EFFECT OF ULTRASONIC TREATMENT ON THE LUMINESCENT PROPERTIES OF CONVENTIONALLY SINTERED YAG: CE^{3+} CERAMICS

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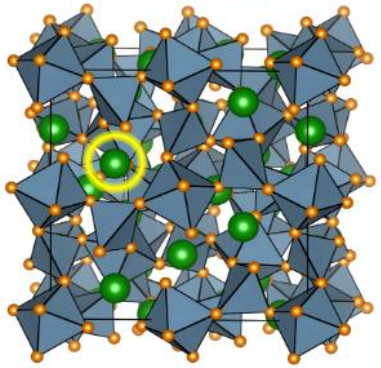
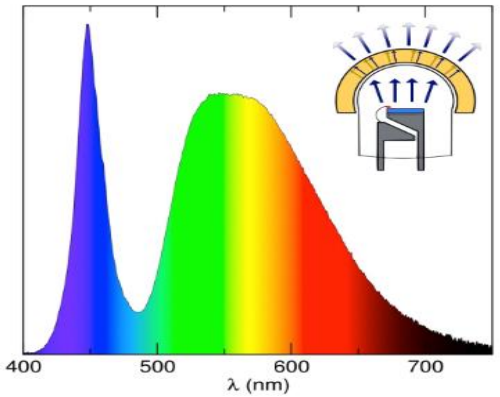
Motivation

