STUDIES OF THE GROWTH PARAMETERS OF Nd^{3+} DOPED YAG CRYSTAL

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ABSTRACT

The Nd:YAG crystal with the dimension of 65 mm in length and 30 mm in diameter has successfully been grown by Czochralski technique using the Automatic Diameter Control – Crystal Growth System (ADC-CGS) software in an argon gases atmosphere. The crystal grown is light purple when exposed to the light. The crack is found at the bottom part of crystal.

***Keywords**: Nd:YAG crystal, Czochralski technique,parameters*

INTRODUCTION

The Czochralski technique or crystal pulling has become the best method for the growth of many bulk oxide materials. This technique through various modifications has become the dominant process used in industry today for the production of semiconductor and oxide single crystals [1]. Materials such as silicon, sapphire (Al_2O_3), GaP, GaAs, InP, $Gd_3Ga_5O_{12}$, Nd:$Y_3Al_5O_{12}$, germanium, and $LiNbO_3$ are normally grown today by this technique [1].

YAG has a cubic crystal lattice system. Incorporated of Nd^{3+} into $Y_3Al_5O_3$ garnet reveals the substituted of Nd^{3+} into eight coordinate of Y^{3+}. This substitution does not affect the crystal structure because on the ionic radius of both Nd^{3+} (1.12 Å) and Y^{3+} (1.01 Å) almost the same [2]. Nd:YAG is usually used in monocrystalline form, fabricated with Czochralski growth method, but there is also ceramic (polycrystalline) Nd:YAG available in high quality and in large sizes. Nd:YAG crystals is ordinarily produced with Nd^{3+} concentrations from 0.18 at% to 1.1at% for applications in all types of solid-state lasers systems [3]. The Nd^{3+} concentration in Nd:YAG crystal normally varies along the grown boules. The concentration is low on the top but slightly increases at the bottom of the boules.

EXPERIMENT PROCEDURE

The Nd^{3+}-doped YAG system was prepared by melting technique in iridium crucible under pure argon gases atmosphere. These samples were prepared from certified reagent grades Y_2O_3 (99.99% purity, Al_2O_3 (99.99% purity) and 4.5 atomic% of Nd_2O_3 (99.99% purity). By using Czochralski technique, the iridium crucible (5.6 cm diameter, 5.6 cm high) is placed at the centre of coil position which surrounded with zirconia insulator in order to protect the high radiation in the furnace as shown in Figure 1. Alumina was mounted around the system to decrease the radial temperature gradient in the melt and the seed used along the <111> direction.

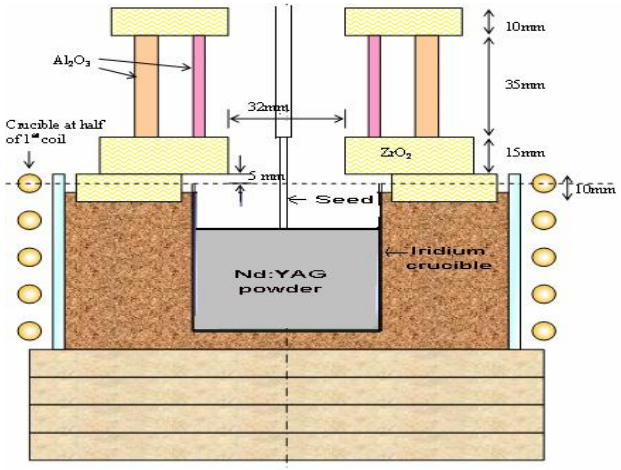

Figure 1: The schematic diagram of Nd:YAG crystal growth using the Czochralski technique

Table 1 shows the setting parameters for growing Nd:YAG crystal using Automatic Diameter Control – Crystal Growth System (ADC-CGS) software. The pulling and rotation rate used are 0.75mm/h and 15 rpm respectively. After the growth completed, the crystal was cooled for 60 hours.

