Modulation of Interlayer Coupling and Photoluminescence in Transferred Bilayer and 1D Nanoscroll WS_2 Structures

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Abstract

Monolayer WS_2 was synthesized via CVD and assembled into bilayer and nanoscroll structures through single-step, two-step transfers, and curling. Using a 532 nm laser Raman spectrometer, we measured PL and Raman spectra. Results reveal that interlayer distance and coupling strength significantly affect PL intensity and bandgap type, offering insights for future optoelectronic device design.

Introduction

Two-dimensional transition metal dichalcogenides (TMDCs) like WS_2 exhibit unique optical properties due to interlayer coupling effects. However, how transfer-induced interface residues and structural changes affect these properties remains unclear. This study aims to explore the modulation of photoluminescence through controlled bilayer stacking and nanoscroll formation.

(a) (b)

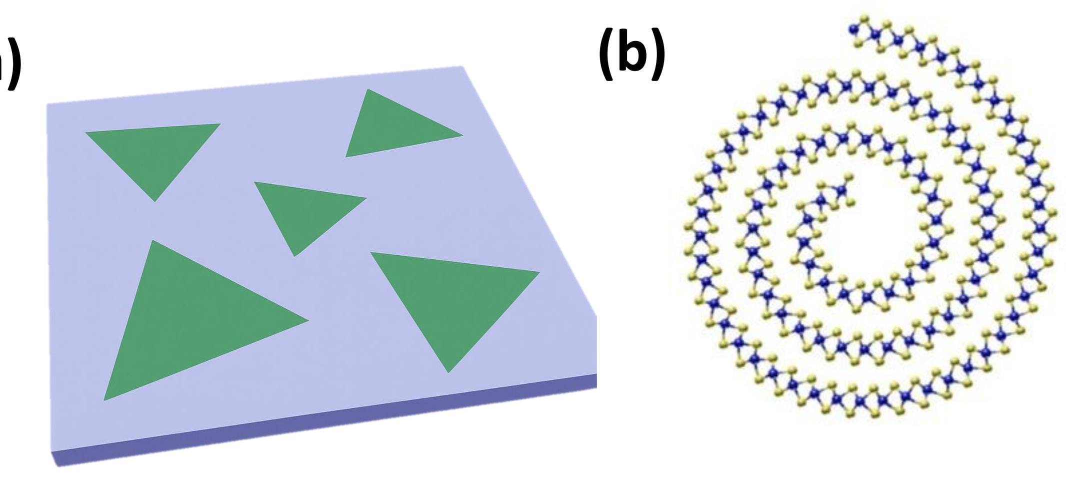


Fig. 1 (a)WS_2 monolayer and (b)nanoscroll structures[3]

Sample preparation

(a) (b) (c)