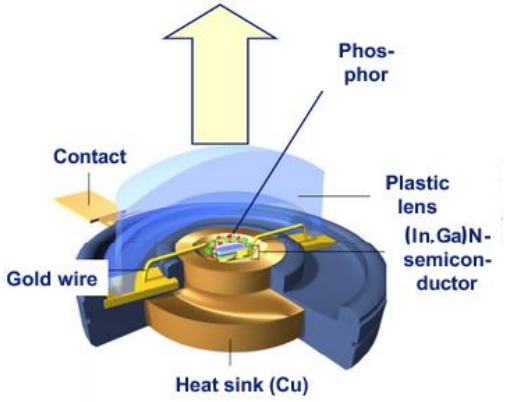
YAG:Ce^{3+}

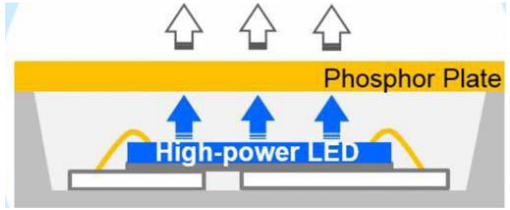
Garnet structure of YAG:Ce^{3+}

$(Y_{2.97}Ce_{0.03})Al_5O_{12}$









Automotive lighting

Laser crystals

YAG:Ce

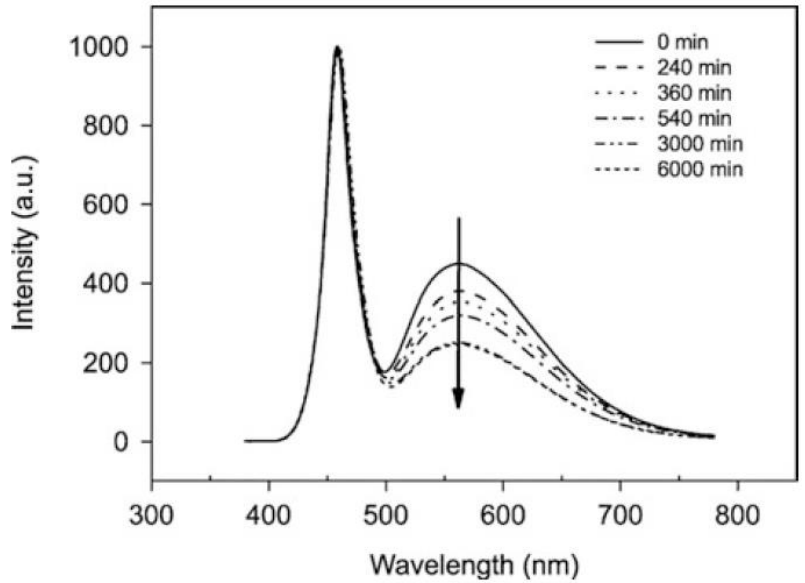
Displays

LEDs

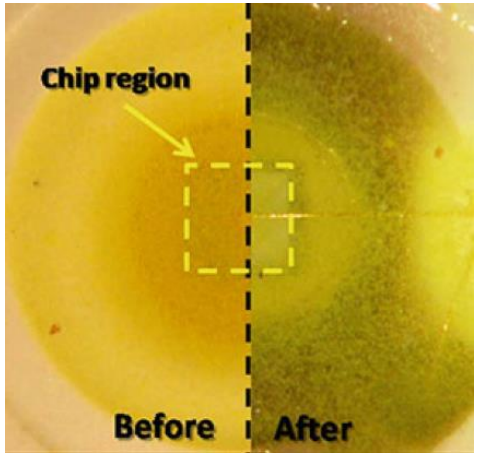
Scintillators

Z. Xia et al. *Chem. Soc. Rev.*, 46, (2017), 275 - 299
George et al. *Annu. Rev. Mater. Sci*, 43, (2013), 2.1-2.21

Scientific problem



EL spectra measured during stress at 200◦C on one of the analyzed white LEDs



Micrograph of the emissive region of one of the analyzed samples, taken before and after stress

Disadvantages of inorganic phosphors placed in a silicon compound:

- poor thermal stability of phosphors;
- low conversion efficiency of LED radiation;
- degradation of the luminescent characteristics of the compound over time

The advantages of ceramics:

- high mechanical strength;
- compactness;
- high thermal stability (from space cold to plasma temperatures in rocket engine nozzles);
- the ability to implement any form;
- ability to withstand high fluxes of ionizing radiation.

J. Qiao et al. Journal of Rare Earths Volume 37 Issue 6 (2019) 565-572
Matteo Meneghini et al. IEEE TRANSACTIONS ON DEVICE AND MATERIALS RELIABILITY, VOL. 8, NO. 2, (2008).

Research goals and objectives

Goal: synthesis and complex spectroscopic study of the luminescent ceramics characteristics based on pre-synthesized garnet phosphors using ultrasound assistance and different temperature modes

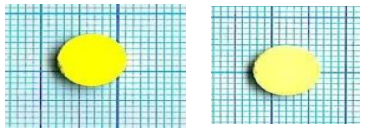
Objectives:

1. Synthesis of YAG ceramics doped with Ce^{3+} by uniaxial pressing with subsequent air atmosphere sintering using ultrasound assistance and different temperature modes;
2. Phase and structural studies, microscopic properties of YAG: Ce ceramics;
3. Complex fundamental spectroscopic investigations of YAG: Ce ceramics;
4. Estimation of luminous efficiency of degradation characteristics of sintering YAG ceramics;
5. Development of light source module based on sintering YAG: Ce ceramics.

YAG:REE ceramics preparation process

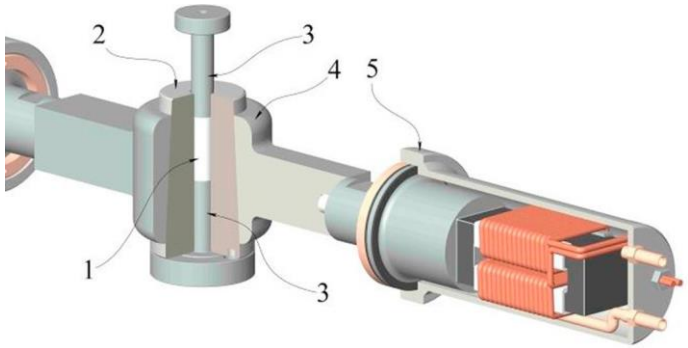
Automatic press «IP-500»

Uniaxial pressing method followed by sintering



h – 1.1 mm
D – 8 mm

YAG:REE ceramic samples



Ultrasound-assisted pressing device:
1 –powder sample; 2 –die; 3 –punches; 4 – waveguide; 5 –magnetostrictive transducer.

