Photoluminescence Properties in 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 candidate for the future optoelectric devices [1,2]. Van der Waals hetero-structures composed of TMDs can be suitable platform to realize functional semiconductor devices. For instance, recent reported ultrafast interlayer charge transfer in monolayer MoS_2-WS_2 hetero-structure [3] provided the possibility to realize the efficient light harvesting devices. Formation of long-lived interlayer excitons in $MoSe_2$-WSe_2 hetero-structure [4] could give to develop exciton engineering including quantum condensation. Despite these intriguing features, optical properties in Van der Waals hetero-structures have been unclear. Further study focusing on charge transfer and interlayer exciton dynamics has been required. We studied photoluminescence (PL) properties of van der Waals hetero-structures building from monolayer (1L-) MoS_2 and $MoSe_2$ and discuss the exciton dynamics in this material.

2. Results and Discussion

1L-$MoSe_2$/1L-MoS_2 hetero-structure was fabricated by transfer method. 1L-$MoSe_2$ exfoliated onto PDMS thin film is placed on 1L-MoS_2 grown on the SiO_2/Si substrate with use of micro stage. It was annealed in vacuum for 2 hour at 200℃ to improve the contact of each layer.

We measured PL spectra of 1L-$MoSe_2$/1L-MoS_2 hetero structure with changing temperature as shown in Fig. 1. At 280 K, two intralayer exciton PL peaks from 1L-MoS_2 (Peak X: ~1.83 eV) and 1L-$MoSe_2$ (Peak Y: ~1.53 eV) are observed. They are quenched and red-shifted as compared with those in isolated monolayers. It suggests that the charge transfer between each layer occurs due to their type II band structure. With decreasing temperature, these peaks are enhanced and blue-shifted as the typical two dimensional semiconductor behaviors. In addition, the broad PL peak (Peak I: ~1.45 eV) is appeared below 160 K and its intensity becomes strong below 100 K. The peak energy of peak I is different from the emission energy of isolated monolayers. We determined the lifetime of this PL as ~ 1 ns by time resolved PL measurement, which is comparable with the lifetime of interlayer excitons in $MoSe_2$-WSe_2 hetero structure [4]. These results indicate that this novel PL feature comes from the recombination of interlayer excitons.

The crossover from intralayer to interlayer exciton PL observed here could be understood by the thermal dissociation due to relatively small conduction band offset (~ 0.07 eV) between two layers. Detailed interlayer exciton dynamics including high density excitation effects in this hetero-structure will be focused in the presentation.

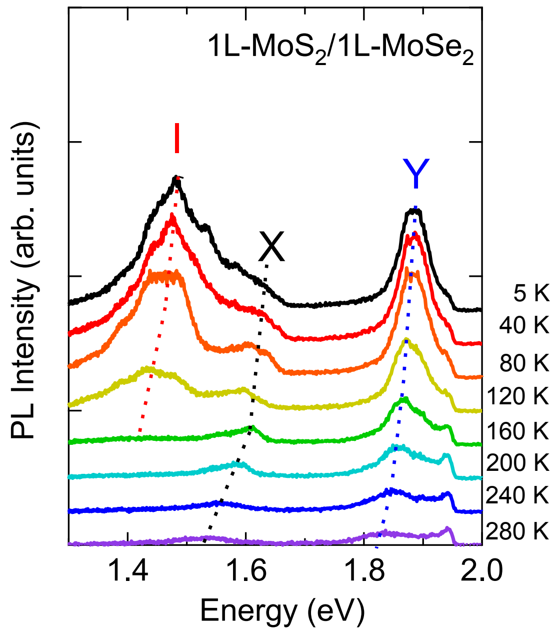

Fig. 1 PL spectra of 1L-$MoSe_2$/1L-MoS_2 hetero structure measured with changing temperature.

3. Conclusions

We found that thermal crossover from intralayer to interlayer exciotn PL in the 1L-$MoSe_2$/1L-MoS_2 hetero-structure. Our finding provides the important perspective for understanding exciton dynamics in Van der Waals hetero-structures and their application for future opto-electronic devices.

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