Control) r.f. heating is reported.The conditions required to grow Nd:YAG single crystals are described. The pull rate was 0.75 mm/h with a seed rotation of 15 rpm. All runs were made with growth along the c-axis <111> direction.

***Keywords*:** Czochralski method, Nd:YAG, crystal growth, oxide crystal

## INTRODUCTION

Czochralski crystal growth (CZ) is a well-established industrial process used for the production of oxide single crystals [1-3]. Oxide crystals are widely used for modern electrical and electro-optical applications in several devices such as diode-pumped Q-switched solid-state lasers, have been demonstrated to have high-efficiency, high average power, and high energy per pulse [4-6]. The central idea of the CZ process is to grow a crystal from a melt by pulling a seed crystal very slowly within a well-regulated thermal environment in a furnace. For the subsequent processing steps, it is important to form a cylindrical crystal with desired radius and length of dimensions which includes very low concentrations of impurities and dislocations, as well as a uniform dopant distribution [7]. This paper describes the relationship of temperature and power to the diameter of the crystal during the growing Nd:YAG single crystal by Czochralski method with ADC.

## EXPERIMENT

To grow high quality Nd:YAG single crystal, an automatic diameter control system for Czochralski crystal growth from melt was used. A Crystal Growth System namely Automatic Diameter Control (ADC) is well-equipped with growth system especially the furnace including the insulator and iridium crucible, power supply using radio frequency of 30 kHz with the output power up to 25 kW, pulling device, process controller by using ADC software with Labview environment. Figure 1 shows a picture of ADC heating zone.

The melts were prepared from the oxide powder of high purity $Al_2O_3$, $Y_2O_3$ and $Nd_2O_3$ with the dopant concentration of Nd is 4.5 atomic weight %. The crystal was grown in an iridium crucible with diameter of 60 mm.

The starting materials of 500 g of Nd:YAG are weighed and put into the iridium crucible. It is sintered at 1100$^{o}$C for half an hour to remove the water vapor. A seed of Nd-doped YAG crystal at <111> direction is selected, and their surface is melted to

 

remove the defect before growing. The growth point temperature is about 1855$^{o}$C. The pulling rate is 0.75 mm/h and rotating rate was kept constant at 15 rpm. Once the growth is complete, the crystal was cooled down to room temperature for 60 hours as to avoid the cracking of the crystal.

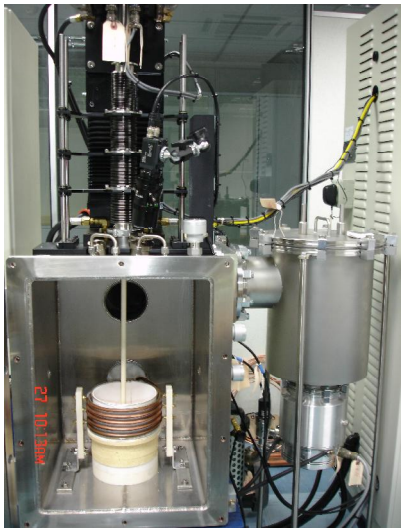

**Figure 1:** Automatic Diameter Control (ADC) heating zone.

## RESULT AND DISCUSSION

Figure 2 shows the Nd:YAG crystal grown using the ADC system. The crystal is completely transparent. The dimensions of the crystal are 65 mm in length, 30 mm in diameter and 63 grams in weight. Some defects in the form of cracks have been observed and could be due to the lowering of the temperature gradient during cooling or jerking off procedure. A similar case has also been reported elsewhere [8,9].


**Figure 2:** Nd:YAG single crystal with the <111> growth orientation

As can be observed in Figure 3, the temperature fluctuations create a periodical variation in the growth rate and thus a periodical change in the crystal diameter. As the growth progress, the diameter of the growing crystal is controlled by adjusting the crucible temperature. The crucible temperature is directly related to the change of power (see Figure

4). Lowering the heating power will accelerate the crystallization and lead to a diameter increase, while increasing the power will act to decrease the crystal diameter [10,11]. In order to get a good shape of straight body crystal diameter, the power should be increased a little bit higher.