Experimental techniques

SEM JSM-7500FA + EDS (JEOL)

X-ray diffractometer XRD-7000 (Shimadzu)

Spectrofluorimeter CaryEclipse

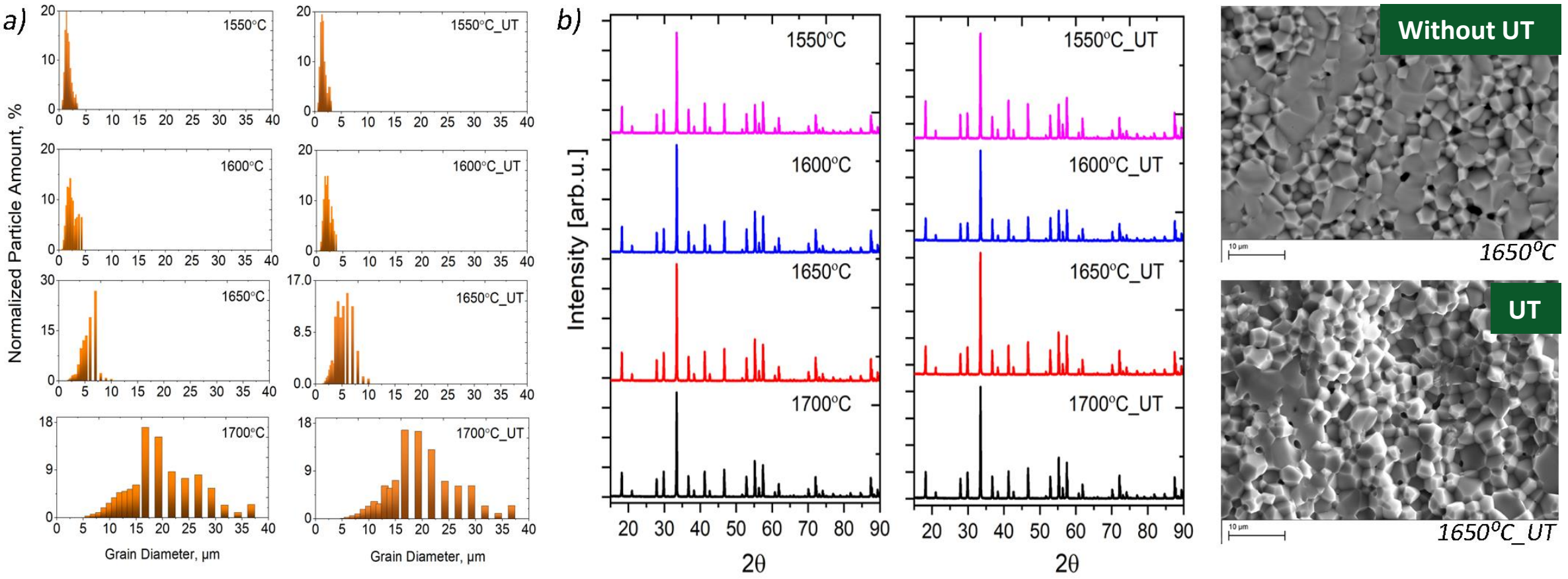
Spectrophotometers UV-1800 (Shimadzu); SF-256BIK (LOMO)

- molding on an automatic press «IP-500 AVTO» («ZIPO», Russia).

- mechanical processing with a grinding and polishing system EcoMet 300 Pro (Buehler, Germany) using diamond suspensions MetaDi (Buehler, Germany).

