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ENHANCED PHOTOLUMINESCENCE 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.* However, significant development is still required for practical applications. For instance, semiconducting 2D materials, in particular, transition metal dichalcogenides (TMDCs) show unique properties of light-matter interaction. The TMDCs possess direct bandgap in monolayer showing strong light-matter interaction, while 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 light matter interactions are limited.
- In order to circumvent such shortcomings, this work, 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, MoS2 keeping the monolayer properties intact in the heterostructure, MoS_2/hBN/MoS_2. Interestingly, the emission spectra of such composites show much stronger radiation density at the heterojunction compared to its monolayer counterpart. Depending upon the hBN thickness, we also found that the enhancement can be tuned. We interpret that such enhancement 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, that make the emission intensity stronger. Our work, therefore, should be beneficial and timely for the development of high-performance nano-optoelectronic devices.

RESULTS

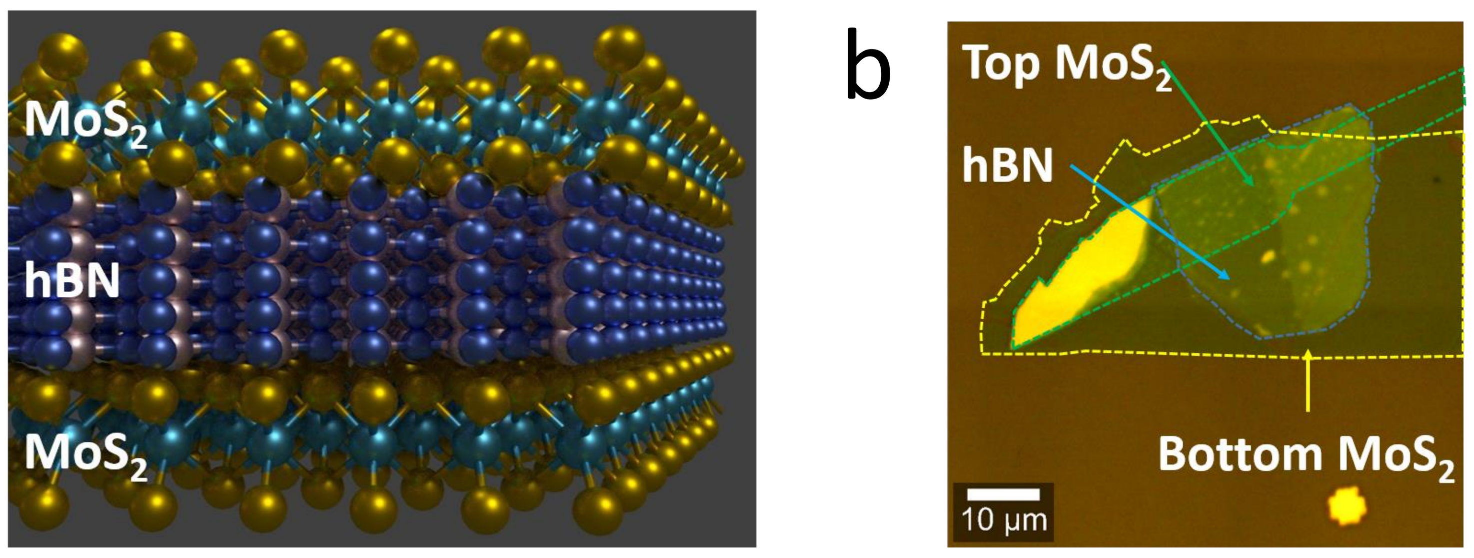

Figure 1: (a) Schematic illustration of the MoS_2/hBN/MoS_2 heterostructure **(b)** Optical Microscopy image of the structure on Si/SiO_2 substrate, where two vertically stacked monolayer MoS_2 are separated by few layer hBN.

