Leibniz-Institut
für Festkörper- und
Werkstoffforschung
Dresden

Addressing Individual Layers in Artificial 2D Heterostructures

Dr. Golam Haider

Institute for Metallic Materials
Leibniz Institute for Solid State and Materials Research Dresden

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Dr. M. Kalbac

Prof. J. Vejpravová

Dr. A. Rodriguez

Dr. V. Varade

Dr. J. Varillas

Charles University and
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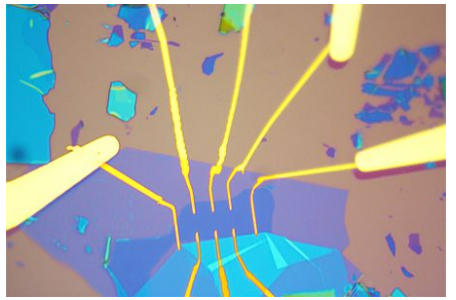
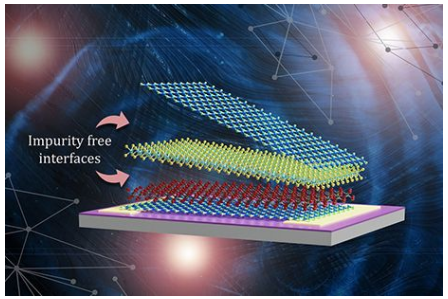


