Award Abstract #1652871

CAREER: Cubic Phase Green Light Emitting Diodes for Advanced Solid State Lighting

NSF Org:	ECCS Div Of Electrical, Commun & Cyber Sys
Initial Amendment Date:	December 15, 2016
Latest Amendment Date:	December 15, 2016
Award Number:	1652871
Award Instrument:	Standard Grant
Program Manager:	Mahmoud Fallahi ECCS Div Of Electrical, Commun & Cyber Sys ENG Directorate For Engineering
Start Date:	February 1, 2017
End Date:	January 31, 2022 (Estimated)
Awarded Amount to Date:	$500,000.00
Investigator(s):	Can Bayram cbayram@illinois.edu (Principal Investigator)
Sponsor:	University of Illinois at Urbana-Champaign SUITE A CHAMPAIGN, IL 61820-7473 (217)333-2187
NSF Program(s):	ELECT, PHOTONICS, & MAG DEVICE
Program Reference Code(s):	091E, 1045
Program Element Code(s):	1517

ABSTRACT

Abstract Title: Investigation of Cubic Phase Green Light Emitting Diodes for Advanced Solid State Lighting

Non-Technical Description:

The research objective of this proposal is to explore the fundamental properties of cubic phase light emitting diodes that will provide the critical knowledge required to close the "green gap" in the visible spectrum paving the way towards advanced solid state lighting and bridging efficient lighting, reliable connectivity, and fast networking via color mixing approach. The proposed research is expected to have significant societal and technological impact. This research will establish a new paradigm in creating green light emitting diodes by exploiting the hexagonal-to-cubic phase transition and an inexpensive, scalable silicon platform. The resulting cubic phase GaN framework will have many ramifications that may impact other micro-/nano- electro-photonic systems in energy, communication, and healthcare. The proposal plans to combine technical and educational platforms, including K-12 Science, Technology, Engineering and Math education efforts, for increasing the economic competitiveness of the United States. The principal investigator will develop a theme-based interactive outreach program, "Solid State Lighting", and will pilot curriculum materials at local middle schools with high (>

50%) minority enrollment. Another key component will be the creation of a portable exhibit to enlighten K-12 students and the general public about light and photonics. All of these materials will also be made available online for broad distribution. Additionally, modules incorporating the findings of the proposed research will be included in undergraduate and graduate courses (~80 students annually). Furthermore, the principal investigator will continue to host one K-12 teacher and one woman or underrepresented minority student in the research group every summer.

Technical Description:

To date, InGaN-based green light emitting diode research has been restricted to naturally-occurring hexagonal phase devices that are limited in power, efficiency, speed, and bandwidth. This problem fueled the research for the development of cubic phase GaN. Cubic phase green light emitting diodes reduce the necessary indium content by ~10% because of a 0.2 eV lower bandgap. Also, they can quadruple radiative recombination dynamics by virtue of their zero polarization. The intellectual merit of this proposal stems from the analysis of GaN devices integrated on nano-patterned Complementary Metal-Oxide Semiconductor-compatible silicon that will shed light on the properties of cubic phase green light emitting diodes and provide transformational, new knowledge in their heterointegration. Specifically, the structural mechanisms governing cubic phase material formation will be studied through a series of experimental characterization techniques aimed at identifying critical substrate-nano-pattern designs maximizing the cubic phase content. Concurrently, the radiative recombination dynamics of these (In)GaN photonic structures will be investigated and their structure-recombination relations correlated. These findings will be quantitatively evaluated in terms of defectivity (± 108 cm-2), phase content (± 0.1%), stress (± 0.01%), alloy content (± 0.01%), crystallographic alignment, bandgap and emission energy (± 1 meV), vibrational energy (± 2 cm-1), recombination dynamics (± 1 ps), and spatial uniformity (< 1.5 nm). The results will also be exploited to improve the radiative recombination dynamics of green light emitting diodes to revolutionize GaN-based photonic device design strategies. The proposed research will be carried out on Complementary Metal-Oxide Semiconductor-compatible silicon substrates to facilitate scalability, industrial adoption, and generate new knowledge on GaN-Silicon heterointegration. The knowledge acquired will help develop new photonic device designs and facilitate a fuller understanding of advanced solid state lighting.