

# Rare earth doping of transparent ceramics for high energy laser applications

Y. Kodera, E. H. Penilla, A.T. Wieg, C. Hardin and J. E. Garay

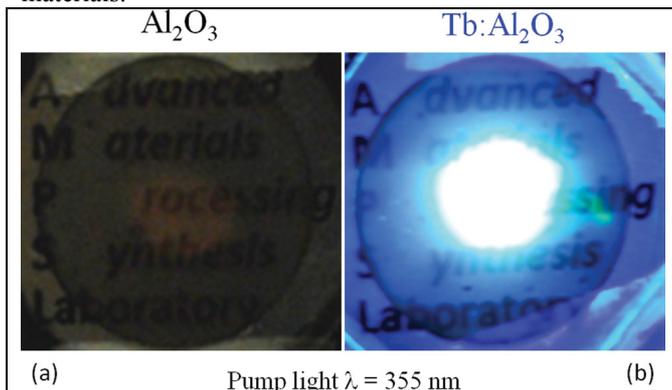
Advanced Materials Processing and Synthesis (AMPS) Laboratory, Department of Mechanical Engineering, Materials Science and Engineering Program University of California Riverside, CA, 92521, USA. E-mail: jegaray@engr.ucr.edu

## 1. Introduction

Thermal management continues to be one of the major challenges in the development of high powered light sources such as solid state lasers. In particular, the relatively low thermal conductivity of standard photoluminescent (PL) materials limits the overall power output and/or duty cycle. We present a method based on current activated pressure assisted densification for the fabrication of high thermal conductivity PL materials: rare earth doped polycrystalline bulk aluminum nitride or aluminum oxide. Specifically, the ceramics are translucent and are doped with Rare earths (RE), allowing for emission in the visible and near IR. Remarkably, the ceramics have a room temperature thermal conductivity of as high as 94 W/(m K) which is almost seven times higher than that of the state of the art host material, Nd-doped yttrium aluminum garnet. These light emitting properties coupled with very high thermal conductivity should enable the development of a wide variety of more powerful light sources.

## 2. Experimental Approach and Results

Here, we present another non-equilibrium method that incorporates relatively large quantities of RE dopants (0.5 at. %) into AlN and Al<sub>2</sub>O<sub>3</sub> ceramics. Our approach is to consolidate AlN or Al<sub>2</sub>O<sub>3</sub> powder along with Tb-containing dopant powders to produce Tb doped aluminum nitride (Tb:AlN) or Tb:Al<sub>2</sub>O<sub>3</sub>. Tb was chosen since the Tb ion is known to fluoresce in the visible in various host materials.



Photographs of CAPAD processed ceramics being excited with 355 nm UV pulsed laser light. The laser light is incident on the back of the samples. The samples were processed using 1200 °C, 105 MPa, 300 °C min<sup>-1</sup> heating rate and 10 min hold time. (a) Undoped alumina. The sample does not photoluminescence causing the picture to be dark. The incident UV light is barely visible near the center of the sample. (b) Tb: Al<sub>2</sub>O<sub>3</sub> alumina. The picture clearly shows blue and green photoluminescence of the ceramic caused by UV (355 nm) excitation.

The current activated pressure assisted densification (CAPAD) method frequently called spark plasma sintering (SPS) was used. This technique has proven effective in densifying a wide variety of hard-to-densify ceramics, including optical ceramics for various applications. We employed much higher heating and cooling rates and shorter overall processing times than are possible with conventional methods. In order to ensure well dispersed rare earth dopants in the AlN, the powders were milled along with the RE dopant using high energy ball milling. The high heating rates promote rapid densification, while short processing times and high cooling rates allow for the retention of high dopant levels. This approach of using reactive CAPAD in conjunction with high energy ball milling is effective for producing bulk RE doped ceramics for light emitting applications. **Fig. 1** shows pictures of undoped Al<sub>2</sub>O<sub>3</sub> and Tb:Al<sub>2</sub>O<sub>3</sub> samples subjected to a 355 nm pulsed laser with a 0.5 cm diameter spot size. The pictures are top-views of the ceramics where the laser light is incident on the back of the ceramic.

## 3. Conclusions

In summary, we have demonstrated the successful incorporation of above equilibrium concentrations of Tb<sup>3+</sup> dopant in polycrystalline bulk alumina and aluminum nitride for the first time. The Tb doped ceramics show two sharp visible photoluminescent peaks, a blue one centered at 485 nm and a green one at 543 nm. The ceramics have higher thermal conductivity than state of the art lasing media and thus have potential to be used for high energy gain media.

## 4. Open Questions

- How can the optical quality of the ceramics be improved?
- Will the ceramics lase and how efficient will they be?
- Is it possible to introduce other dopants?

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## References

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