Superpuddles Lab



Twisted 2D Materials

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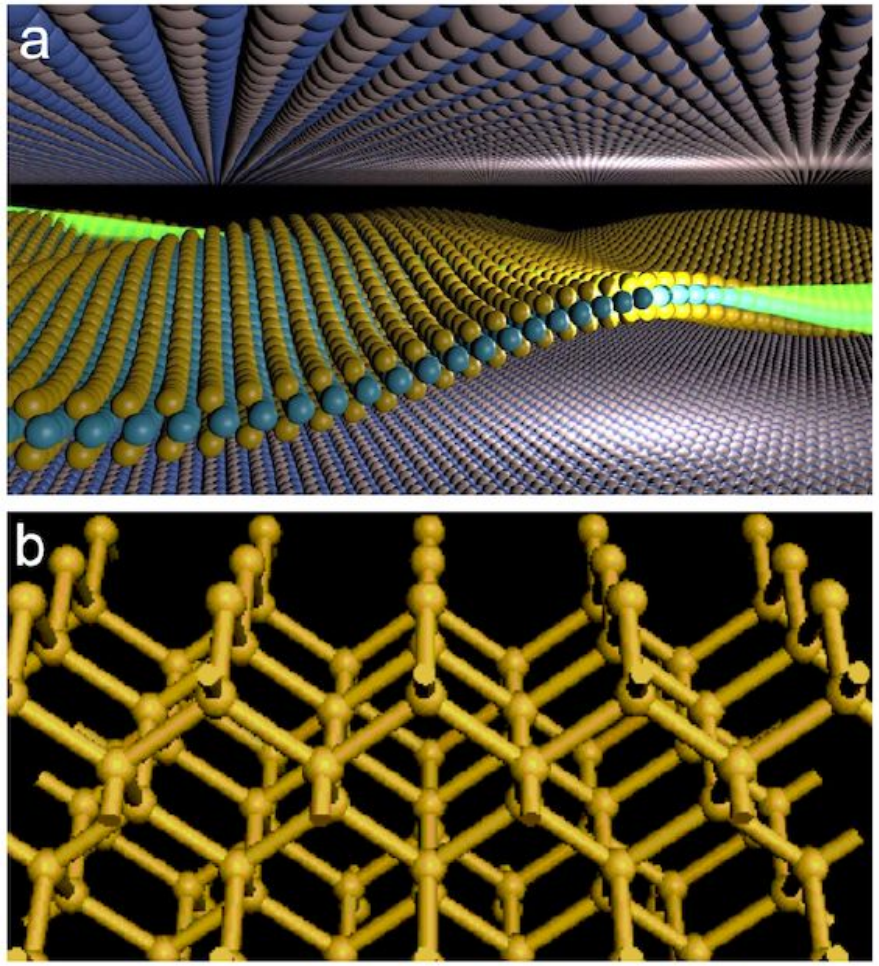
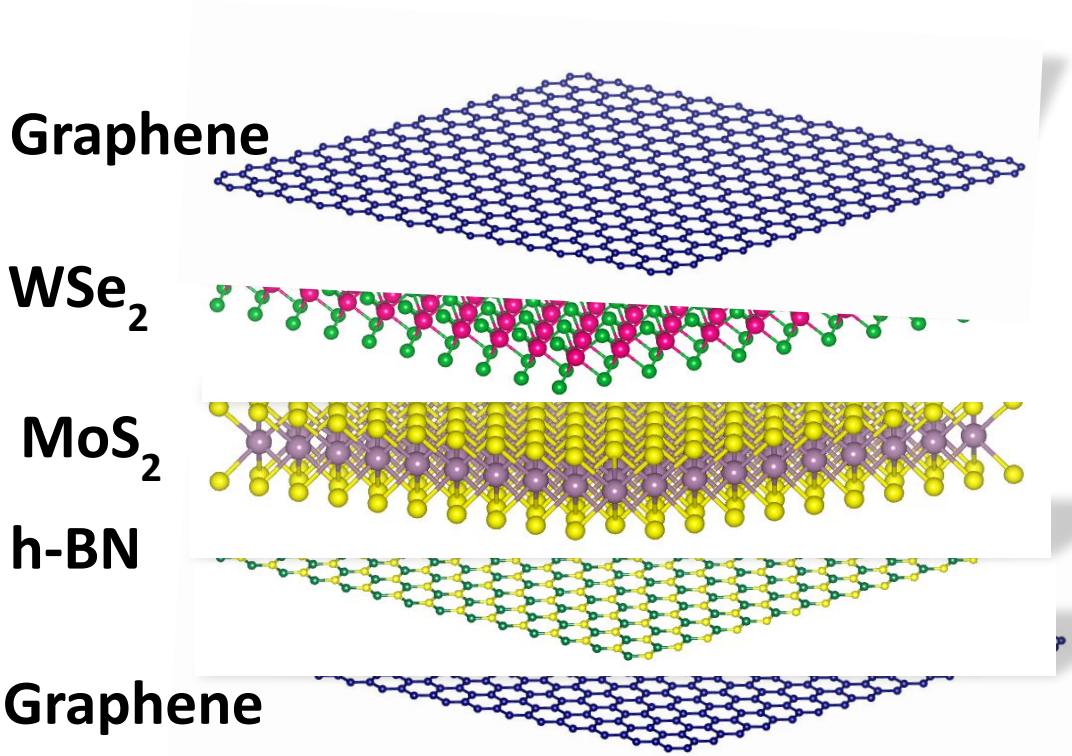
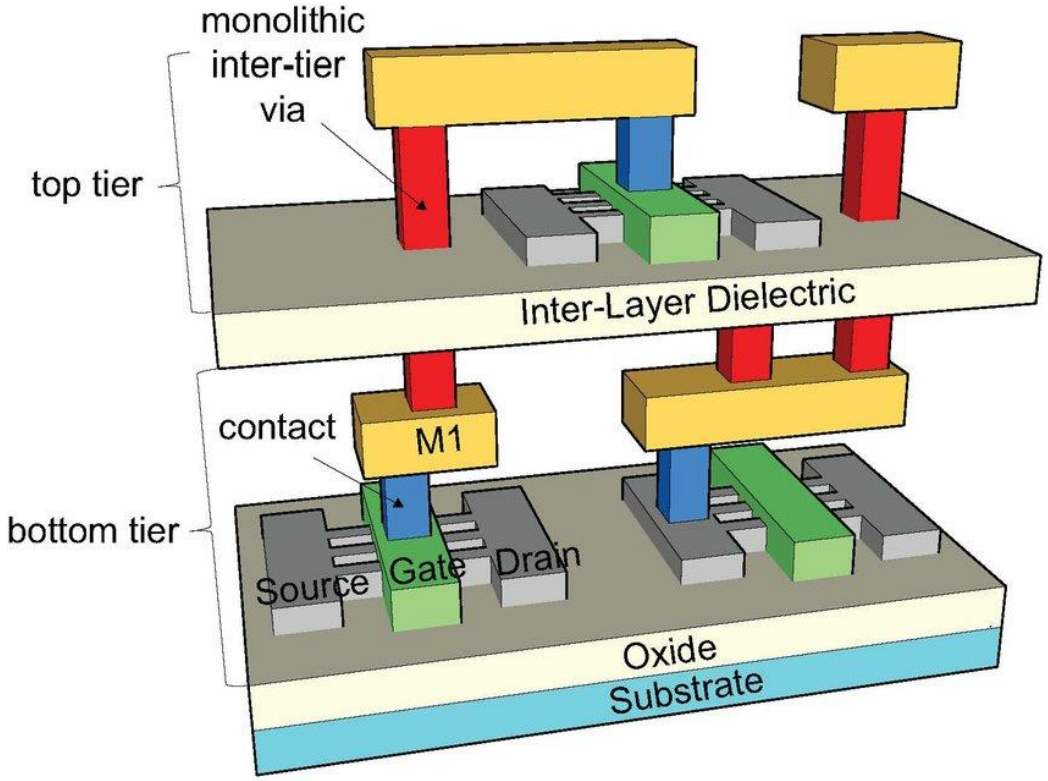
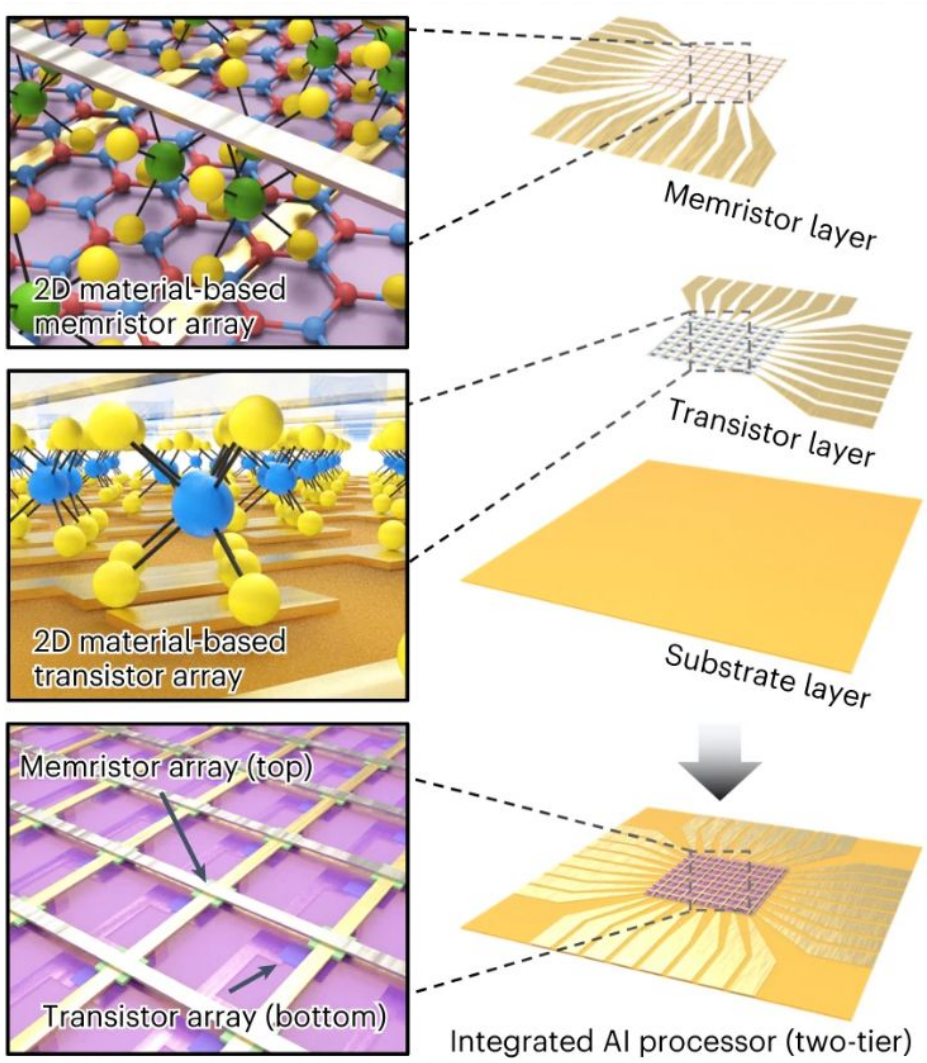
Van der Waals heteroepitaxy





