【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project : Development of semiconductors intra-center photonics

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Research Project Number : 18H05212 Researcher Number : 10181421
Keyword : Semiconductor, Thin films, Optical properties of condensed matter, Optical devices

【Purpose and Background of the Research】

Our surroundings are full of various light sources, which are produced from semiconductors. These lights use transitions that occur between the conduction band and the valence band of the semiconductor, which is referred to as interband photonics. However, this application has critical problems, which lie at the heart of the light emission principle known as Fermi's Golden Rule.

We have worked on the development of semiconductors intra-center photonics. This novel photonics uses the intra-4*f* shell transitions of rare-earth (RE) ions doped in semiconductors. In 2009, we invented a narrow-band red light-emitting diode (LED) using Eu-doped GaN (GaN:Eu). Due to optimization of the device processing, the output power of the LED has been increasing steadily to over 1 mW.

In this project, we move to the next and final step for the development of the GaN:Eu red LED (Fig. 1). We will further enhance the output parameters by intentional manipulation of the radiative recombination probability at the atomic level of the Eu ions, which will be achieved through control of their photon fields using micro- and nano-cavities. Subsequently, we will extend this approach to other RE ions for the realization of a RE-based full-color high-resolution display with exceptional characteristics.

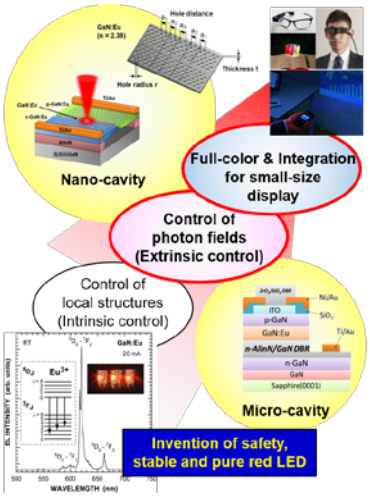

Fig. 1 Contents and flow of this research project

【Research Methods】

(1) Fabrication of micro- and nano-cavities using GaN:Eu, and the characterization of newly emerging Eu intra-4*f* shell luminescence properties under optical pumping in a cavity that has a sufficiently high Q factor.
(2) Fabrication of a LED structure using GaN:Eu with the cavities. The unique luminescence properties will be investigated under current injection.
(3) Extension of the research to Tm- or Er-doped nitride semiconductors to realize a new family of LEDs that operate in the blue and green emission range. Finally, these red, green and blue LEDs will be integrated on the same substrate to demonstrate the feasibility of a monolithic full-color LED display.

【Expected Research Achievements and Scientific Significance】

Research on RE-doped materials has been based on experience obtained through trial and error, not on material design by the precise control of RE doping and an understanding of the energy-transfer mechanisms. This project will provide guiding principles to design RE-doped materials with "made to order" optical characteristics.

【Publications Relevant to the Project】

・B. Mitchell, Y. Fujiwara *et al.*: "Perspective: Highly efficient GaN-based red LEDs using europium doping," Journal of Applied Physics **123** (2018) pp. 160901/1-12.
・B. Mitchell, Y. Fujiwara *et al.*: "Utilization of native oxygen in Eu(RE)-doped GaN for enabling device compatibility in optoelectronic applications," Scientific Reports **6** (2016) pp. 18808/1-8.

【Term of Project】

FY2018-2022

【Budget Allocation】

490,300 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.mat.eng.osaka-u.ac.jp/mse6/