Crystal Growth of Er:YAG and Er,Cr:YSGG for Medical Lasers

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Abstract

Erbium doped garnet crystals were grown by Czochralski method. Relationships between crystal quality and crystal growth factors such as pulling rate, rotation rate and concentration of active ions and sensitizers were investigated. Optimum pulling and rotation rate for high quality Er:YAG crystal were 1 mm/hr and 20 rpm and for Er,Cr:YSGG crystal 2-4 mm/hr and 10 rpm respectively. The size of the crystals grown was up to 20-30 mm in diameters and 95-135 mm in length. Er:YAG crystal grown under the nitrogen atmosphere was pink and transparent and Er,Cr:YSGG under the 98% N_2 and 2% O_2 was dark green and transparent. Under the polarizing microscopic observations with crossed polar, striations and {211} core facets were detected. Spectroscopic properties for both crystals were reported. With the grown crystals, high quality laser rods of Er,Cr:YSGG laser rods with <111> axis, 80 mm in length and 6.3 mm in diameter for medical laser applications of 2.79 μm wavelength were manufactured and then laser oscillation was achieved.

1. Introduction

Erbium doped garnet crystals are promising laser materials for medical applications, because Erbium active ions emit 3 μm wavelength radiation with high efficiency(1). Water absorbs light energy differently, depending on the wavelength. Absorption spectrum of it has maximum around 3 μm wavelength(2). As a result of high absorption of light at 3 μm, laser beam generated by Erbium ions overheated thin section of human skin. Surgery operation with Er laser leaves minimum thermal damage to human body(3). It allows successful applications of Erbium laser for precise surgery including cosmetology.

In this study, we grew Er:YAG and Er,Cr:YSGG crystals by Czochralski method, measured spectroscopic properties and made laser rods for medical laser applications.

2. Experiments

99.99% of Al_2O_3, Y_2O_3, Er_2O_3, Cr_2O_3 and Ga_2O_3 powders were used for this experiment as a starting material. Each powders were weighed, thoroughly mixed, pressed to cylindrical shape of lump and then calcined at 1500℃ for 1 hr. Calcined lump was charged in Iridium crucible and then melted by RF-induction heating.

Suitable insulation plates as heat shields were used for control of temperature gradient at growth zone.

The effects of pulling rate, rotation rate and concentration of active ions and sensitizers, as experimental variables, on crystal qualities were studied for 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 to cylindrical laser rods. Laser oscillation was achieved with these crystal rods. Threshold of lasing and slope efficiency were measured.