Van der Waals heteroepitaxy

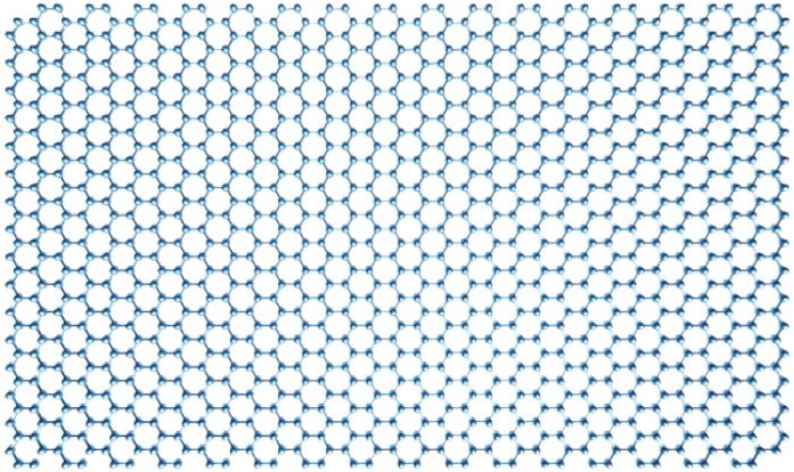


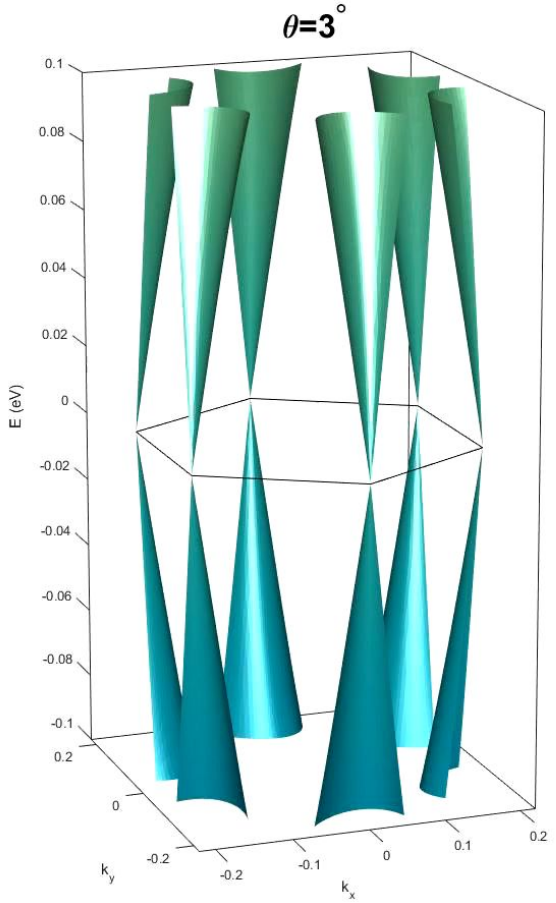


Monolithic 3D integration of 2D materials-based electronics towards ultimate edge computing solutions.

