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

Broad Section D

Title of Project : Development of valley-spin quantum optics in atomically thin artificial hetero-structures

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Keyword : Atomically thin material, Photonics, Quantum Optics

【Purpose and Background of the Research】

Here we will tackle to create new research field of "valley-spin quantum optics" leading to novel optical quantum information devices, which is based on the scientific insights combined with atomically thin material science and quantum optics. There is a coupling of degree of freedom between valley in the momentum space and spin in the atomically thin materials (MX_2:M=Mo, W, X=S, Se, Te), called as valley-spin due to breaking of Kramers degeneracy. In our previous studies, the detail physical understanding of valley-spin degree of freedom and continuous control of valley-spin polarization by external-field were successfully realized as important milestones toward the valleytronics. We found the new strategy to control the valley-spin degree of freedom as quantum states. Thus, the research field of "valley-spin quantum optics" based on the control of quantum states will be newly opened.

In this research project, we will construct the scientific framework of "valley-spin quantum optics" with overcoming the conventional quantum optics in the ultimate zero-dimensional (0D) quantum dots by atomically thin hetero-structures. Moreover, we will develop toward the application of "valley-spin quantum optics" as "valley-spin quantum photonics".

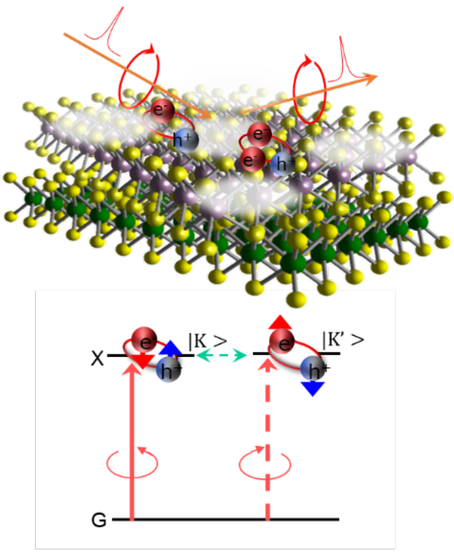

Figure 1 Schematics of atomically thin artificial hetero-structure and valley-spin quantum system

【Research Methods】

According to our studies, the 0D (quantum two-level system) will be realized in the atomically thin hetero-structures by introduction of quantum confined moiré potential. The proposed valley-spin quantum optics are studied as follows, 1) development of fabrication technique of atomically thin artificial hetero-structures and their devices, 2) exploring quantum optical phenomena in the atomically thin artificial hetero-structures, 3) quantum control in the atomically thin quantum dots toward valley-spin quantum optics, 4) application of quantum information devices based on valley-spin control.

【Expected Research Achievements and Scientific Significance】

New routes for the application of optical quantum devices (quantum bit and a single photon source) are expected through the realization of long-term retention of valley-spin quantum coherence and quantum state control. We also expect the novel quantum systems with external interface and controllability of interactions between the quantum bits in the atomically thin hetero-structures, which is much different from other quantum systems. Thus, this project is important not only in the viewpoint of fundamental science but also in the application.

【Publications Relevant to the Project】

・ Y. Miyauchi, S. Konabe, F. Wang, W. Zhang, A. Hwang, Y. Hasegawa, L. Zhou, S. Mouri, M. Toh, G. Eda, and K. Matsuda: Evidence for line width and carrier screening effects on excitonic valley relaxation in 2D semiconductors, Nat. Commun. **9**, (2018) 2598.
・ K. Shinokita, X. Wang, Y. Miyauchi, K. Watanabe, T. Taniguchi, and K. Matsuda: Continuous control and enhancement of excitonic valley polarization in monolayer WSe_2 by electrostatic doping, Adv. Func. Mater. **29**, (2019) 1900260.
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【Term of Project】 FY2020-2024

【Budget Allocation】 151,000 Thousand Yen

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