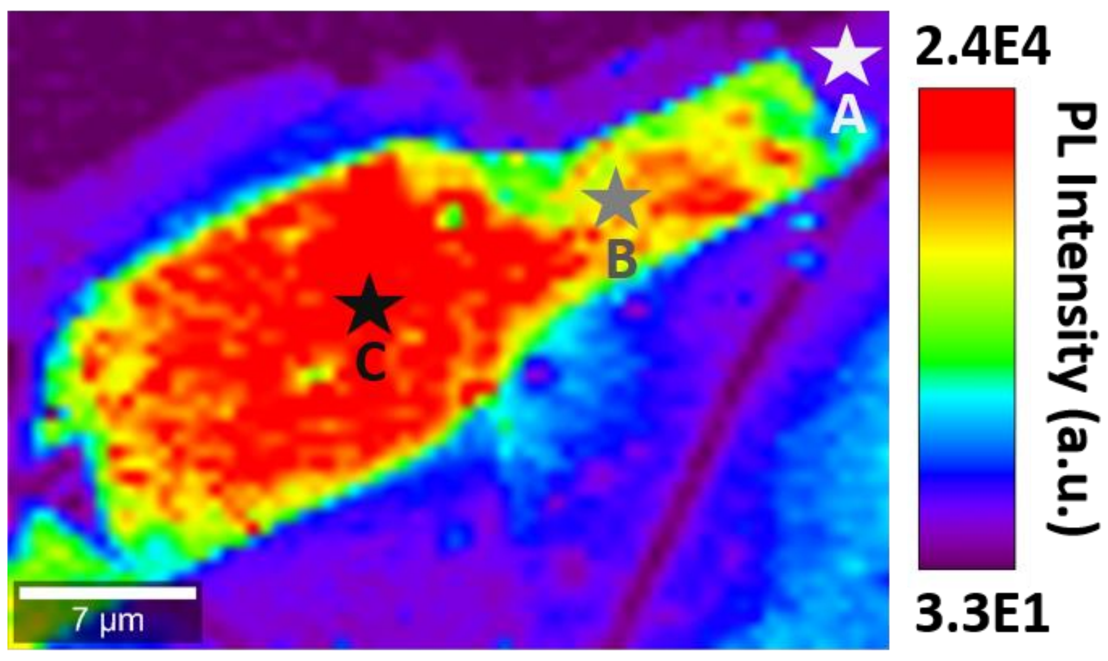

Figure 2: Photoluminescence (PL) map of the MoS_2/hBN/MoS_2 heterostructure obtained at a pump fluence of 130 nW of 633 nm laser.