Kang J.H. et al. Nature Materials, 2023

Correlated electrons in twisted graphene heterostructure

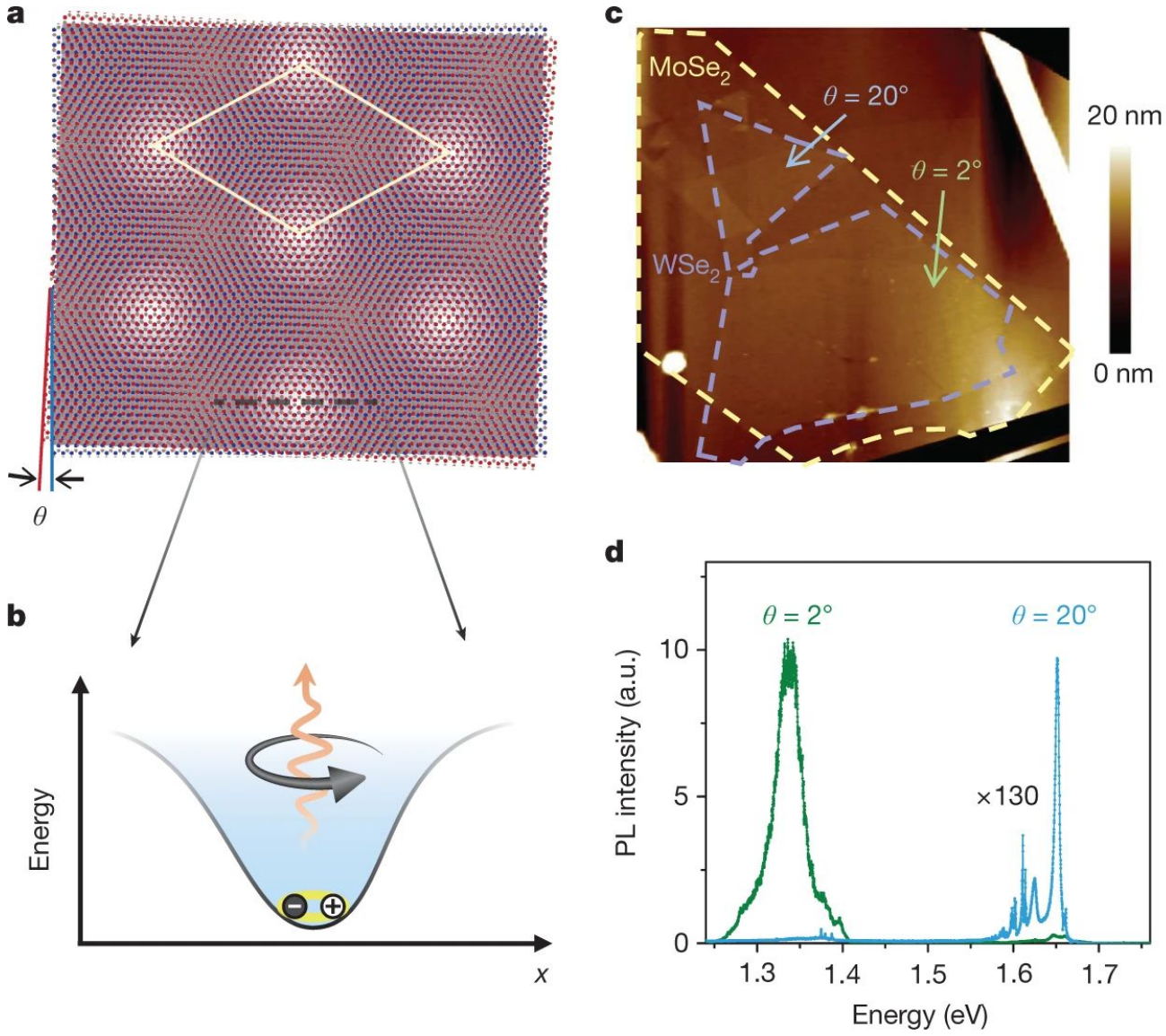




- Twisted bilayer graphene displays various correlated electronic phases associated with forming ultra-flat electronic bands near an interlayer ‘magic angle’ of 1.1°.
- The band structures of moiré materials are fragile and easily manipulated by small structural deformations in the superlattice.

