

電機資訊學院 2026 作 BRAIN PLUS HAND 實作專題競賽

Modulation of Interlayer Coupling and Photoluminescence in Transferred Bilayer and 1D Nanoscroll WS₂ Structures

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Abstract

Monolayer WS₂ 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 (TMDs) like WS₂ 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.

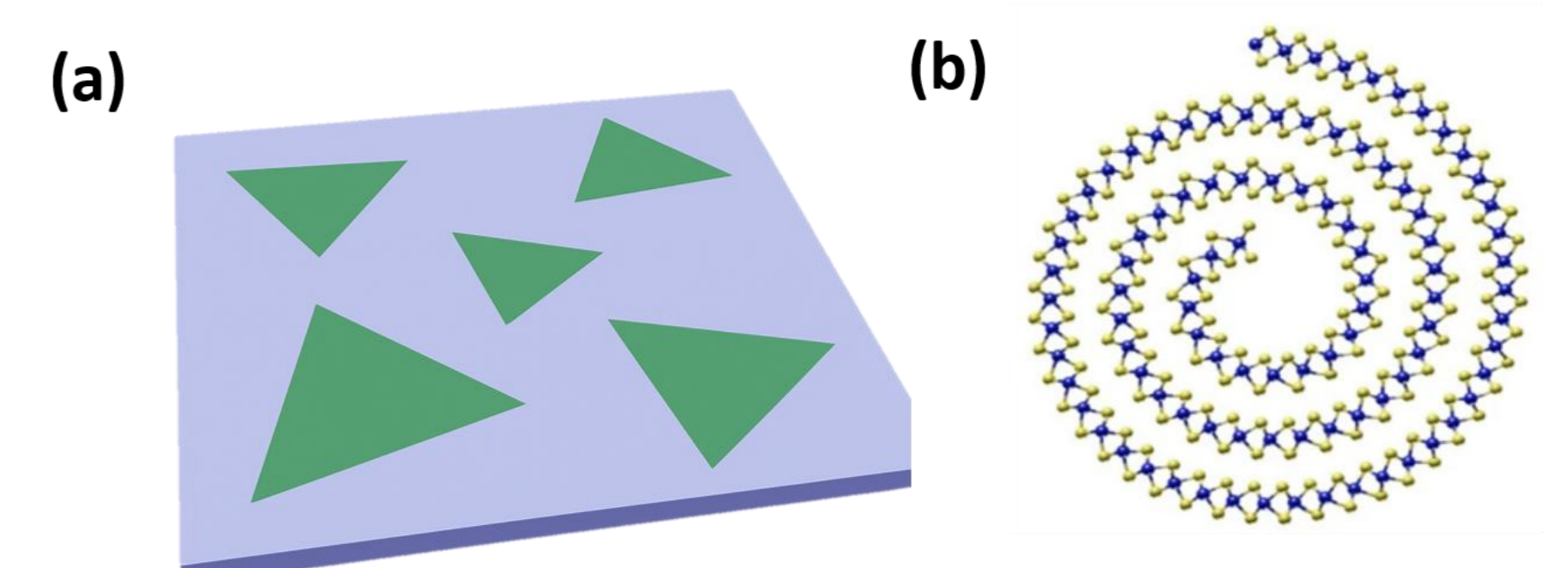


Fig. 1 (a) WS₂ monolayer and (b) nanoscroll structures[3]