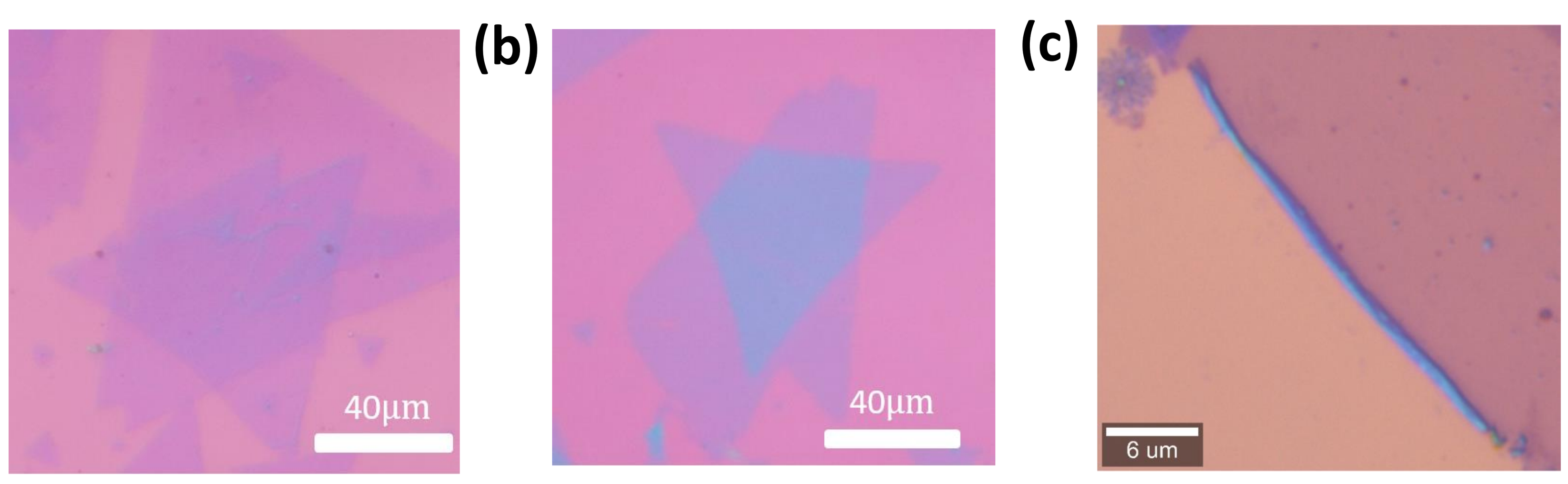
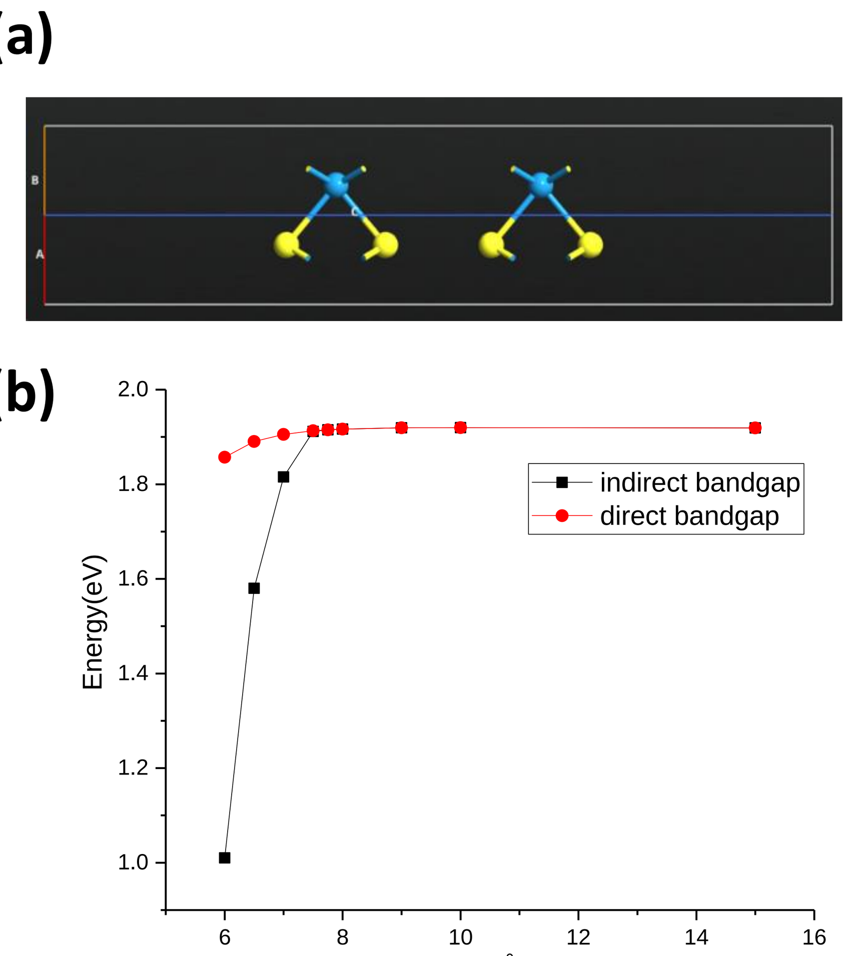


Fig. 2 (a) Single-transfer WS_2 (b) double-transfer bilayer WS_2 (c) 1D WS_2 nanoscroll.

