Interlayer excitons in CVD-grown WS_2/MoS_2 vertical heterostructures

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Heterostructures of transition metal dichalcogenides (TMDCs) have attracted attention because of their emergent optical and electronic properties. As a representative example, the presence of interlayer excitons has been reported for TMDC-based vertical heterostructures [1,2]. However, in previous studies, an observed photoluminescence (PL) peak relating to the interlayer excitons has relatively-large linewidth probably due to the presence of inhomogeneous broadening. To solve this issues, we have developed the CVD process of TMDCs with highly-uniform optical spectra and their heterostructures [3,4]. Here, we report on the observation of sharp PL peaks in high-quality WS_2/MoS_2 vertical heterostructures.

Vertical WS_2/MoS_2 heterostructures are grown on boron nitride (BN) substrates by two-step CVD. The presence of a monolayer WS_2 grain on a triangle-shaped monolayer MoS_2 was confirmed from an atomic force microscope (AFM) image (Fig.1a) and Raman/PL maps. This heterostructure shows three PL peaks between 1.4~1.7 eV (Fig.1b). These fine structures of PL have never been observed in the previous CVD-grown WS_2/MoS_2 heterostructure [2], and can be tentatively assigned to the direct and indirect optical transitions as shown in Fig.1c. Interestingly, only I3 PL peak has redshift with increase in temperature. Compared to the band structures considering thermal expansion, I3 peak can be assigned to the interlayer-derived direct transition at K point. The present results indicate that the high-quality heterostructures are an ideal system for the precise understanding of interlayer coupling.

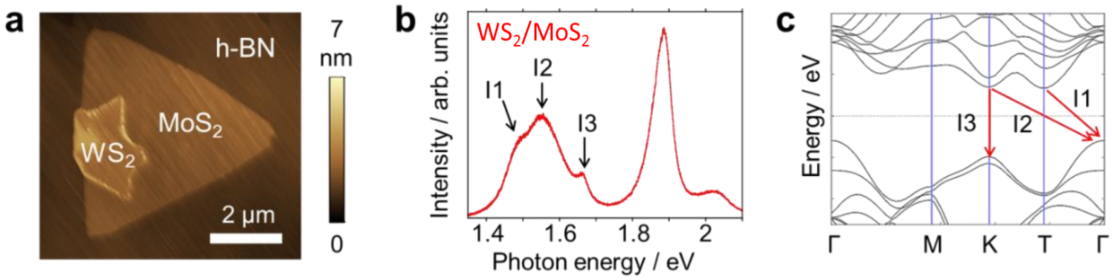

Fig.1 (a) AFM image and (b) PL spectrum of the WS_2/MoS_2 vertical heterostructure on BN. (c) Band structure of the WS_2/MoS_2 vertical heterostructure obtained from first-principles calculations.

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