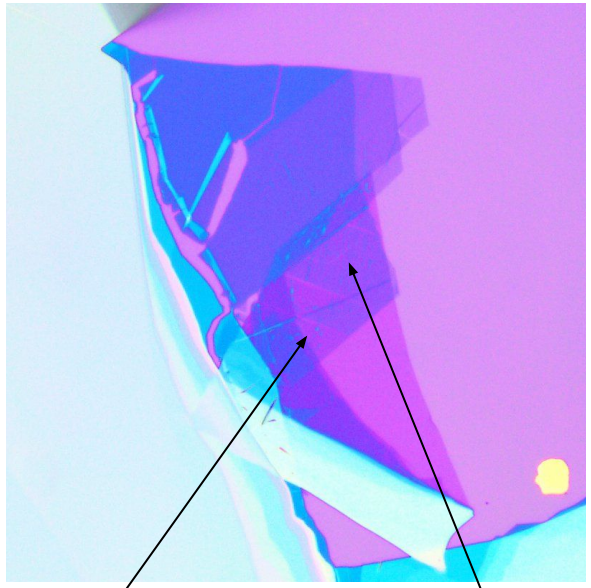
Cao Y. et al, Nature, 2018

Moiré-trapped excitons in $MoSe_2/WSe_2$ heterobilayers

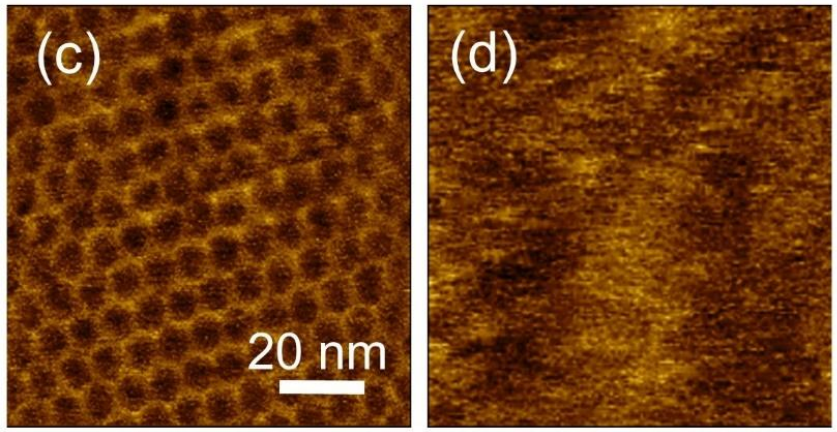


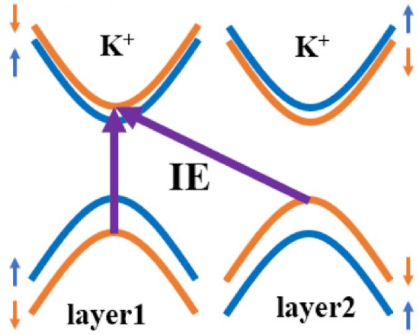
Seyler K.L. et al, Nature, 2018

$MoSe_2/MoS_2$ moiré superlattices

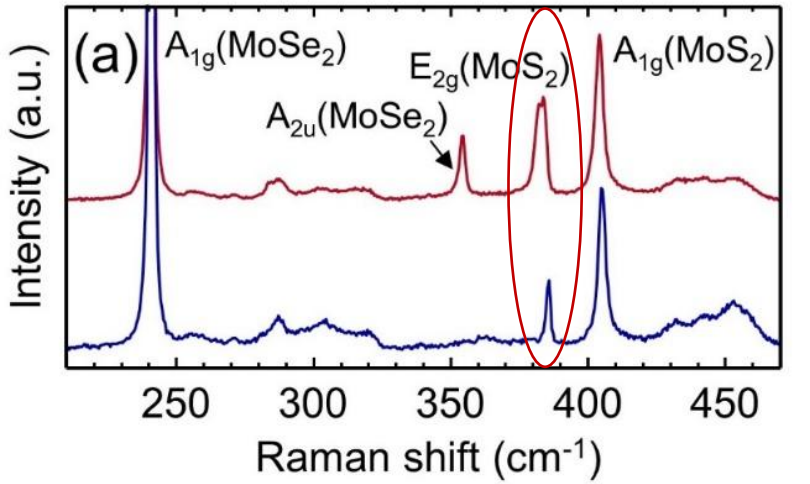


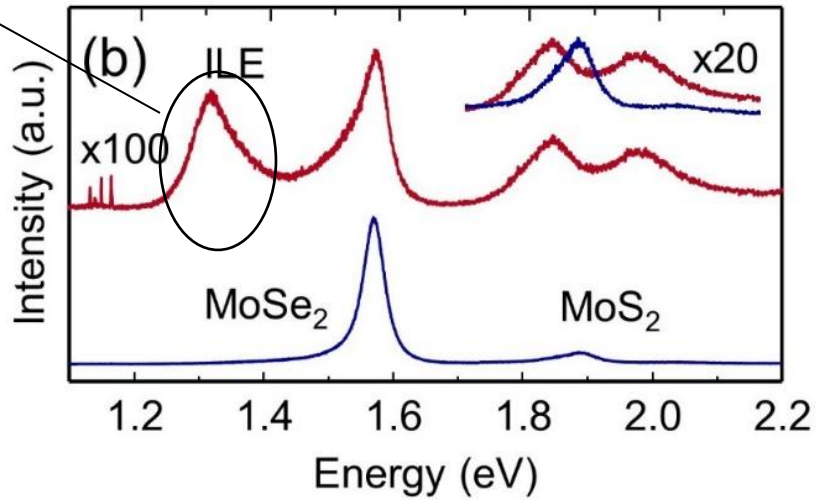
$MoSe_2/MoS_2$





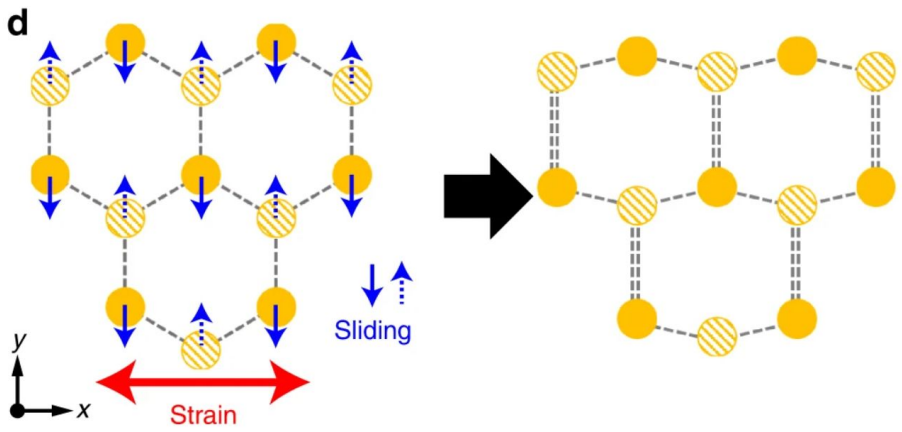
Moiré pattern obtained from high resolution atomic force microscope

