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

Title of Project : Creation of 2D-Atomically-Thin-Layered Hetero-junctions and their Applications to Novel Terahertz Photonic Devices

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Research Area : Engineering, Interdisciplinary Science and Engineering
Keyword : Electron device, Quantum device, Millimeter and terahertz waves, Graphene, Nanophysics

【Purpose and Background of the Research】

Terahertz (THz) is an unexplored electromagnetic frequency band in which conventional electronic and photonic devices cannot operate well due to the substantial physical limitations originating from the transit time delays and/or phonon decoherence. In such a situation, graphene, a carbon atomic monolayer sheet, has attracted attention thanks to its extremely high carrier transport properties of relativistic Dirac Fermions. Recently, study on atomically-thin van der Waals (vdW) heterostructures consisting of graphene, h-BN, and/or transition-metal dichalcogenide (TMD) like MoS_2 has been emerging. We theoretically found that a gated double-graphene-layered (G-DGL) heterostructure can mediate THz photon- and plasmon-assisted resonant tunneling between the GLs, enabling various functionalities in the THz domain with extremely higher quantum efficiencies by orders than ever. The key to make them in practical engineering is to develop the continuous hetero-epitaxial growth (C-H-Epi-G) technology.

This research is aimed to create the C-H-Epi-G technology for the 2D vdW heterojunction systems, and to devise highly efficient various THz functional devices by exploiting unprecedented physical phenomena exhibited among their complex quantum systems governed by electrons, photons, plasmons, as well as phonons (Fig. 1).

【Research Methods】

First, the G-DGL structure consisting of the DGL core shell and the external gate is created as the platform of device implementation. Second, the photon-assisted and plasmon-assisted resonant tunneling are introduced into the G-DGL as the physical operation mechanisms to manifest the advantage of the performances of THz amplification, oscillation, detection, and nonlinear wave control over the existing technologies. Third, the double resonance of the graphene plasmons and the tunneling is introduced as an advanced physical operation mechanism to obtain further improved performances of these functionalities (Fig. 2).

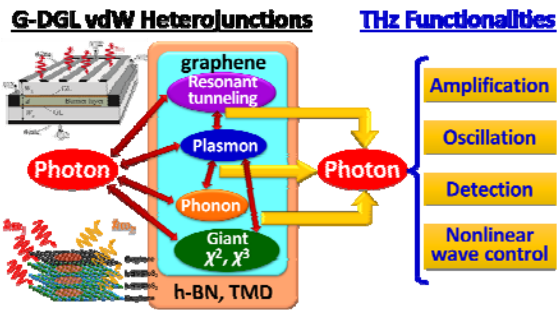

Fig. 1 Nonlinear complex quantum phenomena in G-DGL vdW heterojunctions and their applications to THz functional devices.

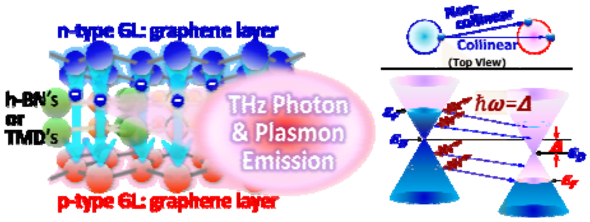

Fig. 2 Photon- and plasmon-assisted resonant tunneling in the G-DGLs for THz emitters.

【Expected Research Achievements and Scientific Significance】

Introduction of unprecedented physical mechanisms of complex quantum systems in the G-DGL is unique and has a great merit and impact to enable ultra-highly efficient THz functionalities.

If successful this study, 100-Gbit/s-class ultra-fast THz wireless communications, such as Trans-fer-Jet that can transfer ultra-high-capacity media instantly, is expected to bring industrial revolution to the future of ubiquitous ICT societies.

【Publications Relevant to the Project】

・T. Otsuji et al., "Active graphene plasmonics for terahertz device applications," **J. Phys. D 47**, 094006 (2014).
・V. Ryzhii et al., "Double-graphene-layer terahertz laser," **Opt. Exp. 21**, 31569-31579 (2013).

【Term of Project】 FY2016-2020

【Budget Allocation】 144,600 Thousand Yen

【Homepage Address and Other Contact Information】

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