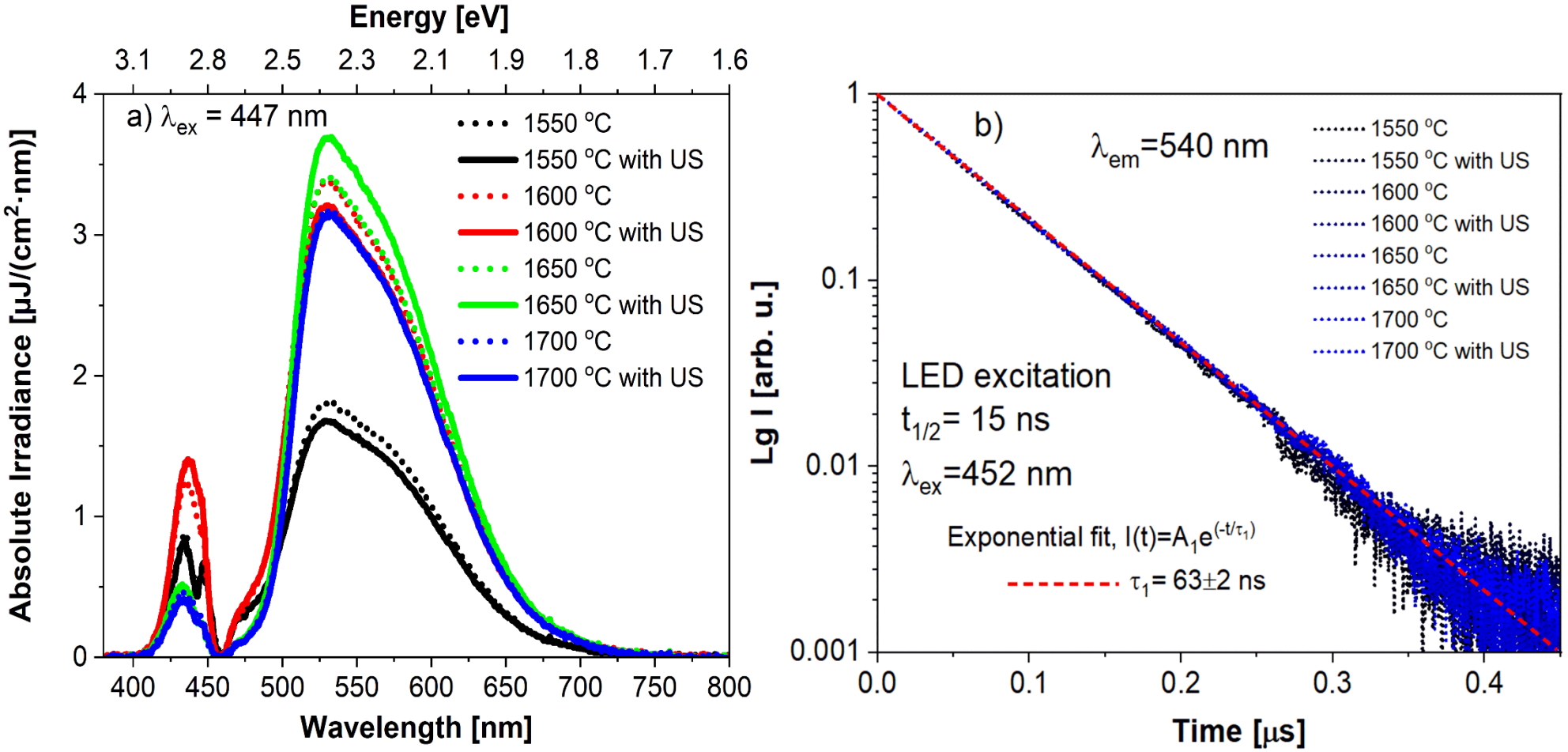
*The study was carried out using the equipment of the Scientific and Research Center "Nanomaterials and Nanotechnologies" TPU. "(**Center Head Prof. Khasanov O. L.**)*

Results



Grain diameter distributions for YAG:Ce ceramics with different annealing temperature and UT.
XRD patterns of YAG: Ce ceramics with and without UT different annealing temperature.
SEM microstructure of YAG: Ce ceramics prepares with and without UT for 1650°C annealing temperature

