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Wide band-gap semiconductor materials with low defect density for future high-power nanophotonics and electronics

Wide band-gap (WBG) semiconductor material scientific and technological research has greatly intensified over the last decade due to their tremendous potential for electricity savings offered by WBG semiconductor materials and devices for solid state lighting (SSL) and power electronics (PE) for grid-scale applications. Replacement of today's light sources with nitride-based SSL offers 10-15% electrical energy savings potential, however, requiring breakthroughs in materials, devices and lighting systems. Similarly, grid-scale implementation of WBG PE offers 10% electrical energy savings through the reduction in power conversion losses in the grid, requiring development of the science and technology of WBG PE devices. To address this opportunity, our group focused mainly on two WBG materials systems: III-nitrides and β -Ga₂O₃. One of the major problems during WBG material and device development is high defect density typically observed in WBG materials. Nano-photonics and electronic devices fabricated from high dislocation density layers demonstrate poorer performance than those made from relatively defect-free layers. Light emitting diode (LED)-based SSL is usually realized by combining blue III-nitride LED light with yellow and red light from down-converting phosphors. The typical LED efficiency is on the order of 100–140 lm/W at low currents, and it falls with injected current density due to the droop phenomenon. To assess possible progress, it suffices to know that the efficiency limit for LED is about 300lm/W. One of the main reasons for efficiency droop is an extremely high density of threading dislocations (TDs). High density of TDs results from the initial inevitable step of epitaxial growth of GaN layer on foreign substrates possessing high lattice mismatch, e.g., sapphire or silicon carbide substrates. We develop a general methodology for the reduction of TD density in III-nitride layers fabricated in (0001) polar growth orientation. We present the results on theoretical and experimental studies of threading dislocations (TDs) behavior in III-nitride layers grown in polar orientation. TDs are defects formed during epitaxial growth of layered electronic and optoelectronic materials. In PE, the full potential of WBG materials can only be realized by using single crystal substrates. Although some commercial devices have been demonstrated, the optimum material/device structure for the MW power applications has not yet been defined. β -Ga₂O₃ due to its reasonable carrier mobility and extraordinary high dielectric breakdown strength, offers clear advantages compared both to Si-based devices and other WBG materials. β -Ga₂O₃ is the only stable polymorph of gallium oxide through the whole temperature range till the melting point. We report flat-surface β -Ga₂O₃ single crystals produced by free crystallization of Ga₂O₃ melt.

Biography

Vladislav E Bougrov is the Director of School of Photonics and Head of Chair of Light Technologies and Optoelectronics at the ITMO University, St. Petersburg, Russia. He has obtained his Master's degree in Optoelectronics from Department of Optoelectronics, PhD in 1999 and DSc in Physics in 2013 from Ioffe Institute, St. Petersburg, Russia. He is the author of more than 60 papers in reputed journals, inventor of more than 100 patent applications, including more than 30 granted patents and has extensive experience with dynamic management of growing international start-up companies. He is the founder of Optogan.

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