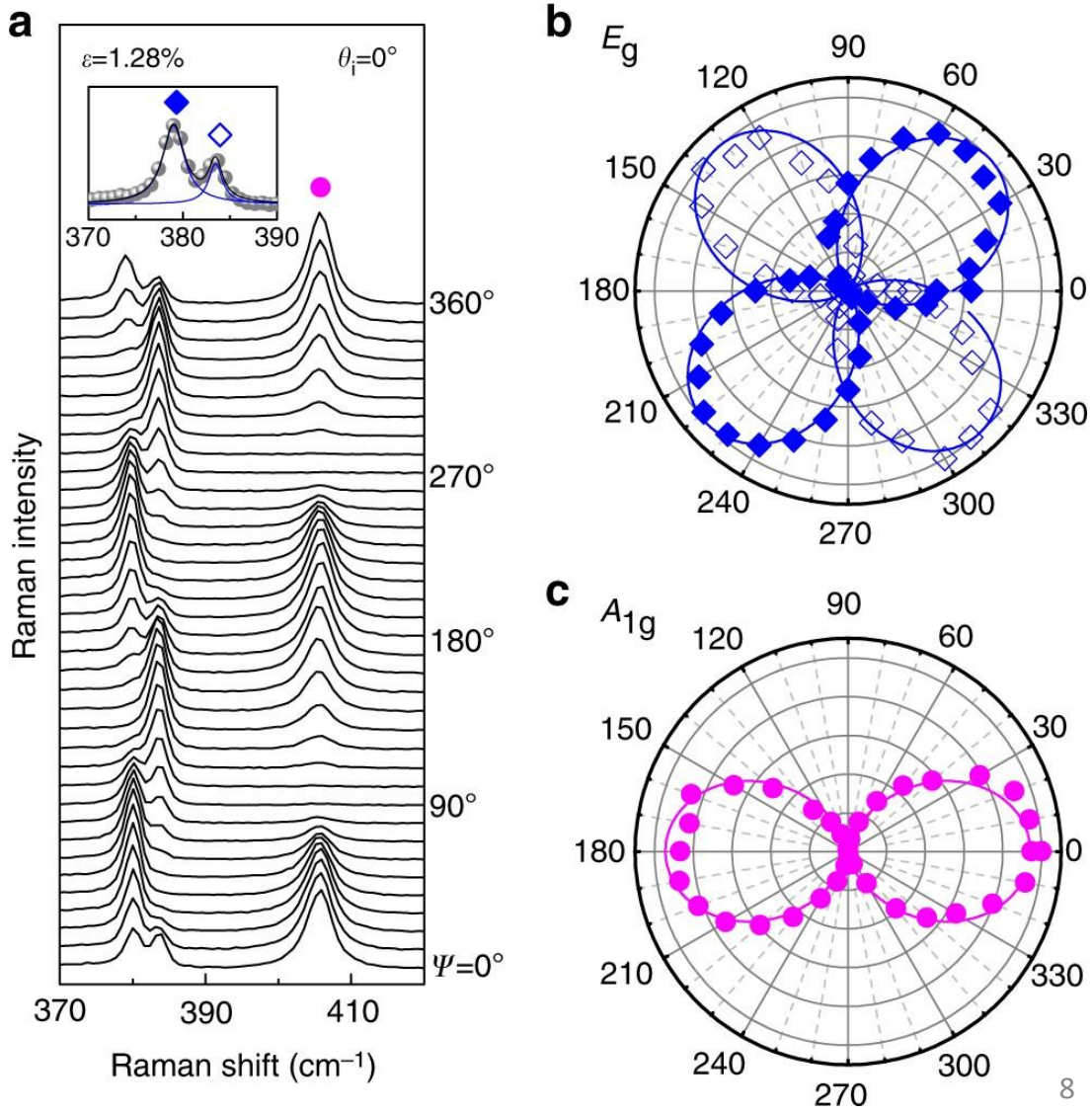




Rodríguez A. and G.H. et al. ACS Nano, 2023

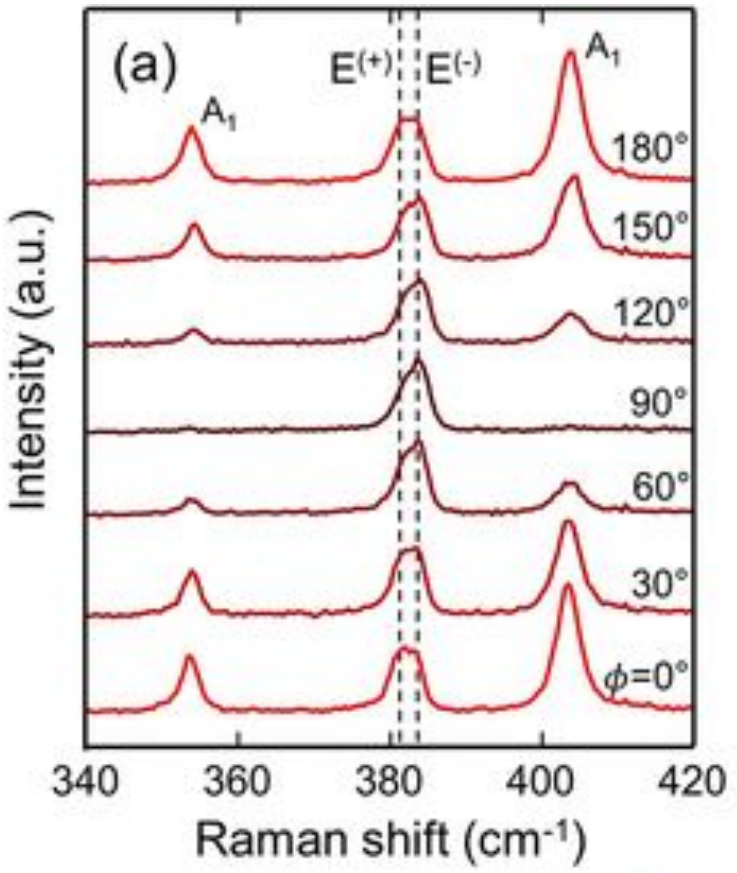
Strain-shear coupling in bilayer MoS_2

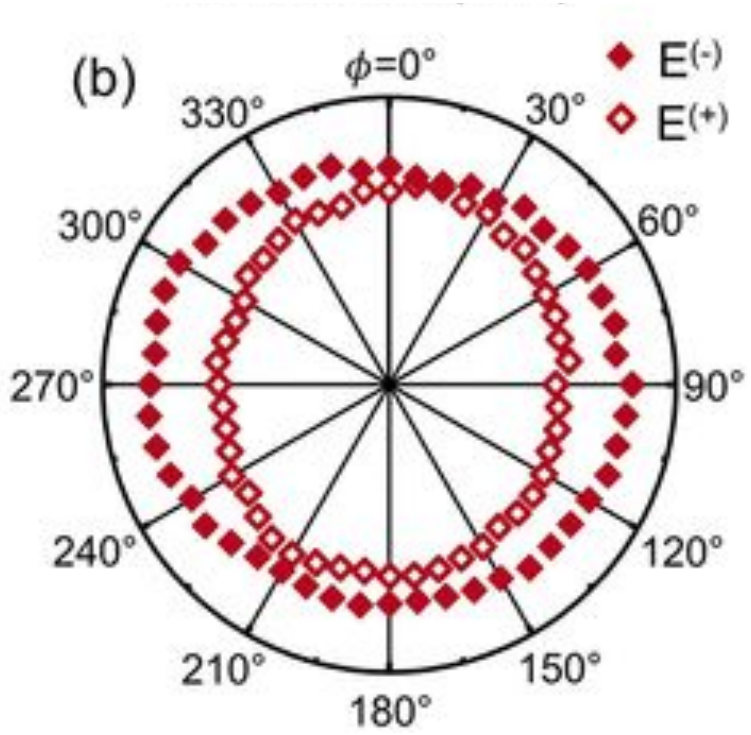




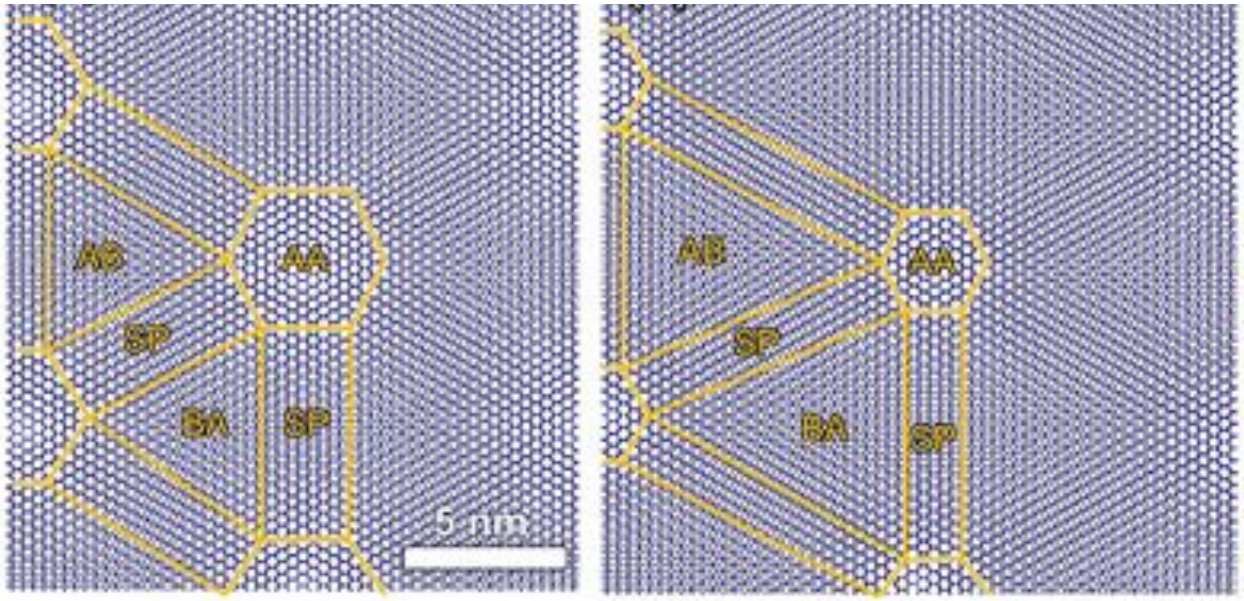