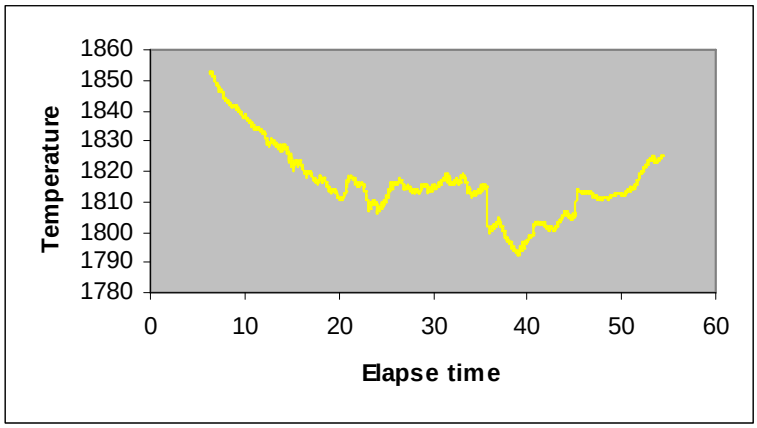


**Figure 3:** The temperature fluctuation during the growth.

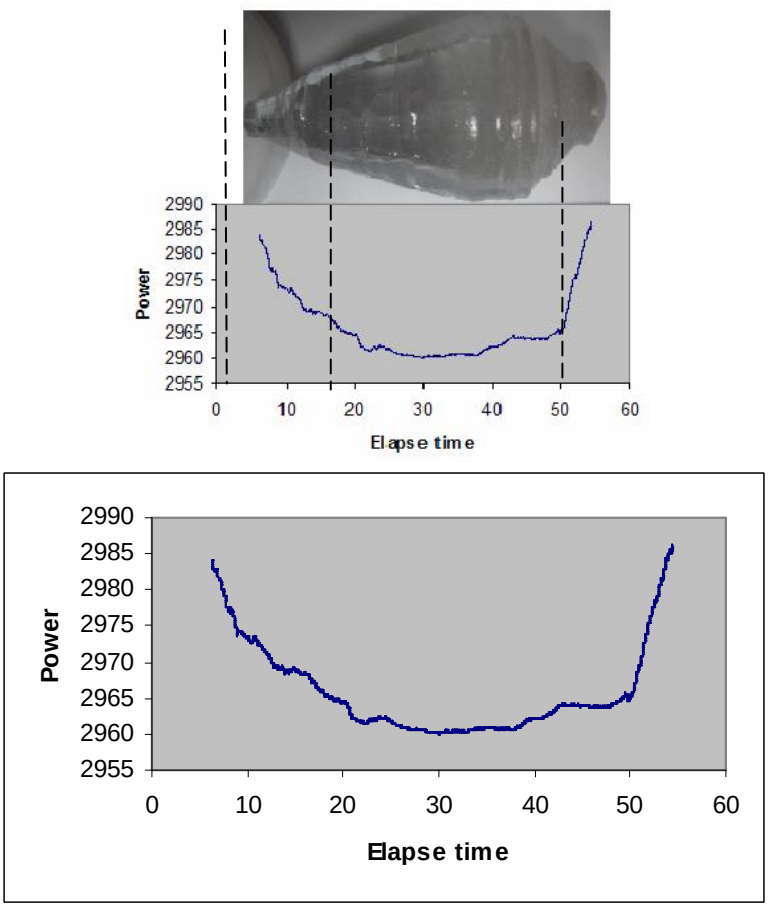


**Figure 4:** The power control during the growth.

## CONCLUSION

In conclusion, a Nd:YAG crystal has been successfully grown by Czochralski method using ADC. In order to control the diameter of the crystal we have to change the thermal environment of the hot zone. In other words, we have to lowering the power control to enlarge the diameter and/or increasing the power for reducing the diameter.

## ACKNOWLEDGEMENTS

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