Sample preparation

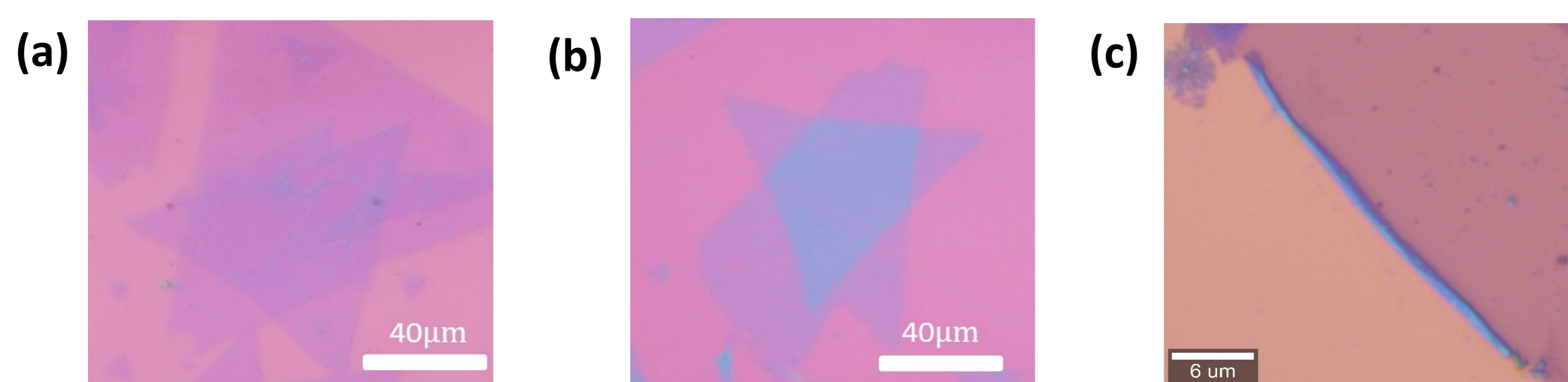


Fig. 2 (a) Single-transfer WS₂ (b) double-transfer bilayer WS₂ (c) 1D WS₂ nanoscroll.