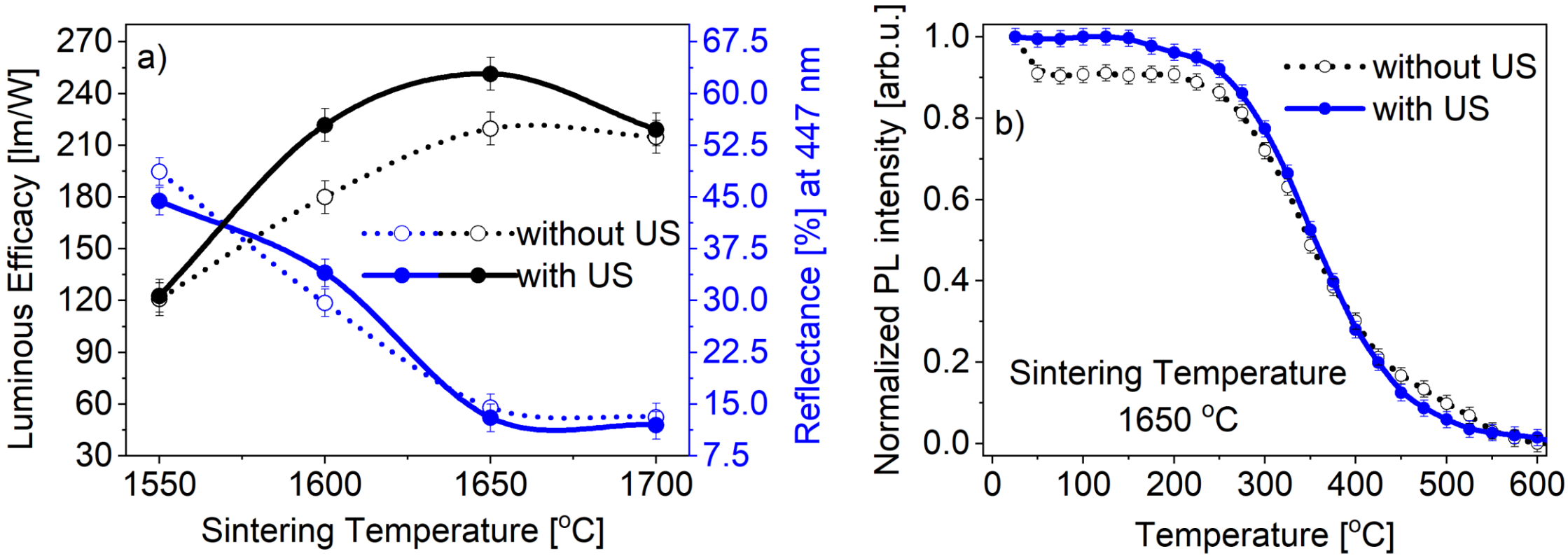
Results



PL spectra **(a)** of YAG: Ce ceramics excited by blue LED chip (λ_{ex}=447 nm).