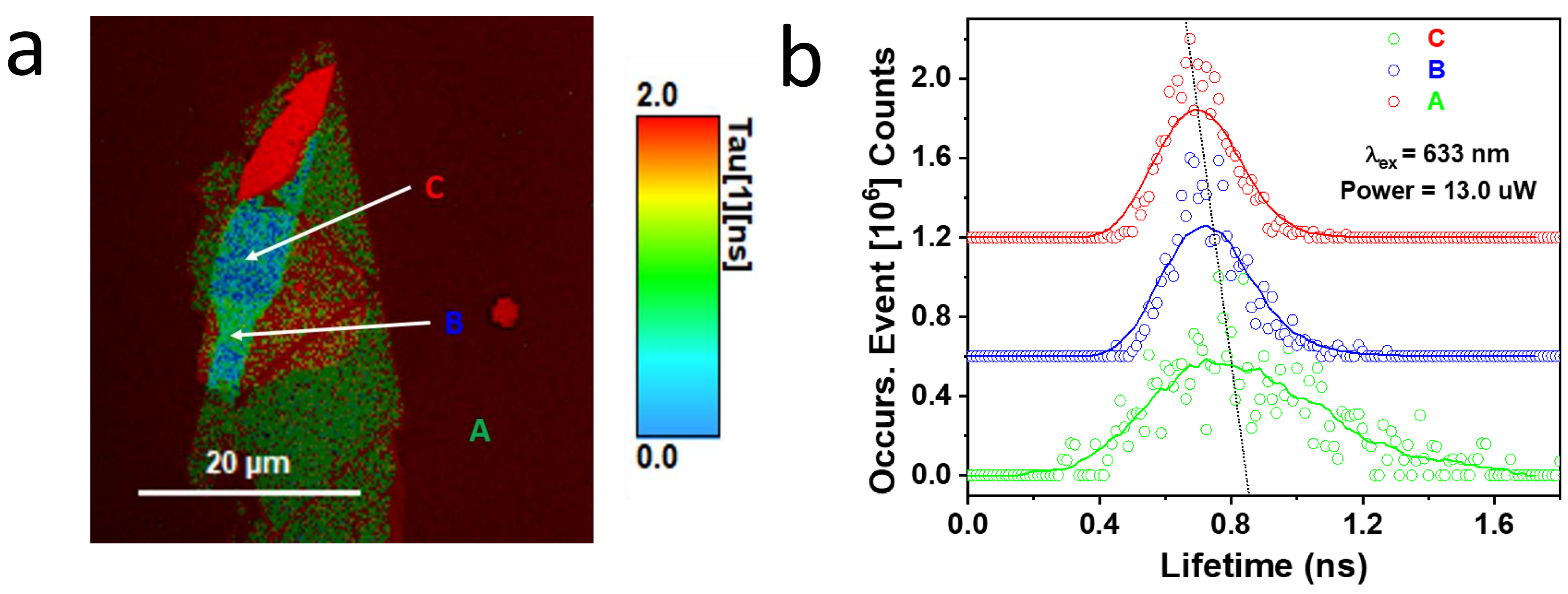

Figure 4: (a) Excited state carrier lifetime distribution along the constituent layers and at the heterostructure. The difference in color at the heterostructure resemble shortening of the lifetime as compared with the original layers. **(b)** Lifetime histogram of 5 µm² area of the sample obtained at different places as marked in Figure 4(a).

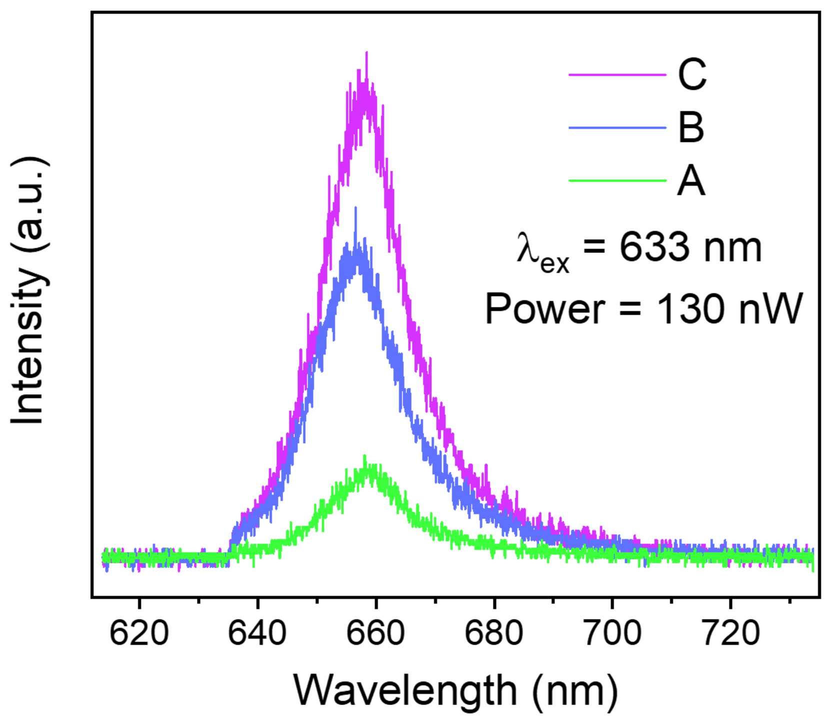

Figure 3: Photoluminescence (PL) spectra of the heterostructure, measured at A, B, and C (see Figure 2) positions, at a pump fluence of 130 nW, of 633 nm laser. The emitted intensity is enhanced >2 times at the heterostructure based on the thickness of hBN film.

DISCUSSION

• The emitted photon intensity strongly enhances at the heterostructure • The enhancement at the thinner hBN is stronger • The carrier lifetime at the heterostructure gets shorter • Thinner hBN causes shorter lifetime as compared with thicker one • The observations resembles interlayer exciton coupling at the heterojunction • Thinner hBN makes coupling stronger which reduces the excited state carrier lifetime and increases the emitted radiation density • Our strategy will be very useful to design high performance optoelectronic devices.

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