Abstract

This Ph.D. thesis focuses on investigating the structural, luminescence, photoconversion, and elastic properties of garnet-based epitaxial structures for application as phosphor converters (**pc**) in white light-emitting diodes (WLEDs). The aim of the research is to better understand the behavior of garnet-based materials as efficient and reliable **pc** in WLEDs and contribute to their optimization for lighting applications. The liquid phase epitaxy (LPE) method was used for the growth of film and composite color converters based on the epitaxial structures of garnet compounds. The single crystalline films (SCF) of Ce^{3+} doped $Lu_3Al_5O_{12}$ (LuAG:Ce), $Tb_3Al_5O_{12}$ (TbAG:Ce), and $Tb_{1.5}Gd_{1.5}Al_5O_{12}$ (TbGdAG:Ce) garnets were grown onto undoped $Y_3Al_5O_{12}$ (YAG) and Ce^{3+} doped $Y_3Al_5O_{12}$ (YAG:Ce) substrates using LPE technique. The thesis also includes a comprehensive structural investigation of the films and composite converters using optical microscopy, scanning transmission electron microscopy (STEM), and X-ray diffraction (XRD) analyses. These characterization techniques provide valuable insights into the crystal structure, morphology, and interface properties of the garnet-based epitaxial structures.

Within the theoretical and numerical research, a microscopic layered model is developed to describe the propagation of ultrasonic waves in the epitaxial structures. This modeling approach aims to identify the elastic properties of the garnet-based films and substrates. Experimental investigations using ultrasonic microscopy are conducted on LuAG:Ce SCF/YAG:Ce substrate epitaxial structures for the frequencies ranged from 35 to 200 MHz. To identify the mechanical (i.e., elastic) properties of the investigated films and substrates, the results acquired withn ultrasonic studies are further analyzed using an optimization-based algorithm, which utilizes the microscopic model of wave propagation and numerical analysis.

The optical properties of the film and composite converters under study are examined through measurements of absorption, cathodo- and photoluminescence spectra. This analysis helps assess their spectral characteristics. The investigation of photoconversion properties is an essential aspect of the research. Measurements of color coordinates (CC), color temperature (CCT), color rendering index (CRI), and luminous efficacy (LE) are performed both for the film and composite converters. These properties play a crucial role in determining the color quality, temperature, and efficiency of the emitted light, thereby contributing to the optimization of garnet-based phosphor converters for WLED applications.

Finally, the prototype of WLED photoconverters were created based on the SCFs of Ce^{3+} doped $Lu_3Al_5O_{12}$, $Tb_3Al_5O_{12}$, and $Tb_{1.5}Gd_{1.5}Al_5O_{12}$ garnets with different thickness, grown onto YAG substrates. Furthermore, the composite color converters based on the TbAG:Ce and $Tb_{1.5}Gd_{1.5}$AG:Ce SCF films with different thicknesses and Ce^{3+} doped YAG substrates with various Ce concentrations and thicknesses, were developed. The photoconversion properties of developed film and composite converters were studied and the best compositions were selected.