Result and Discussion

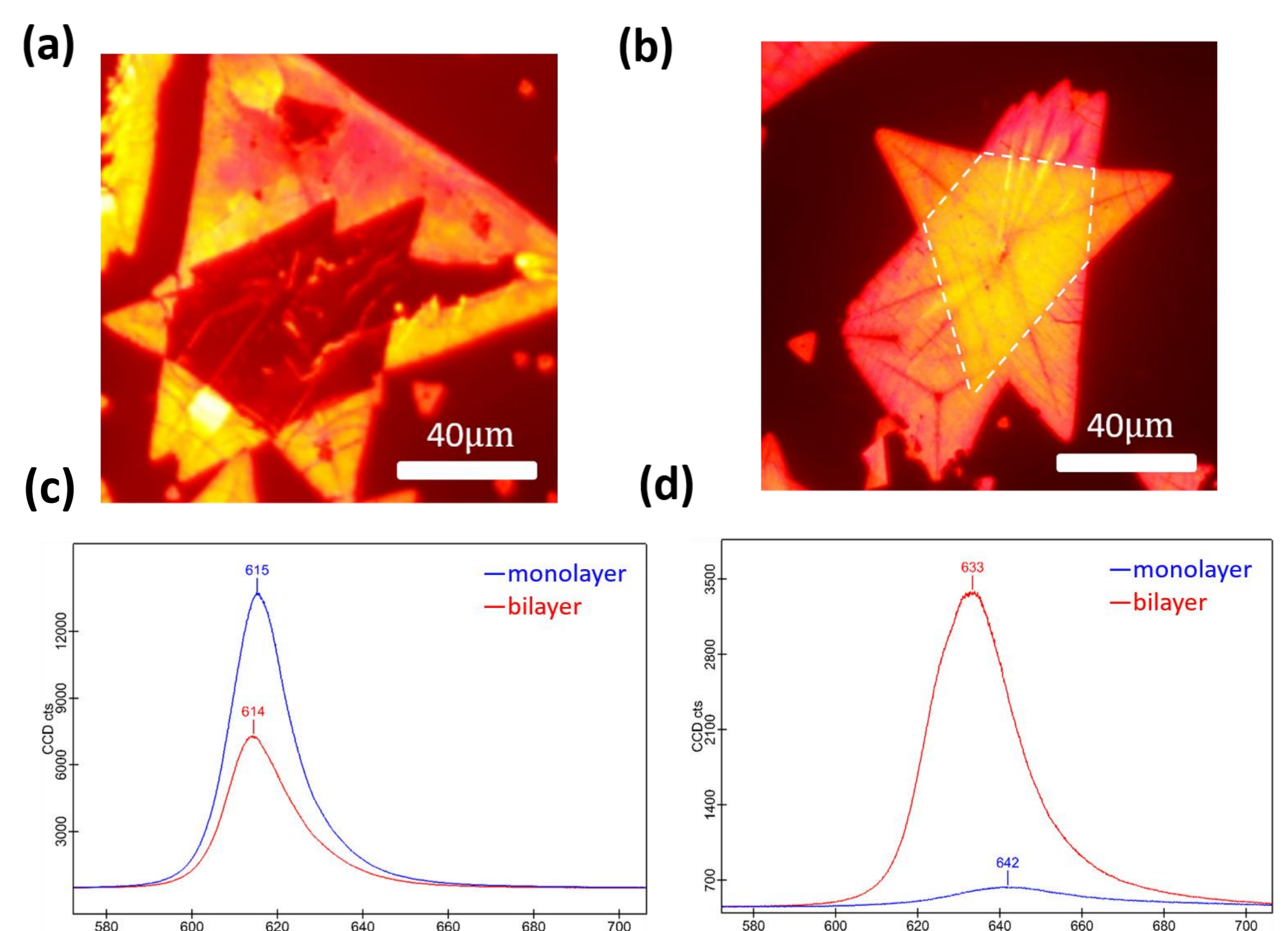


Fig. 4 WS₂ (a) PL of single-transfer and (b) double-transfer WS₂. (c-d) Corresponding PL spectrum of monolayer (blue) and bilayer (red).