Lee J.U. et al. Nature Communication, 2017

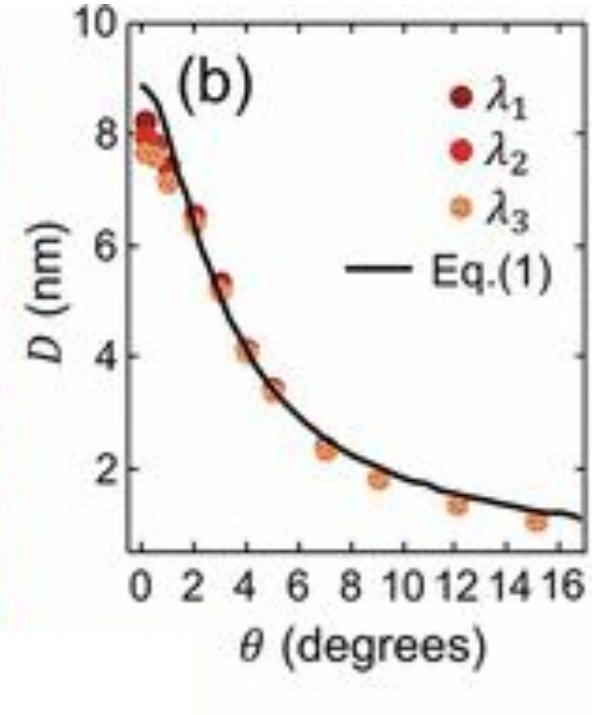
Complex strain scapes in $MoSe_2/MoS_2$ moiré superlattices





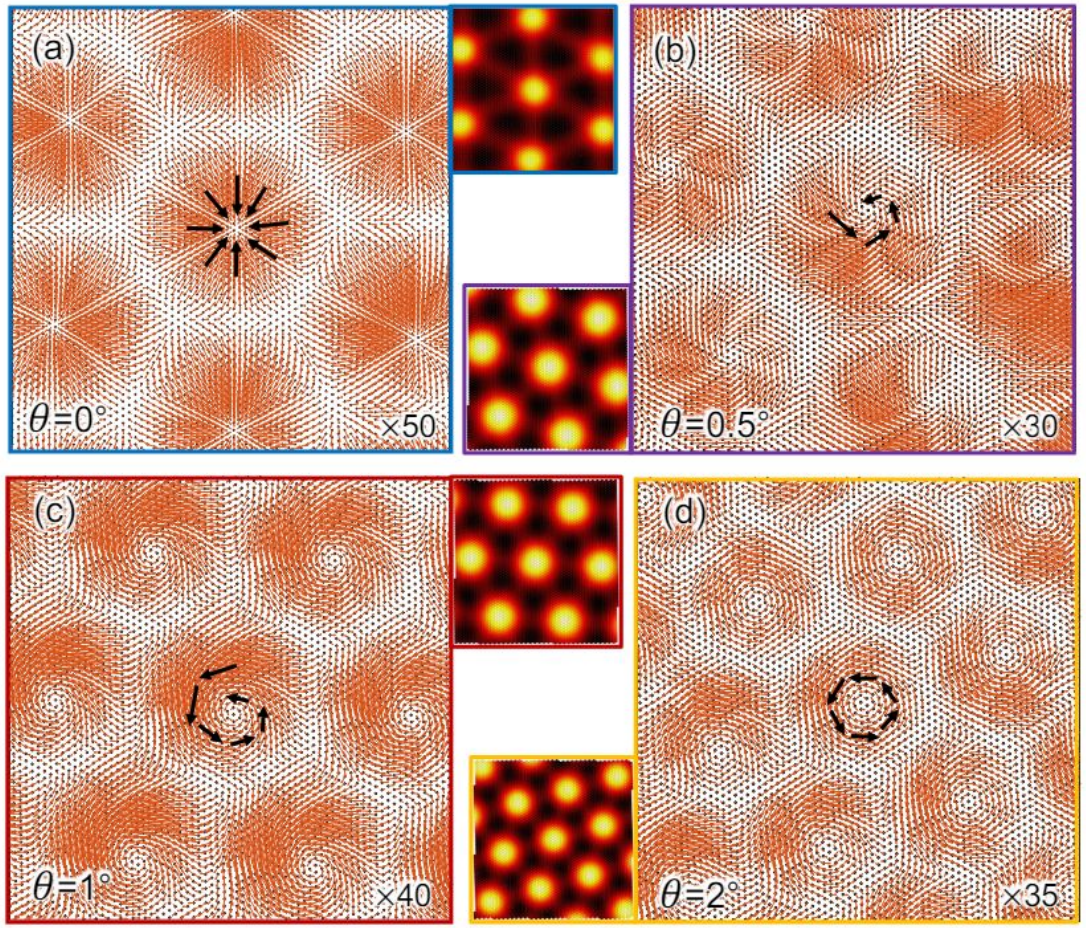
Reconstructed $MoSe_2/MoS_2$ moiré superlattices