DFT simulation

(a) (b)



(c) (d)

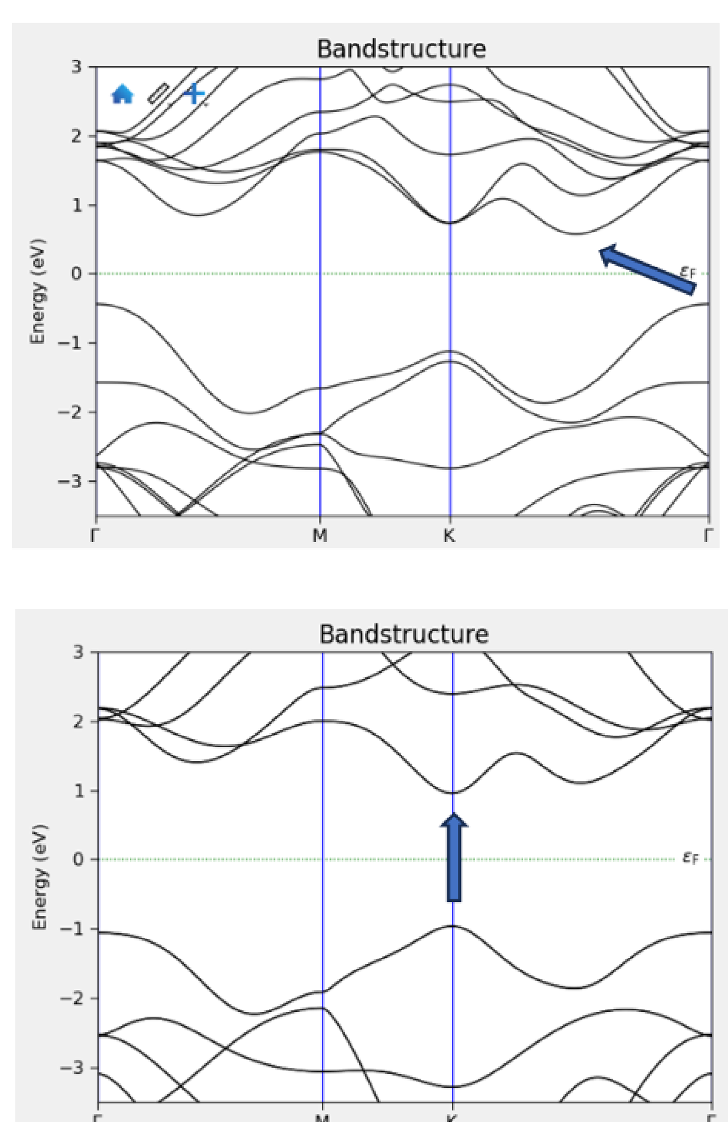


Fig. 3 (a) Schematic of bilayer WS_2.
(b) Calculation of interlayer distance in bilayer WS_2 by DFT simulation (c)(d) Band structures of bilayer WS_2 with different interlayer distances.

Result and Discussion

(a) (b) (c) (d)