DFT simulation

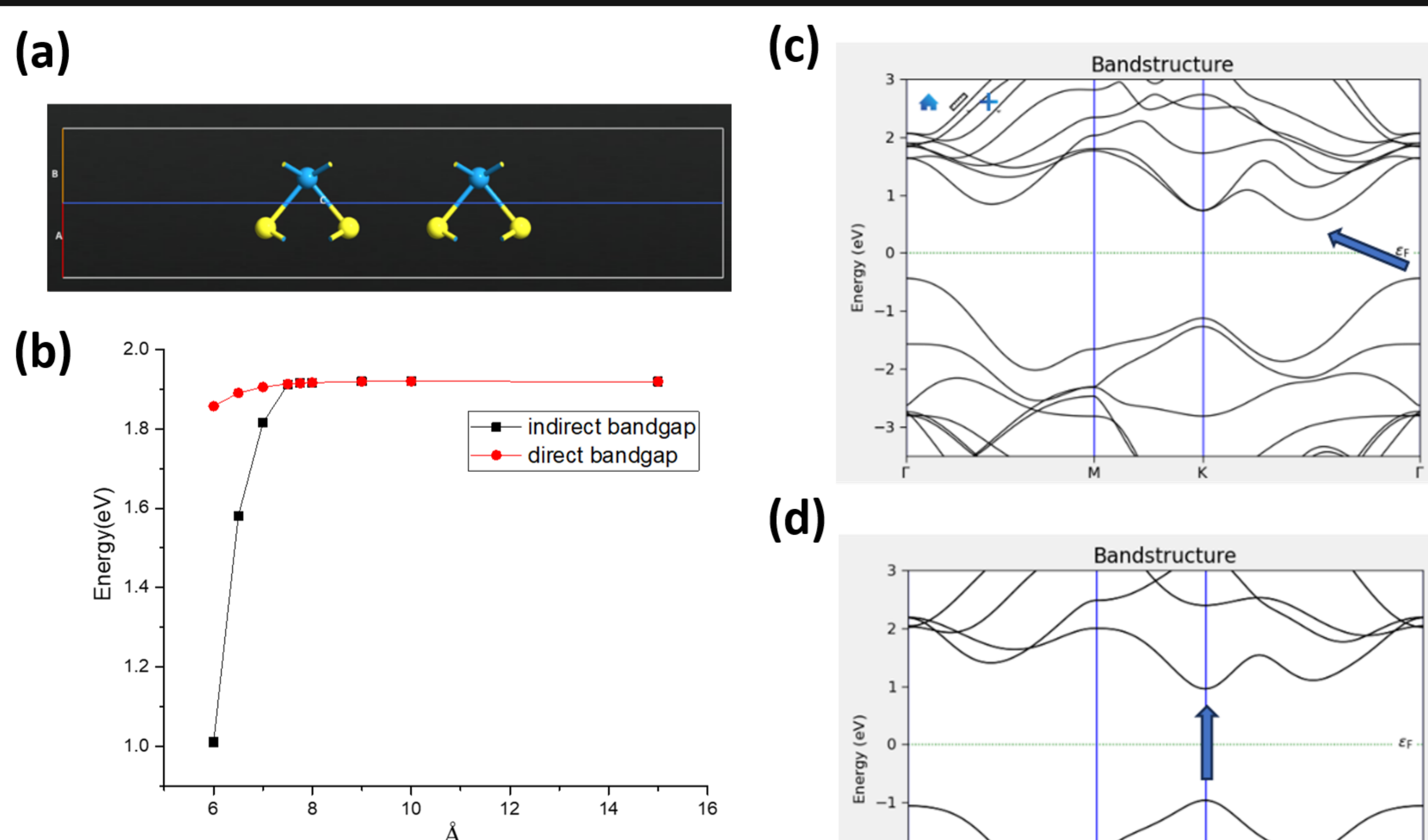


Fig. 3 (a) Schematic of bilayer WS₂. (b) Calculation of interlayer distance in bilayer WS₂ by DFT simulation (c)(d) Band structures of bilayer WS₂ with different interlayer distances.

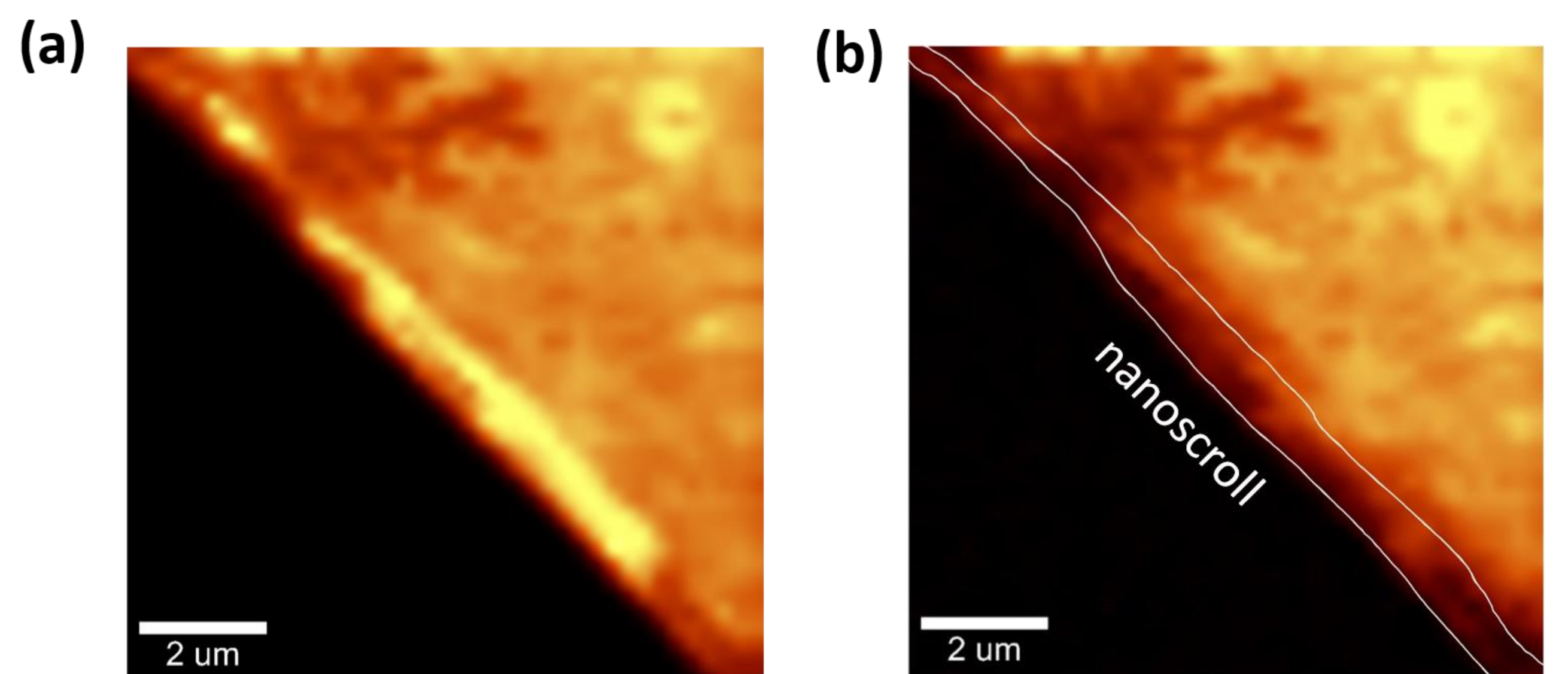


Fig. 5 WS₂ nanoscroll before (a) and after (b) high-energy laser annealing.

Conclusion

- Interlayer coupling in bilayer WS₂ 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.