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Zinc Oxide Optical Ceramic Codoped with Er³⁺ and Yb³⁺ Ions

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Zinc oxide (ZnO) is a well-known wide-bandgap semiconductor possessing a hexagonal wurtzite-type structure. In the past years, ZnO nanostructures of various shapes attracted a lot of attention for applications in UV emitters, scintillators, phosphors, *etc.* [1]. The absorption and emission properties of ZnO-based materials are related to defect states and can be further adjusted by doping with rare-earth ions RE³⁺ due to efficient ZnO ↔ RE³⁺ energy transfer. In the present work, we report on the fabrication, microstructure and spectroscopic properties of ZnO optical ceramics containing erbium (Er³⁺) and ytterbium (Yb³⁺) ions.

ZnO optical ceramic codoped with 0.6 wt% Er and 0.8 wt% Yb was prepared by uniaxial hot pressing of ZnO, Er₂O₃ and Yb₂O₃ commercial powders at 1180 °C in vacuum [2]. The ceramic disk (Φ25 mm, thickness: 0.5 mm) had grey coloration, Fig. 1(a). The structure of ceramics (hexagonal, sp. gr. *P6₃mc*, unit-cell parameters: *a* = 3.251 Å, *c* = 5.202 Å) was confirmed by XRD, Fig. 1(b). The XRD pattern also revealed the crystallization of Er₂O₃ and Yb₂O₃ phases with a cubic bixbyite-type structure (sp. gr. *Ia3⁻*, *a* = 10.545 Å and 10.441 Å, respectively), inset in Fig. 2(a). The average size of RE₂O₃ crystals was about 75 nm. According to the EDX analysis, Fig. 2(c-e), apart from the stoichiometric RE₂O₃ phases, the Er³⁺ and Yb³⁺ ions are also localized on the surfaces of ZnO grains.

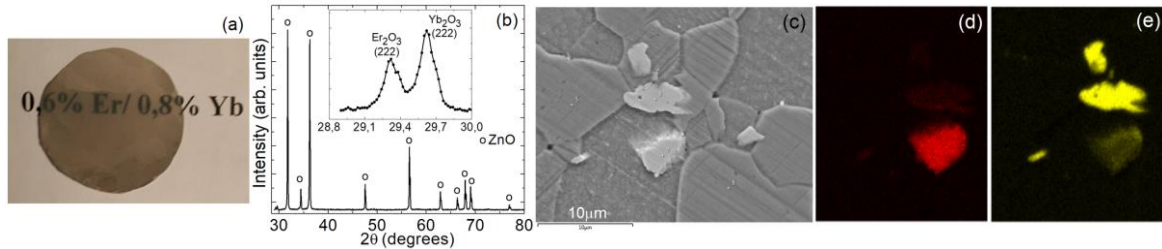


Fig. 1 Er,Yb:ZnO optical ceramic: (a) photograph of the polished ceramic disk; (b) XRD pattern, *inset* – a close look on the main diffraction peaks of Er₂O₃ and Yb₂O₃; (c) SEM image of the polished and etched surface of the ceramic; (d,e) EDX element mapping of (d) Er (Mα) and (e) Yb (Mα).

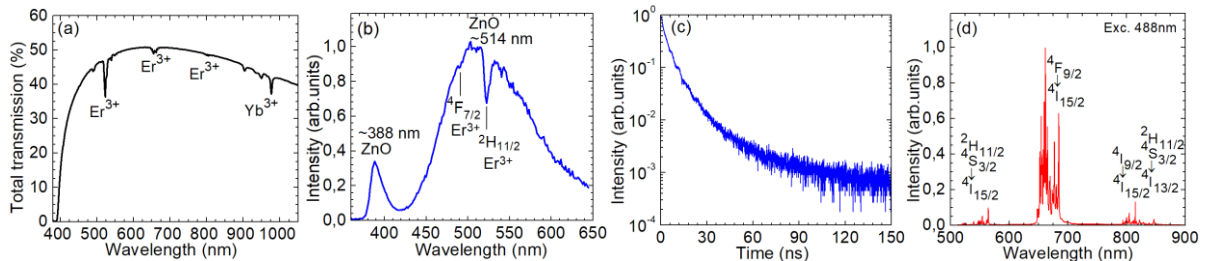


Fig. 2 Spectroscopy of Er,Yb:ZnO optical ceramic: (a) total transmission spectrum (thickness: 0.5 mm); (b) X-ray luminescence spectrum, *vertical lines*: deeps due to the Er³⁺ absorption; (c) decay curve of X-ray luminescence; (d) photoluminescence spectrum, $\lambda_{exc} = 488$ nm.

The maximum total transmittance of the ceramic disk is 50.9% at ~0.6 μm, Fig. 2(a). The absorption bands are due to Er³⁺ and Yb³⁺ ions in the corresponding RE₂O₃ phases. The X-ray luminescence spectrum, Fig. 2(b), has two intense emission bands both being characteristic of ZnO. The band at ~388 nm is due to the near-band-edge (NBE) transitions. The second broad band centered at ~514 nm represents the defect emissions. The spectral “holes” coincide with the absorption of Er³⁺ ions. The average X-ray luminescence decay time in the “fast” time domain of 0–50 ns is 6–8 ns, Fig. 2(c). Note that it is about 65 ns for undoped ZnO ceramic [2], indicating the ZnO → RE³⁺ energy transfer. Under optical excitation at 488 nm, the photoluminescence spectrum contains emission bands assigned to Er³⁺ ions in RE₂O₃ crystals, Fig. 2(d). The work on determining the most promising Er³⁺/Yb³⁺ codoping ratio is in progress. The developed Er³⁺,Yb³⁺-codoped ZnO optical ceramic demonstrates high radiation stability. It is promising for optoelectronic applications.

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