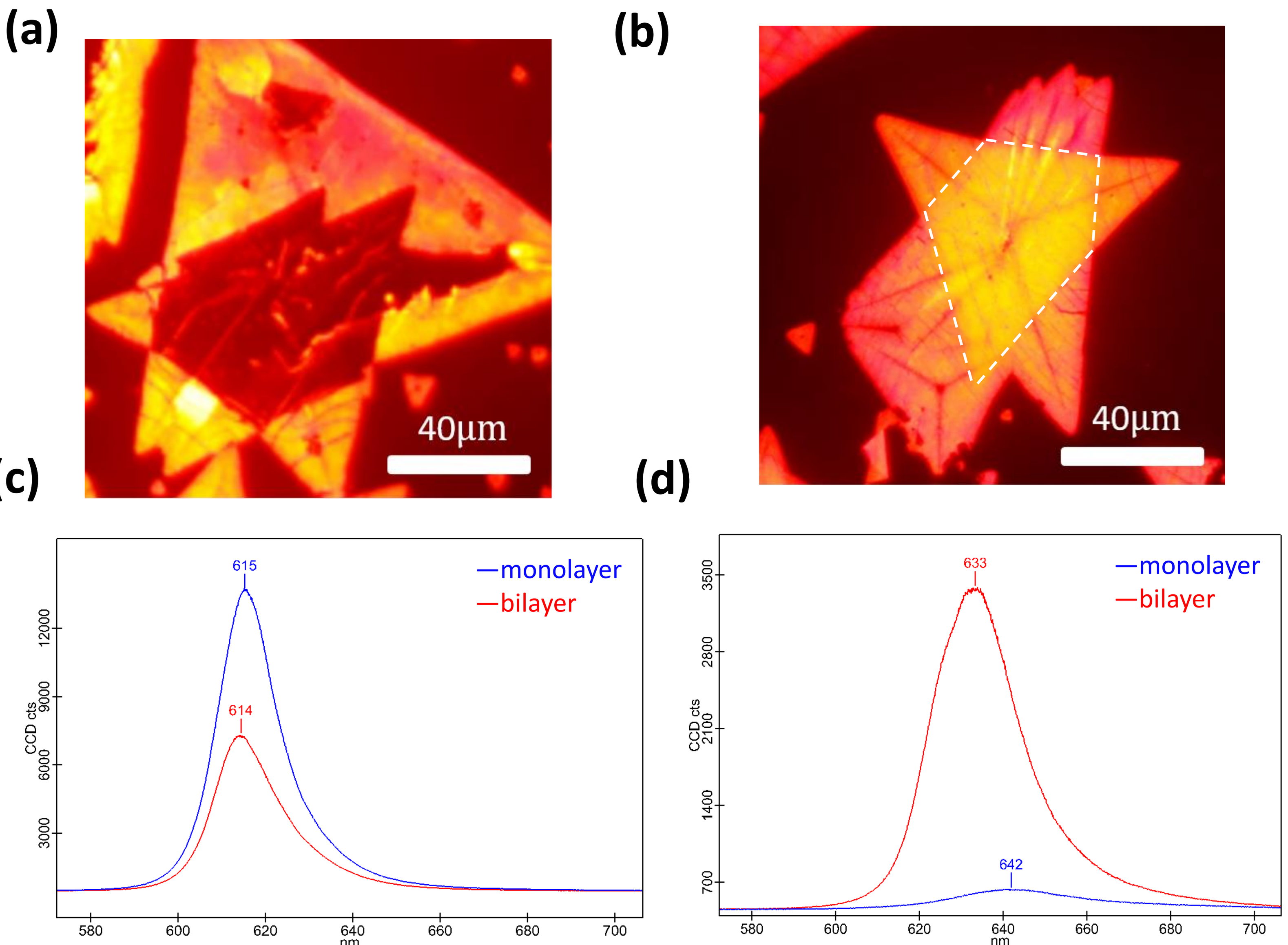


Fig. 4 WS_2 (a) PL of single-transfer and (b) double-transfer WS_2. (c–d) Corresponding PL spectrum of monolayer (blue) and bilayer (red).

