【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Interdisciplinary Science and Engineering)

Title of Project : Research on Unexplored Frequency Quantum-Cascade Lasers Using Nitride Semiconductors

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Research Area : Interdisciplinary Science and Engineering
Keyword : Heterostructure

【Purpose and Background of the Research】

Nitride semiconductor is a material having a potential for realizing wide frequency range of quantum-cascade lasers (QCLs) including unexplored frequency 5～12 THz, as well as room temperature operation of THz-QCL.

LO phonon energy of nitride semiconductor is about three times larger than that of GaAs or InP. Also, the conduction-band discontinuity of GaN/AlN is more than three times larger than that of InGaAs/AlGaAs. Such a unique material properties are quite attractive for the development of frontier research of QCLs. The operation frequency range of the THz-QCL can be expanded to 3～20 THz by introducing GaN semiconductors, by avoiding LO phonon absorption of GaAs or InP. Also, 1～8 μm infrared (IR)-QCL is expected by using huge band discontinuity of AlN(AlGaN)/ GaN. The purpose of this work is to develop unexplored frequency QCLs by using nitride semiconductors.

【Research Methods】

Figure 1 shows schematic structure of GaN/AlGaN THz-QCL with single metal plasmon waveguide fabricated on sapphire substrate. We grow GaN/AlGaN QC structures by using molecular beam epitaxy (MBE) in order to obtain a precise control of the QC layer thickness, as well as, 1-nomo-layer accuracy sharp hetero-interfaces. The layer structure of the GaN/AlGaN THz-QCL is consisting of a 100-200 periods active region sandwiched by Si-doped GaN contact layers.

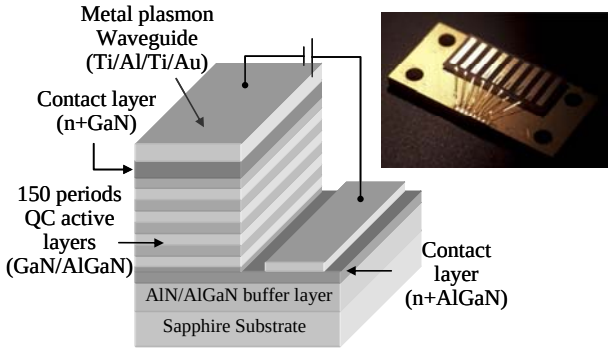

Figure 1 Schematic structure of GaN-based QCL

We introduce 'pure-three-level' quantum structure for QC active regions, as shown in Fig 2, in order to obtain stable QCL operation avoiding un-degenerate level emissions. The "pure-three-level" design is quite simple realized by two quantum wells (QWs).

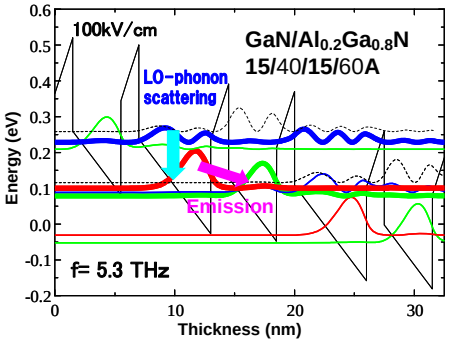

Figure 2 Quantum design used for GaN-based QCL

【Expected Research Achievements and Scientific Significance】

THz-QCL is a compact terahertz laser source with high output power, narrow emission line-width, and cw operation, and expected for variety of applications such as in medical imaging, security screening or wireless communications, etc. The application fields are expected to be much expanded by realizing unexplored frequency QCLs.

【Publications Relevant to the Project】

H. Hirayama et al, "Recent progress and future prospects of THz quantum-cascade lasers", Novel In-Plane Semiconductor Lasers XIV, Proc. of SPIE, 9382-41 (2015).
W. Terashima and H. Hirayama, "Development of terahertz quantum cascade laser based on III-nitride semiconductors", The Review of Laser Engineering, vol. **39**, no. 10, pp. 769-774 (2011).

【Term of Project】 FY2015-2019

【Budget Allocation】 154,500 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.riken.jp/lab/THz-device/