Bulk as if Monolayers: Electronically and Vibrationally Decoupled ReS_2

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Semiconducting transition metal dichalcogenides consist of monolayers held together by weak forces where the layers are electronically and vibrationally coupled. Isolated monolayers show changes in electronic structure and lattice vibration energies, including a transition from indirect to direct bandgap. Here we present a new member of the family, rhenium disulphide (ReS2), where such variation is absent and bulk behaves as electronically and vibrationally decoupled monolayers stacked together. From bulk to monolayers, ReS2 remains direct bandgap and its Raman spectrum shows no dependence on the number of layers. Interlayer decoupling is further demonstrated by the insensitivity of the optical absorption and Raman spectrum to interlayer distance modulated by hydrostatic pressure. Theoretical calculations attribute the decoupling to Peierls distortion of the 1T structure of ReS2, which prevents ordered stacking and minimizes the interlayer overlap of wavefunctions. Such vanishing interlayer coupling enables probing of two-dimensional-like systems without the need for monolayers.

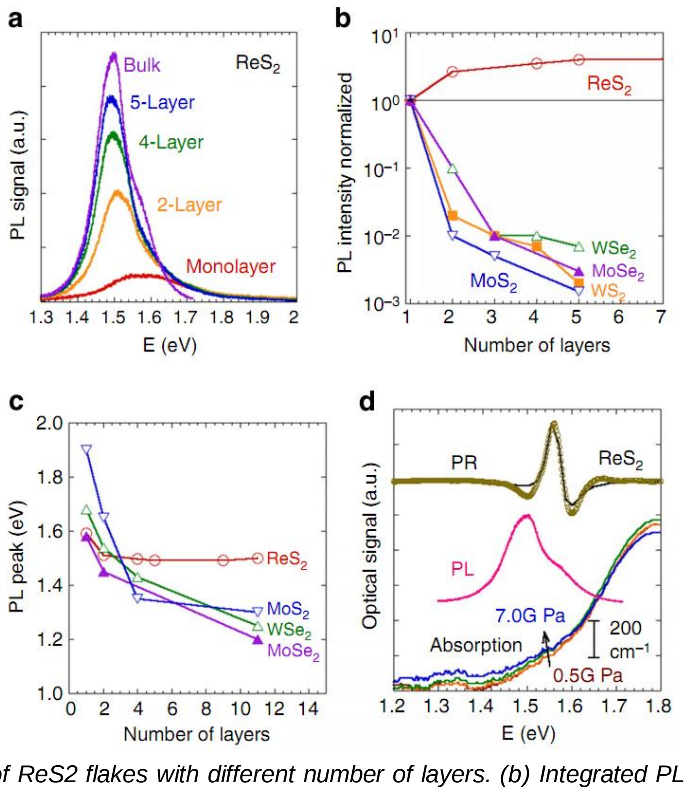

Figure (a) PL spectrum of ReS2 flakes with different number of layers. (b) Integrated PL intensity as a function of number of layers (normalized to that of monolayer) in ReS2, MoS2, MoSe2,WS2 and WSe2.(c) Change in the PL peak position as a function of number of layers in ReS2, MoS2, MoSe2 and WSe2.(d) Absorption coefficient of a bulk ReS2 flake (thickness B10 mm) at hydrostatic pressures ranging from 0.5 to 7.0GPa. Also shown is the PL and photo-modulated reflectance spectra of bulk ReS2 taken at ambient condition. It can be seen that a direct bandgap exists at 1.55±0.05 eV and is insensitive to the pressure.

References

[1] S. Tongay et al. Nature Communications, in press (2014)