Preparation and characterization of up-conversion materials with garnet structure in Al_2O_3-Y_2O_3-Yb_2O_3-Er_2O_3 system

J. Michalík[1], J. Valúchová[2], R. Klement[3], A. Prnová[2,3], D. Galusek[2,3]

[1]Faculty of Chemistry and Food Technology, Slovak University of Technology,
Radlinského 9, 812 37 Bratislava, Slovakia
(E-mail: jakub.michalik@tnuni.sk)
[2]Vitrum Laugaricio-Joint Glass Center of the IIC SAS, TnUD and FCHTP STU,
Študentská 2, Trenčín, Slovakia
[3]Centre for functional and surface functionalized glass, Alexander Dubček University of Trenčín,
Študentská 2, Trenčín, Slovakia

Recently, yttrium aluminum (YA) glasses have been extensively investigated, primarily for their potential as equivalent substitutes for commercially utilized yttrium aluminum garnet (YAG) materials in various optical applications. These materials, similarly to YAG doped with Er^{3+} ions, exhibit up-conversion emission in the green and red spectral regions, rendering them suitable for applications in semiconductor lasers, lamps, and optical fibers [1]. The optical properties of Er^{3+}-doped YA glasses can be enhanced by co-doping with Yb^{3+} ions, which serve as sensitizers [2]. Compared to crystalline aluminates, YA glasses demonstrate superior capacity for incorporating rare earth ions, higher infrared transparency, and excellent chemical and thermal stability. However, their high melting point and pronounced tendency to crystallize pose challenges for manufacturing. A more practical approach involves the preparation of glass microspheres via flame synthesis, followed by hot-press sintering to produce larger glass, glass-ceramic, or ceramic components [1].
In this study, six samples with YAG composition, substituted with 20, 25, and 30 mol.% Y_2O_3 for Yb_2O_3 and doped with 0.25 and 0.1 mol.% Er_2O_3, were fabricated into microspheres using a combination of the sol-gel Pechini method and flame synthesis. X-ray diffraction analysis confirmed the predominantly amorphous nature of the prepared systems, with amorphous phase contents ranging from 75 to 99 wt.%. Scanning electron microscopy (SEM) revealed that the majority of the microspheres exhibited spherical morphology. Differential scanning calorimetry (DSC) curves of all systems displayed one or two exothermic peaks in the temperature range of 918–939 °C, depending on the composition. These peaks correspond to the crystallization of YAM, YAP, and YAG phases within the samples. Photoluminescence (PL) spectra of the microspheres, measured at 378 nm excitation, exhibited characteristic Er^{3+} ion emissions in the green (520–570 nm) and red (650–700 nm) spectral regions, with the green emission being predominant. At 980 nm excitation, strong red emission was observed across all samples, with the highest intensities recorded in the samples with the greatest crystalline phase content (Yb20Er0.25 and Yb25Er0.10). These effects may be attributed to variations in the distribution of Yb^{3+} and Er^{3+} ions within the crystalline and amorphous matrices, as well as differences in the phonon energies of these matrices. Crystallized samples emitted radiation in the same spectral ranges but with reduced intensities. Calculated chromaticity parameters indicated emission in the yellow region for microspheres containing 30 mol.% Yb_2O_3, and blue and violet emissions for samples Yb20Er0.25 and Yb25Er0.10. These findings suggest that luminescence properties of the microspheres can be tailored by controlling crystallization. The results highlight the potential of these materials as promising candidates for the development of lasers and optical devices.

This research was created thanks to the financial support of the FunGlass project (Horizon 2020, grant no. 739566) and projects VEGA 2/0028/21, VEGA 2/0141/21, VEGA 2/0077/24 and APVV-23-0424

[1] A. Prnová, J. Valúchová, N. Mutlu, M. Parchovianský, R. Klement, A. Plško, D. Galusek 2020 *J. Therm. Anal. Calori.* **142** 129-138.
[2] A. Prnová, K. Bodišová, R. Klement, M. Migát, P. Veteška, M. Škrátek, E. Bruneel, I. V. Driessche, D. Galusek 2014 *Ceram. Int*. **40** 6179-6184.