3. Results and Discussions

Grown crystals are shown at Fig. 1. Grown Er:YAG crystal was sized 20 mm in

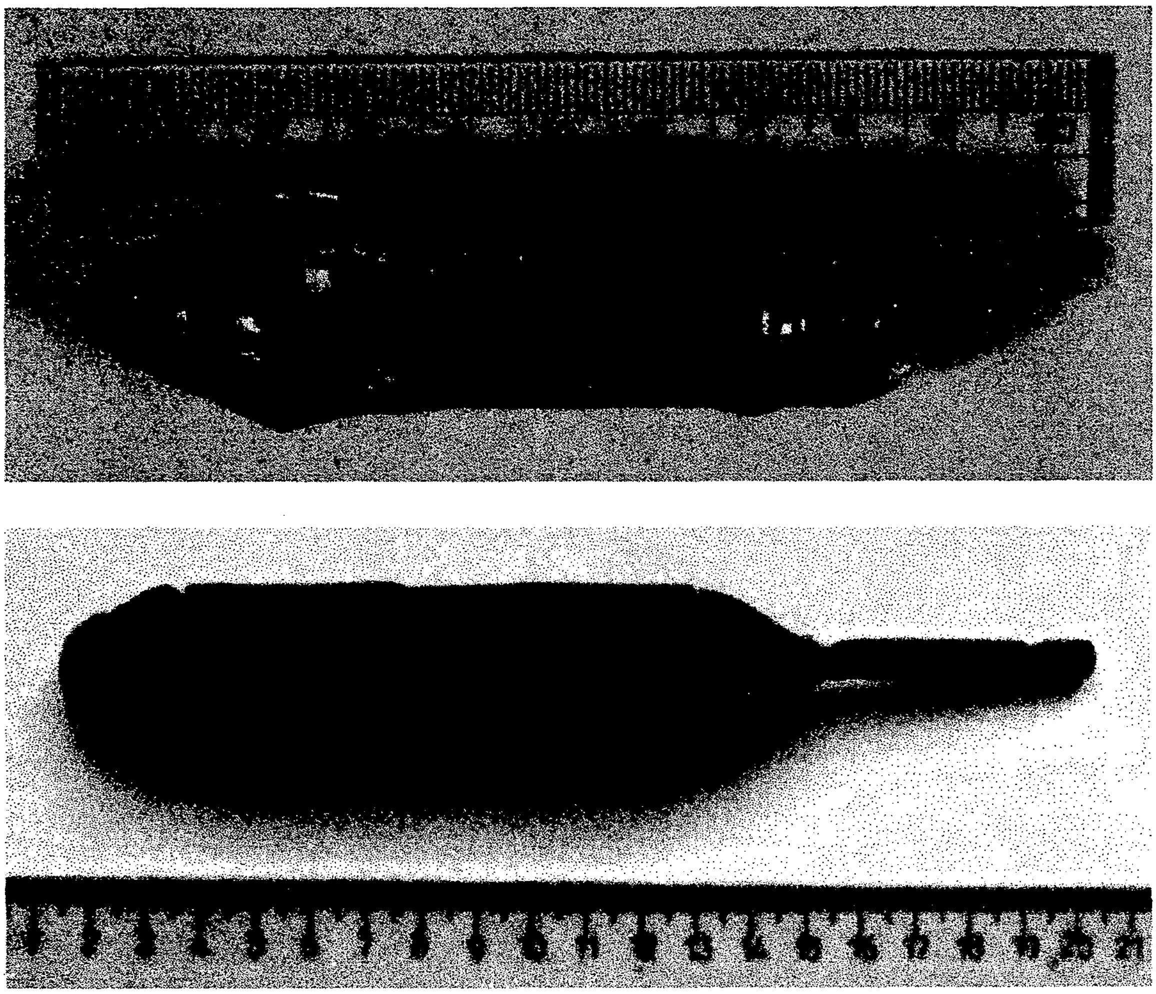

Fig. 1. Examples of grown Er:YAG (upper) and Er,Cr:YSGG (lower) crystals.

diameter and 95 mm in length. It shows dark pink color and high transparency. It appears that suitable concentration of Er ions for Y ions was 50%. Optimum pulling rate and rotation rate for high quality Er:YAG crystal were 1 mm/hr and 20 rpm under the N_2 atmosphere respectively.

Er,Cr:YSGG was sized 30 mm in diameter and 135 mm in length. Er,Cr:YSGG grown under the 98% N_2 and 2% O_2 was dark green and transparent. It appears that suitable concentration of Er ions for Y ions was 33% as active ions and Cr ions for 1.5% for octahedral site as sensitizer ions. Optimum pulling rate and rotation rate for high quality Er,Cr:YSGG crystal were 2-4 mm/hr and 10 rpm respectively. Grown crystals were identified with garnet structure by X-ray diffraction method. Growth direction for both crystals that determined by Laue method from growth normal wafers was analyzed to <111>.

Under the polarizing microscopic observations with crossed polar, striations and {211} core facets were detected. With 10-20 rpm of rotation rates shape of solid-liquid interfaces for two kind of crystals were convex toward the melt.

Spectroscopic properties such as absorption, fluorescence and lifetime were measured and reported. It was measured that lifetimes of Er,Cr:YSGG at 990 nm, 1022 nm and 1550 nm were 1.3, 1.3 and 7.6 msec respectively.

