Strain Induced Negative Differential Resistance in Transition Metal Dichalcogenides

A.R. Hengst
L.J.M. Westenberg, Y. Wang, and P. Bampoulis
Physics of Interfaces and Nanomaterials, MESA+ Institute, University of Twente, P.O. Box 217, 7500AE Enschede, The Netherlands
a.r.hengst@utwente.nl

We demonstrate that strain induced modifications of the band structure in several 2H-MX_2 (M = Mo, W; X = S, Se) transistion metal dichalcogenides (TMDs) and their twisted stacks leads to the formation of local flat bands, which could result in negative differential resistance (NDR) in local tunnel junctions. The key in realizing the NDR is a combination of strain and band alignment. We demonstrate that this can be achieved in two ways: through the underlying substrate (for example via nanobubbles and wrinkels) or via tip-induced lifting of the TMD layer. NDR is characterized by a peak in the current-voltage (IV) curve that results in a peak followed by a negative valley in the differentiated (dI/dV) curve. We attribute the NDR effect to the formation of flat bands under the influence of local high strain. These flat bands become isolated due to bandgaps forming around them. Favorable alignment between these isolated flat bands in the TMD layer(s) and the Fermi levels of the contacts allows for resonant tunneling. The strain induced flat band states in the TMDs therefore act as intermediate resonant states for tunneling. This strain-assisted tunneling mechanism is highly controllable as there are various ways to introduce the strain in different configurations and under different circumstances. The observation of this mechanism across different materials, twist configurations, temperatures, and measurement techniques establishes strain-engineered flat band resonance as a universal route to NDR in TMD systems.

References

[1] Alawein, M.; Ager, J. W.; Javey, A.; Chrzan, D. C., Physical Review Materials, 9 (2025) L021002
[2] Hernández López, P.; Heeg, S.; Schattauer, C.; Kovalchuk, S.; Kumar, A.; Bock, D. J.; Kirchhof, J. N.; Höfer, B.; Greben, K.; Yagodkin, D.; Linhart, L.; Libisch, F.; Bolotin, K. I., Nature Communications, 13:1 (2022) 1–9
[3] Trainer, D. J.; Zhang, Y.; Bobba, F.; Xi, X.; Hla, S.-W.; Iavarone, M., ACS Nano, 13 (2019) 8284–8291

Figures

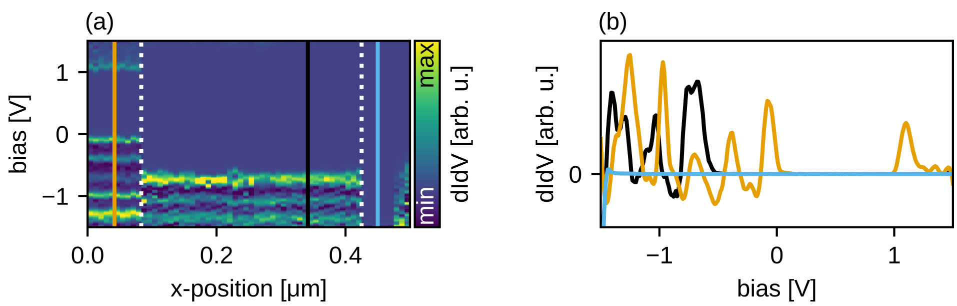

Figure 1: Flat bands and NDRs observed on strained WS_2 by STM at 77 K in UHV. (a) Numerically derived dI/dV linetrace where the dotted lines indicate a tip change. (b) dI/dV curves extracted from (a) at the location inidicatd by the corresponding colored vertical lines.