Exciton Hall effect and transport of valley exciton in monolayer MoS_2

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1. Introduction

Transition metal dichalcogenides (TMDs) have attracted vast interest as layered semiconductors with high electrical and optical properties. Among them, monolayer MoS_2 is a direct gap semiconductor with its gap energy in the visible range (Fig. 1(a)). Interestingly, excitonic states in monolayer MoS_2 are stabilized owing to the intrinsic two-dimensional nature, and the binding energy reaches several hundred meV.

Because of the broken inversion symmetry, the minima (maxima) of the conduction (valence) band at the K and K' points in the Brillouin zone are energetically degenerate but inequivalent, giving electrons (holes) valley degrees of freedom. These valleys are coupled with optical helicity and finite Berry curvature with opposite signs.

The valley-polarized excitons, which are the composite particles excited by circularly polarized light (Fig. 1b), in this system also have the valley degree of freedom [1]. Here the transport phenomena of the valley-polarized composite particles is an issue of concern of this study.

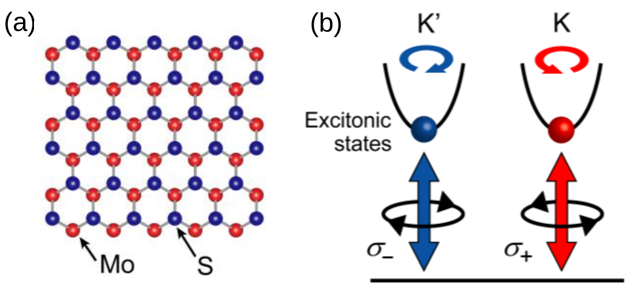

Figure 1: (a) Crystal structure of monolayer MoS_2. (b) Valley excitons coupled with circularly polarized light [2].

2. Methods

Monolayer MoS_2 flakes were mechanically exfoliated on SiO_2/Si substrates. All optical experiments were carried out at 30 K in the He-flow cryostat. The excitons were created by He-Ne laser (632.8 nm), which gives near-resonant excitation of the A-excitons. By shining the laser at the edge of the flake, the potential gradient is formed along the flake and subsequent exciton diffusion occurs.

For tracing the trajectory of valley exciton during the diffusion, we measured polarization resolved photoluminescence (PL) mapping image.

3. Results

At first, we observed exciton diffusion in monolayer MoS_2 at low temperature. The diffusion length is around 2.2 μm, which is consistent with previous researches about TMDs [3,4]. Furthermore, the valley diffusion length reaches as much as 2 μm, meaning that valley information pumped by circularly polarized light is preserved in a micrometer-scale.

Secondly and more importantly, we observed valley-selective transverse motion of valley excitons under zero magnetic fields. This is the first observation of the Hall effect of exciton (exciton Hall effect, EHE), and the observed EHE reflects the intrinsic topological nature of the valley excitons in monolayer MoS_2. The Hall angle of the EHE is deduced to be around 0.2.

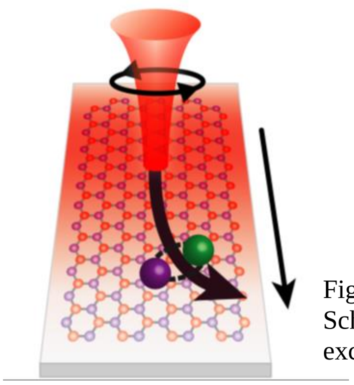

Figure 2: Schematic image of the exciton Hall effect [2].

4. Conclusions

We observed transport of valley exciton in a micrometer-scale and a new Hall effect of excitonic quasiparticles [2]. These results will open new Hall physics of composite particles and exciton-based valleytronics in two-dimensional materials.

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