Optical Properties in Van der Waals Heterostructure of Monolayer $MoSe_2$ and Perovskite Manganese Oxide

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1. Introduction

Artificial van der Waals (vdW) heterostructures composed of semiconducting monolayer transition metal dichalcogenides (TMDs) on the different types of materials such as metallic, superconducting, and magnetic materials have been attractive platforms for emerging novel optical properties. However, the systematic optical studies of vdW heterostucture composed of semiconducting monolayer TMDs and magnetic-transport phase transition materials have not been reported until now. In this study, we have investigated the charge transfer and magnetic proximity effect for the optically generated excitonic states (excitons and trions) in semiconducting monolayer $MoSe_2$ (1L-$MoSe_2$), and strongly correlated electron system of double-layered perovskite Mn oxide ($(La_{0.8}Nd_{0.2})_{1.2}Sr_{1.8}Mn_2O_7$) vdW heterostucture.

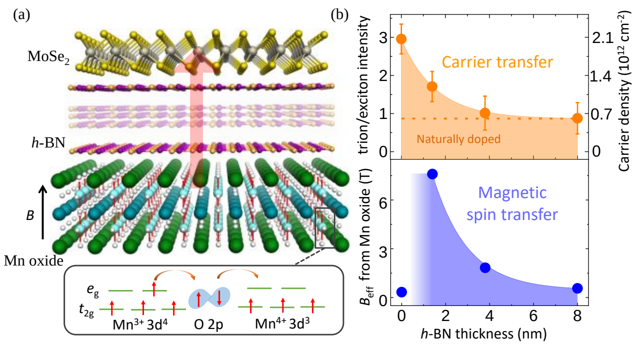

Figure 1. (a) Schematic diagram of vdW heterostructure. (b) Doped carrier density and effective magnetic field from Mn oxide as a function of *h*-BN thickness from analysis of PL spectra.

2. Results and discussion

The vdW heterostucture studied here ($MoSe_2$/*h*-BN/Mn oxide) was created by dry transfer method as shown in schamtic of Figure 1a. The Mn oxide shows the magnetic and electronic phase transition from paramagnetic-insulator (PI) to ferromagnetic-metal (FM) at Curie temperature (T_C) via double-exchange interactions of *d*-electrons on the Mn sites [1]. The temperature and magnetic field dependence of photoluminescence (PL) spectra arising from recombination of exciton and charged exciton (trion) were measured in the vdW hetero-structure. We experimentally observed the discontinuously change of exciton PL intensity in $MoSe_2$ due to the change of dielectric screening effect with striking the temperature of T_C from PI to FM in the Mn oxide [2]. The efficient charge transfer from metallic Mn oxide to $MoSe_2$ is also indicated by threefold higher PL intensity of trion than that of exciton. Moreover, the non-linearly enhanced valley splitting and polarization of $MoSe_2$ by the FM Mn oxide have been revealed in polarization resolved PL spectra under magnetic field, which is the demonstration of lifting the valley-spin degeneracy via large magnetic proximity effect equivalent to about 8 T by FM using extremely thin spacer layer of *h*-BN. We have also revealed the characteristic length scale of several nanometers in charge transfer and magnetic proximity effect, as shown in Figure 1b.

3. Conclusions

In summary, we have studied the charge transfer and magnetic proximity effect for excitons and trions in 1L-$MoSe_2$/*h*-BN/Mn oxide vdW heterostructure. The vdW structures using electronic and magnetic phase transition materials demonstrated here can provide new opportunities for the modulation and controllability of excitonic states by dielectric screening, charge carriers, and magnetic spins.

References

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