From the grown Er,Cr:YSGG crystal, high quality laser rods, shown in Fig. 2., with <111> axis, 80 mm in length and 6.3 mm in diameter were manufactured and then laser oscillations for medical laser applications of 2.79 μm wavelength was executed. It was measured that lasing threshold was 53 J and slope efficiency was 0.5%.

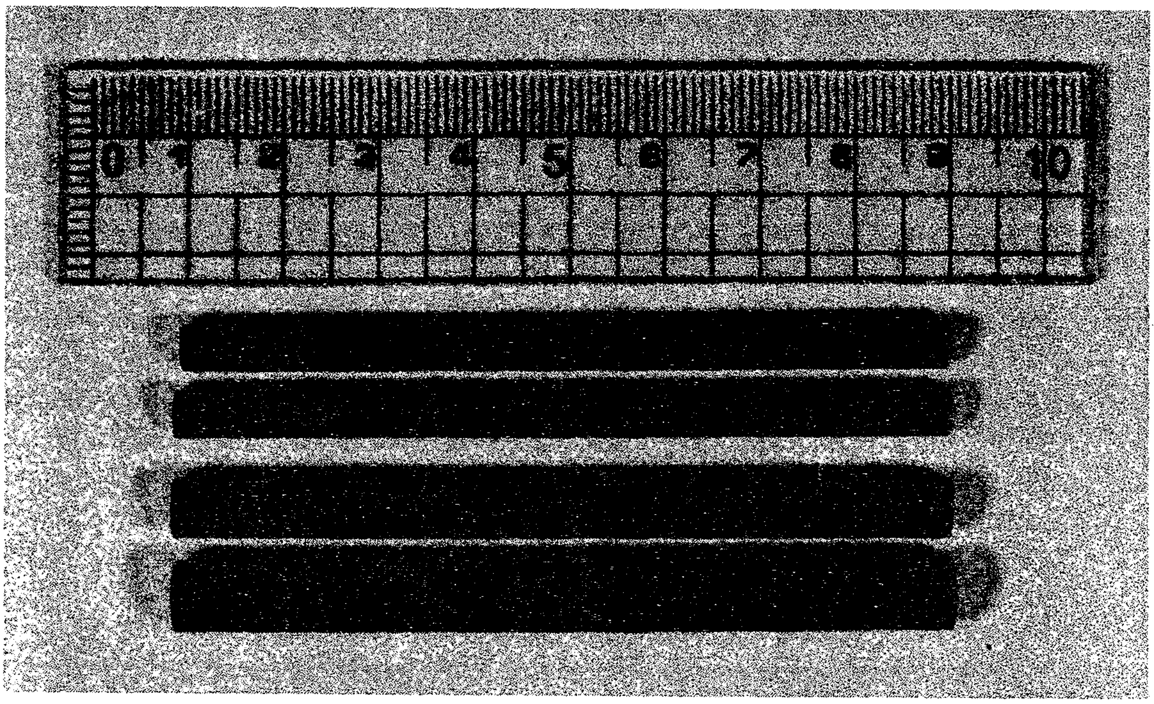

Fig. 2. Laser rods manufactured from grown Er,Cr:YSGG crystal for 2.79 μm laser.

4. Conclusions

We developed the technologies and know-how on growth of Er:YAG and Er,Cr:YSGG crystals by Czochralski method and fabrication of laser rods for 3 μm laser. For the growth of Er:YAG, 1 mm/hr of pulling rate, 20 rpm of rotation rate and 50 atomic% of Er ions were used. For the growth of Er,Cr:YSGG, 2-4 mm/hr of pulling rate, 10 rpm of rotation rate, 33 atomic % of Er ions and 1.5 atomic % of Cr ions were used. Laser rods with the size of 6.3 mm in diameter and 80 mm in length were cut and precisely polished. Spectroscopic properties and laser action with fabricated laser rod from the grown crystals were reported.

References

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