Modulation of Optical Properties of Monolayer $MoSe_2$-MoS_2 Hetero-Structures

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1. Introduction

Transition metal dichalcogenides (TMDs) have attracted much attention as a novel two-dimensional semiconductor, and also are promising candidates for the future optoelectronic devices [1,2]. Van der Waals hetero-structures (vdWHs) composed of TMDs are key structures to develop these devices. Efficient charge separation [3] and formation of long-lived interlayer excitons [4] due to the type II band alignment enables exciton engineering including valleytronics [5] or novel light harvesting devices [6]. In this context, modulation of interplaying between inter-layer and intra-layer excitons/trions is an important issue to control optical device performance. In this study, we report the modulation of intra-layer and inter-layer exciton/trion properties in monolayer (1L)-MoS_2/1L-$MoSe_2$ vdWH by means of the field effect gating.

2. Results and Discussion

1L-MoS_2/1L-$MoSe_2$ vdWH was fabricated using transfer method by poly dimethylsiloxane (PDMS) film [7]. This hetero-structure becomes *n*-type because of initially doped electrons. We found that strong photoluminescence (PL) from interlayer excitons can be observed below 120 K around 1.45 eV, which is apart from the intra-layer trion emissions of isolated 1L-MoS_2 (Peak X: ~1.83 eV) and isolated 1L-$MoSe_2$ (Peak Y: ~1.64 eV). This thermal crossover behavior can be caused by the thermal dissociation of interlayer excitons due to the small exciton binding energy (~ 80 meV) resulting in the screening by doped electrons**.**

We also measured PL spectra of 1L-MoS_2/1L-$MoSe_2$ hetero-structure with changing applied gate voltage at 50 K as shown in Fig. 1. Inter-layer exciton PL intensity (Peak I) is increased gradually with increasing the negative voltage despite the small change of intra-layer trion PL intensity in 1L-$MoSe_2$ (Peak Y: ~1.64 eV). In the large negative voltage region, electron density of each layer becomes small due to the compensation of initially doped electrons in by field effect doping. This could reduce the intra-layer trion formation and enhance the photo-carrier separation between layers. As a result, inter-layer excitons are stabilized in such large negative voltage region.

Conclusions

We found that modulation of intra-layer trion PL and inter-layer exciotn PL in the 1L-$MoSe_2$/1L-MoS_2 hetero-structure. Our finding provides the important perspective for understanding exciton and trion dynamics in Van der Waals hetero-structures and their application for future opto-electronic devices.

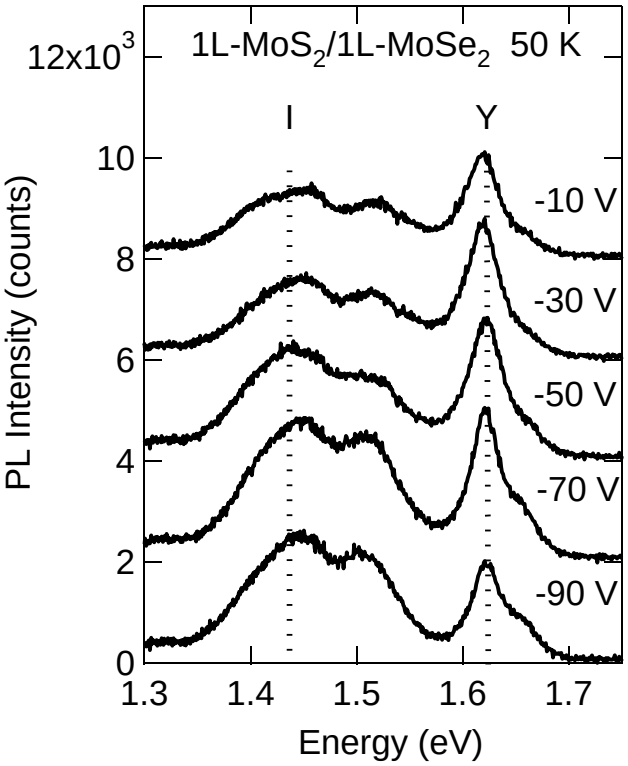

Fig. 1 Photoluminescence spectra of 1L-MoS_2/1L-$MoSe_2$ hetero-structure measured at various gate voltages.

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