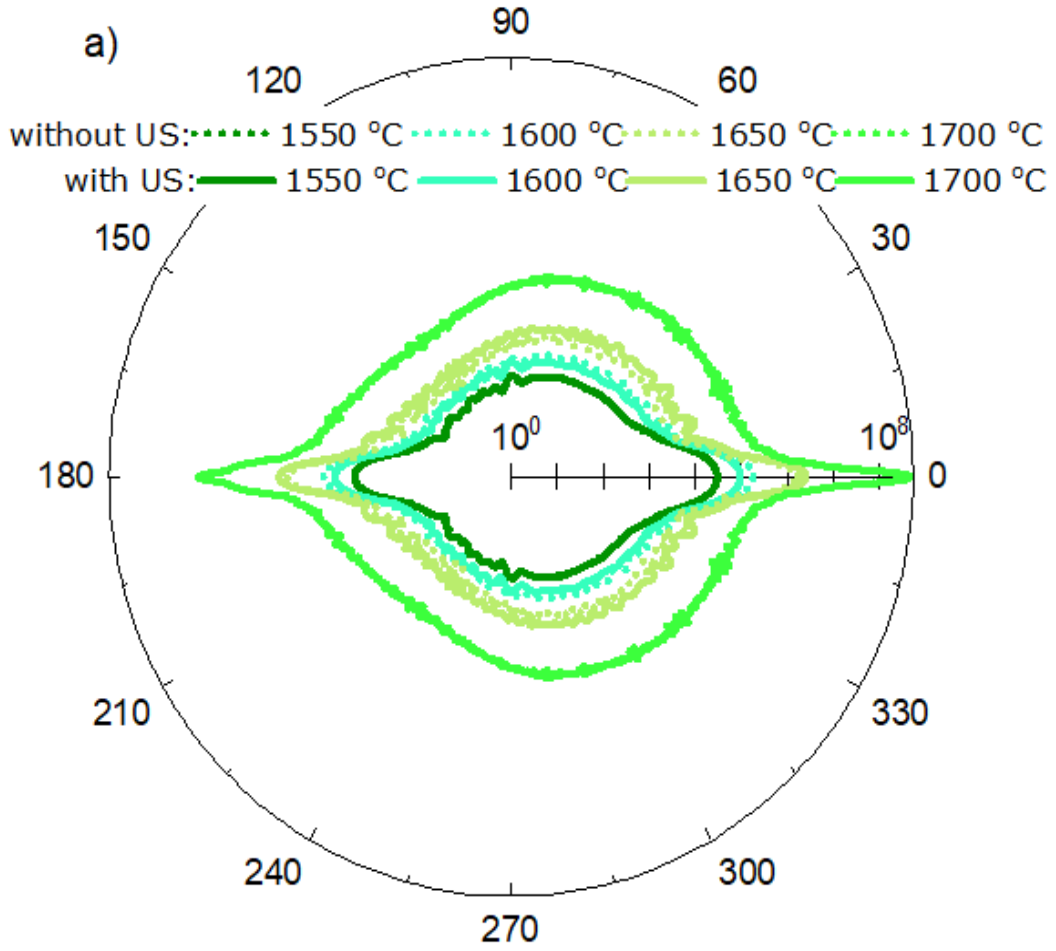
Luminescence decay kinetics **(b)** for YAG: Ce ceramics excited by blue LED chip (λ_{ex}=452 nm).