Table 1: Setting Parameter for Nd:YAG Crystal Growth

Dimension		**Power Control**		**Control The Crystal Shape**	
Seed Diameter (mm)	5.0	Max Control Power (mV)	3000	Pull Speed (mm/hr)	0.8
Full Diameter (mm)	20.0	Max Output Power (kW)	25	Rotation Rate (rpm)	15
Shoulder Angle	63.4	Rate Limit (mV/hr)	10	Proportional Gain	5
Neck Length (mm)	5.0	Heat-up Time	2.0	Integral Gain	10
Desired Length (mm)	30.0	Cool Down Time	60.0	Derivative Gain	0
Tail-off Angle	73.3	Generator Filter	0.005	Base Rate Time	0.25
Tail-off Min. Diameter	5.0	Heat-up Start Power	1200	Jerk-out Speed (mm/hr)	3600
Tail Length	2.0	Generator Gain	1.0	Jerk-out Height (mm)	15

RESULT AND DISCUSSION

The Nd:YAG crystal which has successfully been grown with this technique. It has a weight of 63 grams and has a length 65 mm and 33 mm in full diameter. The Nd:YAG crystal parameters are depending on the growth setting parameters. Figure 2 shows the actual Nd:YAG crystal which has been grown by this method and the graph of control power and temperature versus elapsed time from the seeding phase until the separation phase of the crystal from the melt.

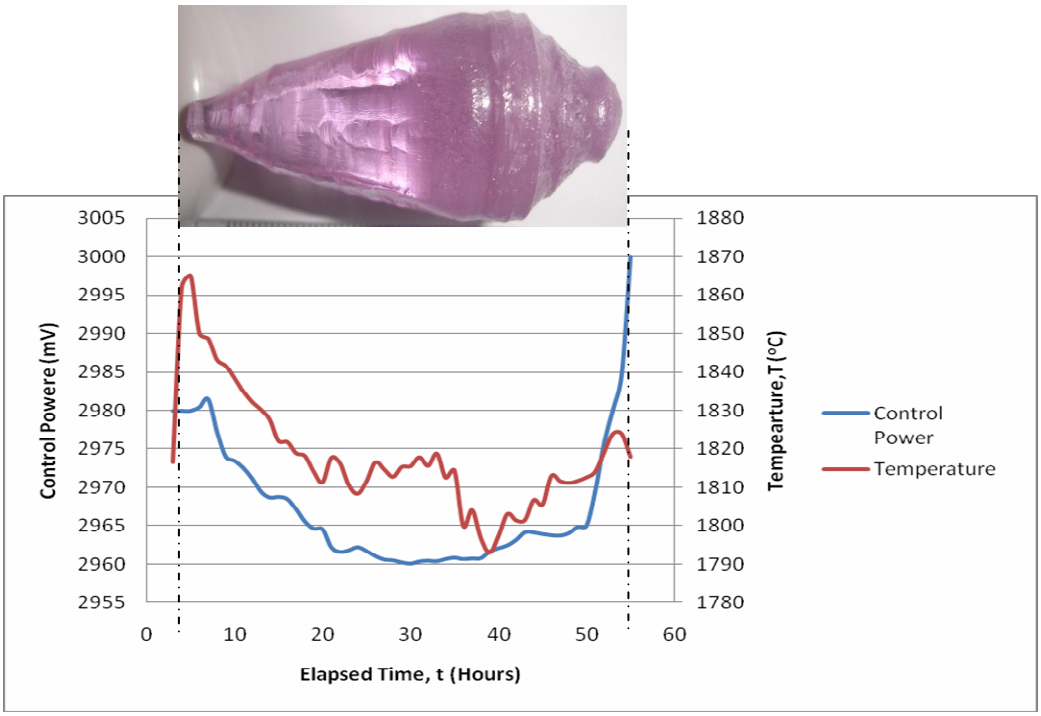

Figure 2: The graph of control power and temperature versus elapsed time

It is observed that the crystal is visually light purple but it gradually become the dark purple as the content of Nd^{3+} is higher. This is due to the changes in valence state of Nd^{3+} in the crystal. The crack is found at the bottom part of the crystal. It might be due to the jerking out effect during the pulling of the crystal from the melt. Acordding the graph, temperature fluctuation is occurred as the control power changes with time. The temperature fluctuations are caused by poor control of environmental variables such as room temperature, water flows and hot zone design.

CONCLUSION

The Nd:YAG crystal has successfully been grown using the Czochralski technique with Automatic Diameter Control – Crystal Growth System (ADC-CGS). The Nd:YAG crystal is light purple when exposed to the light. The macroscopic defect such as a crack is found at the bottom part of crystal.

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