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Exciton Dynamics in a Monolayer WS_2–WSe_2 Lateral Heterostructure with Wide Alloy Region

Monolayer transition metal dichalcogenides have various intriguing physical properties mainly arising from excitons [1]. Recently, the exciton dynamics in monolayer vertical/lateral heterostructures or alloy monolayers have attracted much attention, because novel excitonic phenomena including the interlayer exciton [2], exciton dissociation [3], and exciton energy change [4] emerge owing to the modulation of exciton energy structures. These results indicate that the combination of such structures potentially provide a platform for exploiting novel exciton physics.

Here, we report the exciton dynamics in a monolayer WS_2–WSe_2 lateral heterostructure with wide alloy region between the pure WS_2 and WSe_2 regions using photoluminescence (PL) spectroscopy. The lateral heterostructure was synthesized by a chemical vapor deposition method. It has the alloy region with the width of about 20 μm, where the composition ratio of WS_2 and WSe_2 gradually changes as a function of spatial coordinate. For PL spectroscopy, we used the 2.33 eV or 2.22 eV continuous-wave lasers to excite both monolayers of WS_2 and WSe_2. The laser spot had 13.4 μm at full width at half maximum, intensity was 3.5 kW/cm^2 in the linear response regime, and all the measurements were performed at room temperature.

We conducted spectrally-resolved PL mapping on the lateral heterostructure across the wide alloy region. The PL peak from the pure WS_2 region observed at 1.94 eV is assigned to the A exciton. By scanning laser spot across the alloy region of $WS_{2(1-x)}Se_{2x}$, the PL peak showed a gradual redshift, and finally matched with that of the A-exciton of pure monolayer WSe_2 at 1.70 eV. The continuous shift of the exciton energies indicates formation of a potential gradient in the wide alloy region, in contrast to the sharp potential change caused by lattice mismatch [5] and piezo effect [6] in lateral heterostructures with a sharp interface.

Next, we focused on exciton diffusion profile in the wide alloy region. We performed spatial- and spectral-resolved PL measurements, and found that the position of the brightest PL spot deviated from the laser excitation spot by 0.6 μm in the wide alloy region. This was contrast to the observation at the pure WS_2 and WSe_2 regions, where the brightest PL spot was observed at the same position as the laser excitation spot. We analyzed the spatial profile of PL intensities using a diffusion model considering the effect of potential gradient, and found that the potential gradient mainly causes the exciton drift. In the presentation, we will discuss the details of exciton transport phenomena in the wide alloy region.

References

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