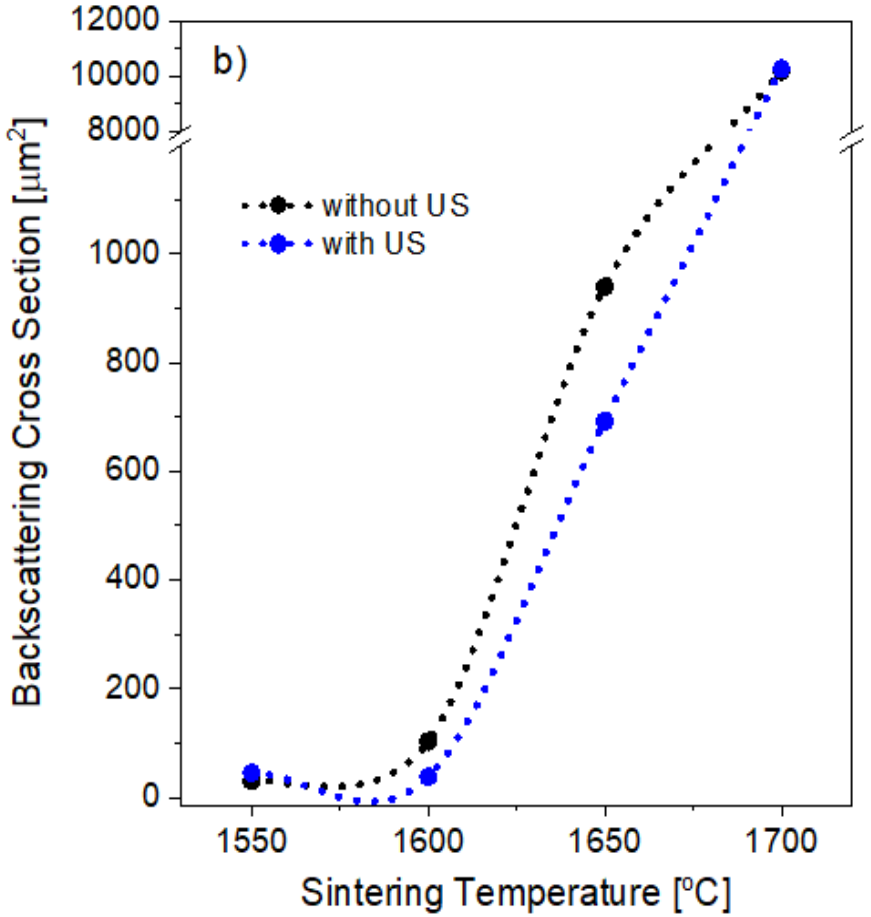
Results



The dependences of the reflection coefficient and energy efficiency on the sintering treatment for YAG: Ce ceramics. The PL intensity for YAG:Ce ceramics at maximum luminescence with and without UT as function of temperature.

