Excitonic coupling induced photoluminescence enhancement in layered 2D heterostructure

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Abstract

Two-dimensional materials (2D) have attracted substantial attention in nano-optoelectronic and electronic industries owing to their unique physical and structural properties. A great deal of research has been done in the past few years exploring the optoelectronic properties of semi-metallic, semiconducting, and insulating 2D materials, etc. But, significant development is still required to achieve practical applications, which can be adopted by the industries. For instance, the semiconducting 2D materials, in particular, transition metal dichalcogenides (TMDCs) show unique properties of light-matter interaction. The TMDCs have direct bandgap in monolayer showing strong light-matter interaction, but in bulk, they show indirect bandgap, which reacts less significantly compared to its monolayer counterpart. Meanwhile, owing to the lack of materials in monolayer, the carrier density of states responsible for absorption or emission is limited. In this work, we adopt a new strategy to circumvent the issue. We have designed vertical stakes of the monolayer (1L) TMDCs separated by few-layer hexagonal boron nitrides (hBN), an insulating 2D material, which separates the 1L TMDCs, MoS_2 keeping the monolayer properties intact in the superlattice, MoS_2/hBN/MoS_2, see Figure 1a. The optical microscopy image of the device is shown in Figure 1b. Interestingly, the emission spectra of such superlattice show much stronger radiation density at the heterojunction compared to its monolayer counterpart, see Figure 2a. Depending upon the hBN thickness, we also found that the enhancement can be tuned. We interpret such enhancement of emission is due to the exciton coupling at the heterojunction. We further map the excited state carrier lifetime, which shows a much shorter lifetime at the heterojunction confirming the coupling induced emission at the junction, see Figure 2b, that make the emission intensity stronger. Our work, therefore, should be beneficial and timely for the development of high-performance nano-optoelectronic devices.

Figures

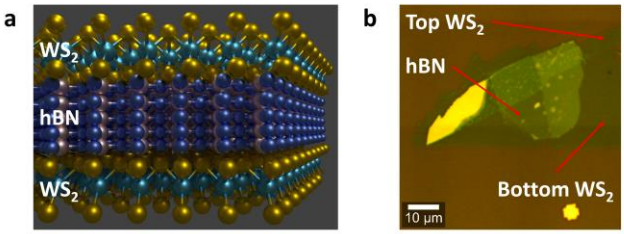

Figure 1: a, schematic image of MoS_2/hBN/MoS_2 superlattice device. **b**, The Optical microscopy image of the device.

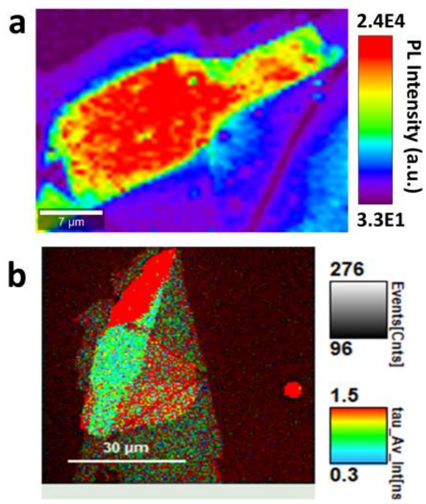

Figure 2: a, Photoluminescence and **b**, carrier lifetime map of the device under the excitation of 532 nm laser at 1μW pump flounce.