(a) (b)

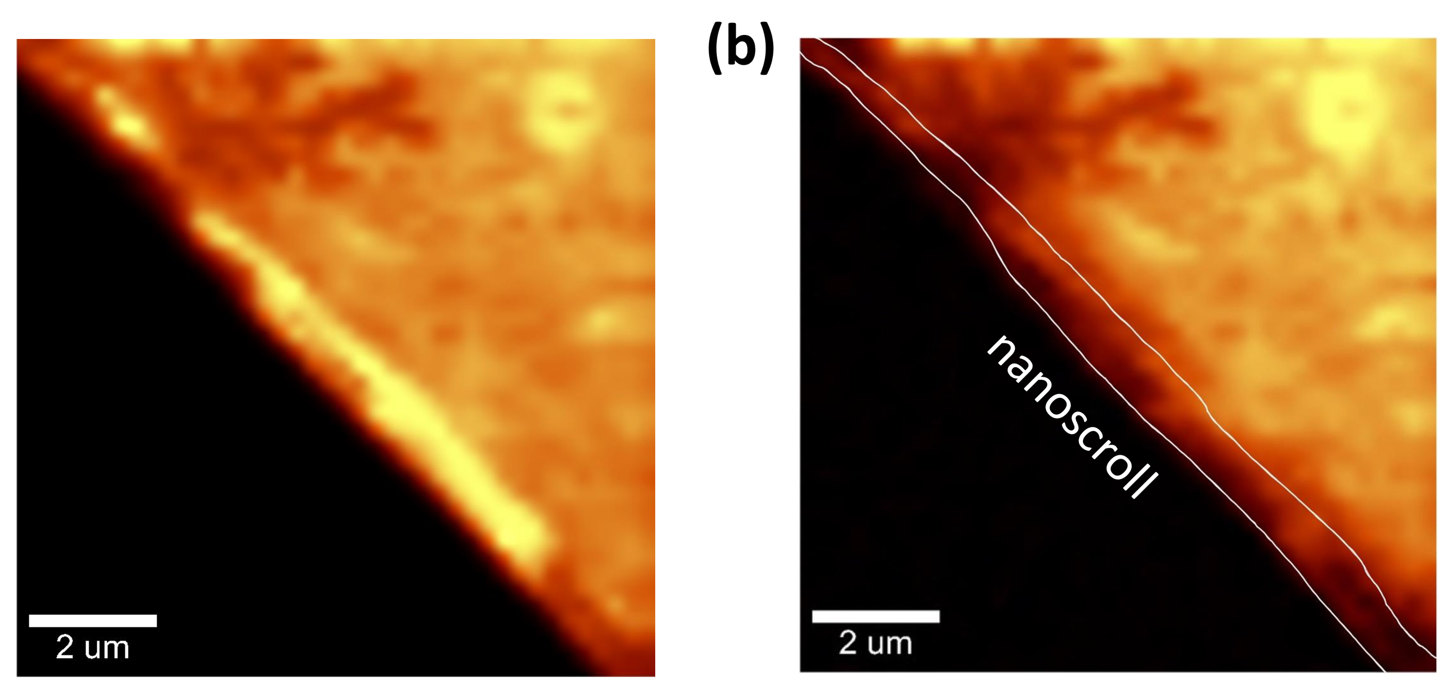


Fig. 5 WS_2 nanoscroll before (a) and after (b) high-energy laser annealing.

Conclusion

- Interlayer coupling in bilayer WS_2 can be effectively modulated by varying the transfer process steps and conditions.
- Photoluminescence intensity increases significantly when the interlayer spacing is enlarged by double transfer or scroll formation.
- High-energy laser annealing removes residual solvents, restores coupling strength, and results in quenched PL emission in nanoscrolls.

Reference

[1] C. Lin et al., "Direct band gap in multilayer transition metal dichalcogenide nanoscrolls with enhanced photoluminescence," ACS Materials Letters, vol. 4, no. 8, pp. 1547-1555, 2022.
[2] S. Qiao, Y. Qiu, Y. Lu, Z. Wang, M. Yuan, and Q. Ji, "One-dimensional MoS2 Nanoscrolls as miniaturized memories," Nano Letters, vol. 24, no. 15, pp. 4498-4504, 2024
[3] X. Cui et al., "Rolling up transition metal dichalcogenide nanoscrolls via one drop of ethanol," Nature communications, vol. 9, no. 1, p. 1301, 2018.