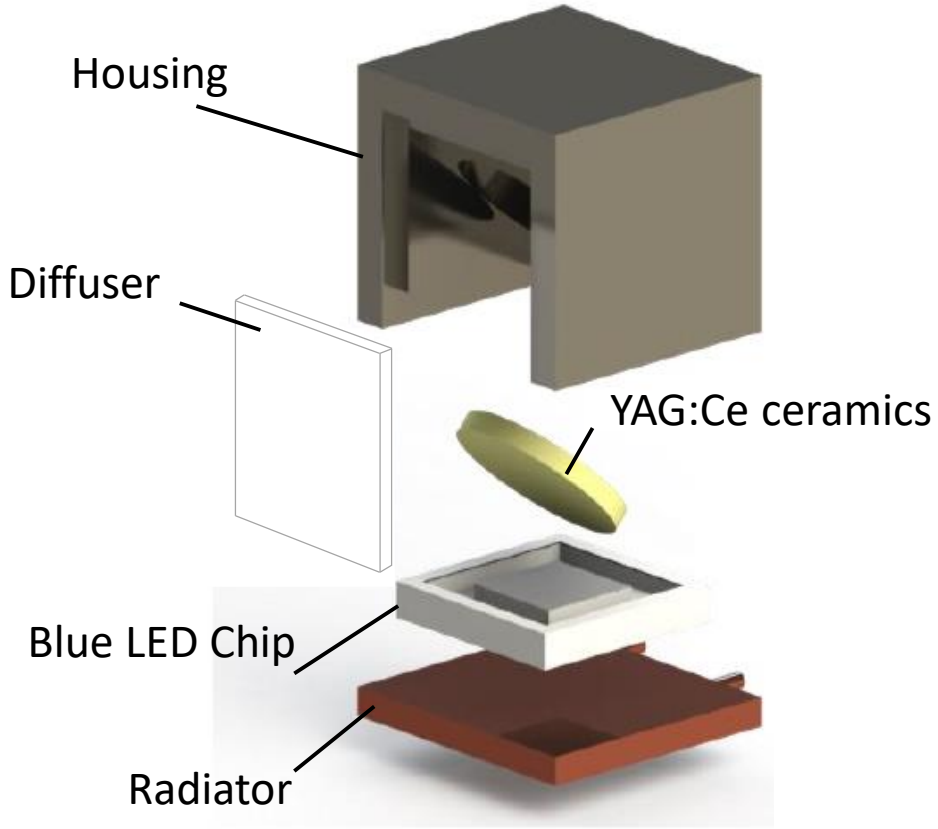
Results



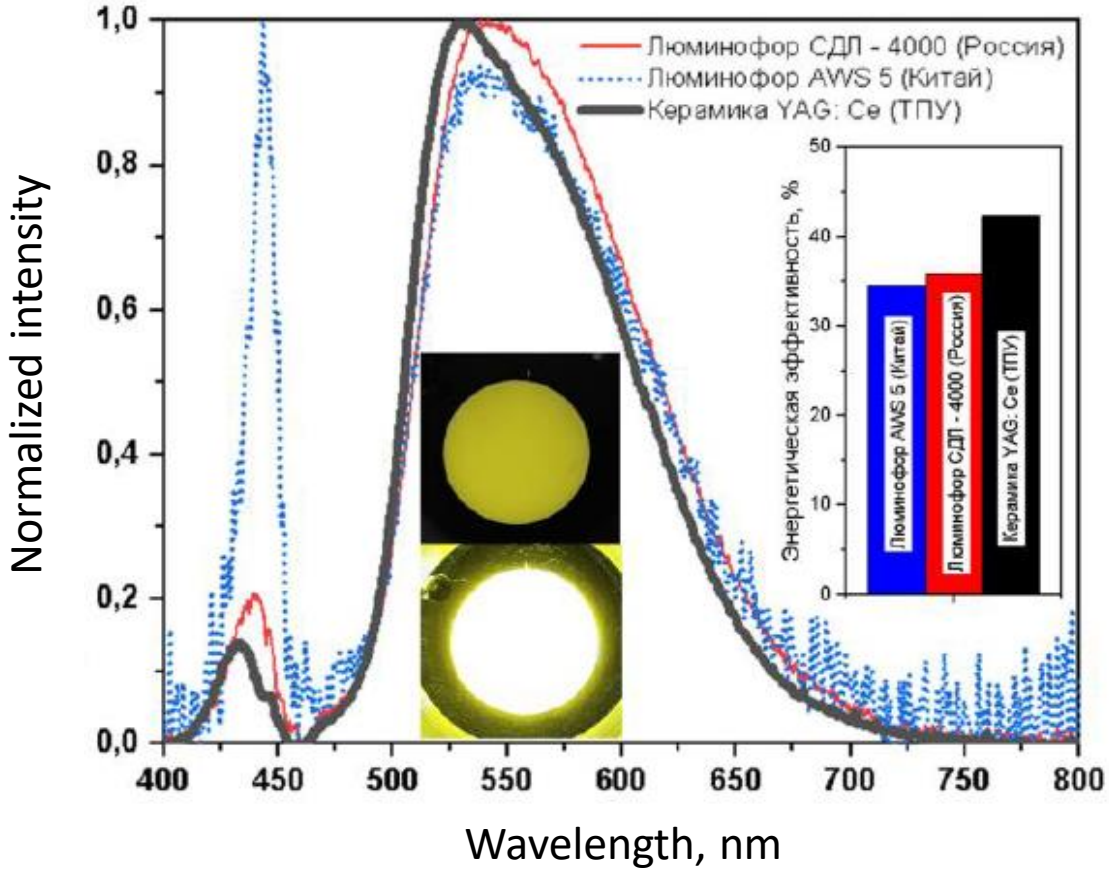


Calculating values of the backscattering cross section and scattering pattern using Mie theory

White emitter design layout



Layout of white light emitter based on YAG:Ce ceramics



Comparison of the spectral characteristics of the YAG sintered ceramics with commercial phosphors

Summary

- Luminescent ceramics based on yttrium aluminum garnet were obtained by uniaxial pressing using ultrasound assistance and different temperature modes;
- A comprehensive characterization of the microstructure, phase composition of consolidated YAG:Ce ceramics was carried out;
- The degradation characteristics of ceramics have been studied: in the range of 0 - 150 °C, the change in radiation intensity is insignificant, at temperatures of 150 - 500 °C, a sharp decrease in intensity is observed.
- Developed prototypes of luminescent ceramics with a relative density of 99.78% with an energy conversion efficiency of up to 42%, which exceeds commercial analogs based on inorganic phosphors placed in a silicon compound (for comparison, common industrial phosphors with a similar luminescence spectrum SDL-4000 have an energy efficiency of less than 39%)
- A layout of the design of a ceramic emitter of white light based on luminescent ceramics has been developed.

Acknowledgments

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