

Investigation of Exotic Optical Anisotropy in 2D WS₂ and hBN

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The optical anisotropy of 2D materials represents a crucial driving force behind the development of next-generation optoelectronics and information technology. In this study, we investigate optically anisotropic behaviour in monolayer tungsten disulfide (WS₂) induced by transverse acoustic (TA) and longitudinal acoustic (LA) phonon modes, as well as strain-induced 180° periodic anisotropy in hexagonal boron nitride (hBN). In monolayer WS₂, we identified two low-frequency Raman (LFR) peaks at 27.8 cm⁻¹ and 45.2 cm⁻¹, which are distinct from the conventional low-frequency modes, layer-shear (LS) and layer-breathing (LB) modes, theoretically predicted to occur only in bilayer and thicker structures. These modes remain invariant throughout sample transfer procedures and persist in free-standing samples independent of the substrate (Fig. 1a). Unlike the LS and LB modes, their spectral positions show no layer-number dependence (Fig. 1b). Polarized LFR spectroscopy reveals polarization-dependent behaviours analogous to those of acoustic phonons: the TA mode peak at 27.8 cm⁻¹ is suppressed under cross-polarization geometry, while the LA mode peak at 45.2 cm⁻¹ remains unaffected [1]. Leveraging the high resolution of synchrotron-based Fourier-transform infrared (FTIR) spectroscopy, we uncovered uniaxial strain-induced anisotropy in hBN. Under tensile strain, a redshift in the FTIR peak position of hBN was observed (Fig. 2a). In stretch-relaxation cycling experiments, the peak blue shifted with increasing strain and gradually redshifted during relaxation (Fig. 2b), indicating stress release. Polarization-dependent measurements elucidated the origin of these spectral shifts. We observed that the FTIR peak position and intensity of hBN evolved from an initially irregular pattern (Fig. 2c) to a well-defined 180° periodicity under strain—distinct from the intrinsic 120° periodicity [2] of its crystal lattice (Fig. 2d).

References

- [1] Qing-Hai Tan, et al., 2D Material, 4 (2017) 031007.
[2] Jun-Zhu Li, et al., Nature Communications, 15 (2024) 8589.

Figures

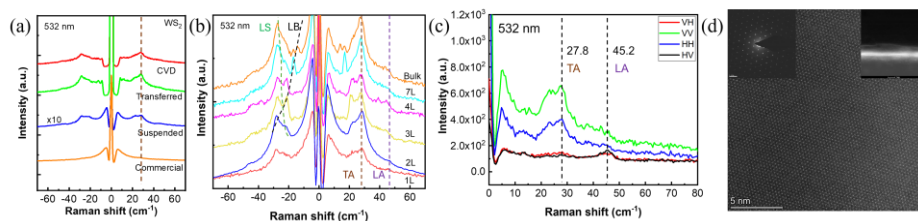


Figure 1: Substrate-interaction dependent Raman LFR spectra of monolayer WS₂ (a), thickness-resolved LFR spectra (b), and HRTEM image (d). (c) Polarized LFR characterization of trilayer WS₂.

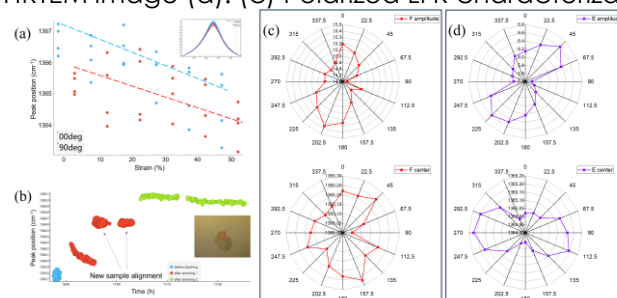


Figure 2: (a) Strain-dependent FTIR peak position of hBN. (b) Stretch-relaxation cycle measurements of hBN. Polarized FTIR of unstrained (c) and strained hBN(d).