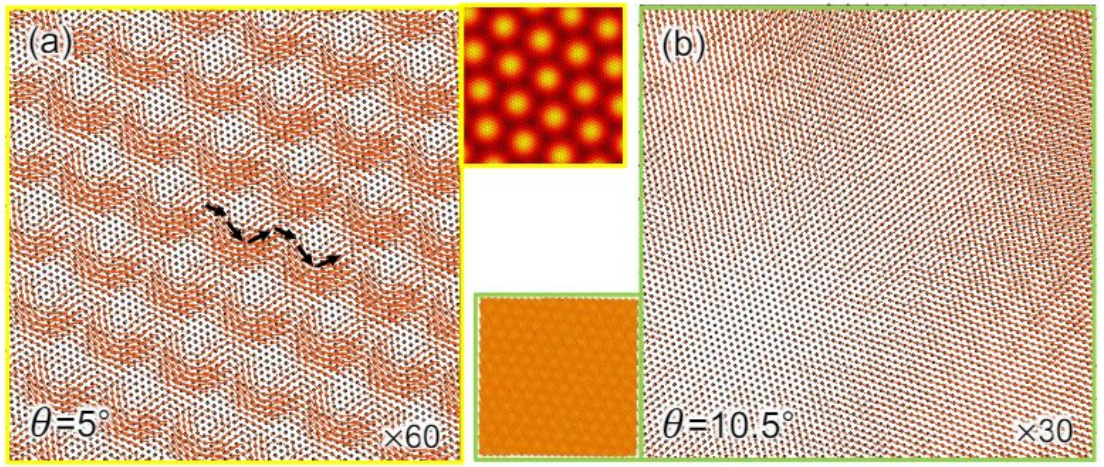


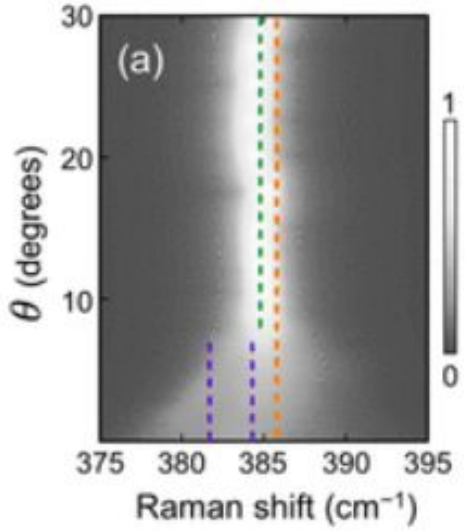


$$D(\theta) = \frac{d_{MoS_2}\delta}{\sqrt{1+\delta^2-2\delta\cos\theta}} \qquad \textbf{(1)}$$

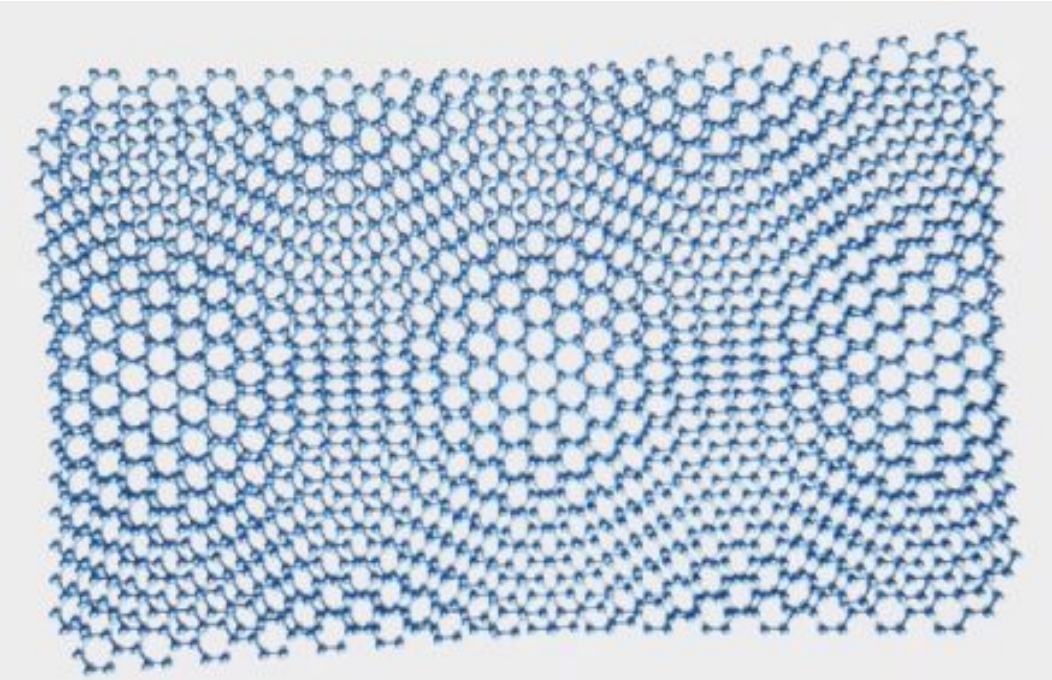
Reconstructed $MoSe_2/MoS_2$ moiré superlattices



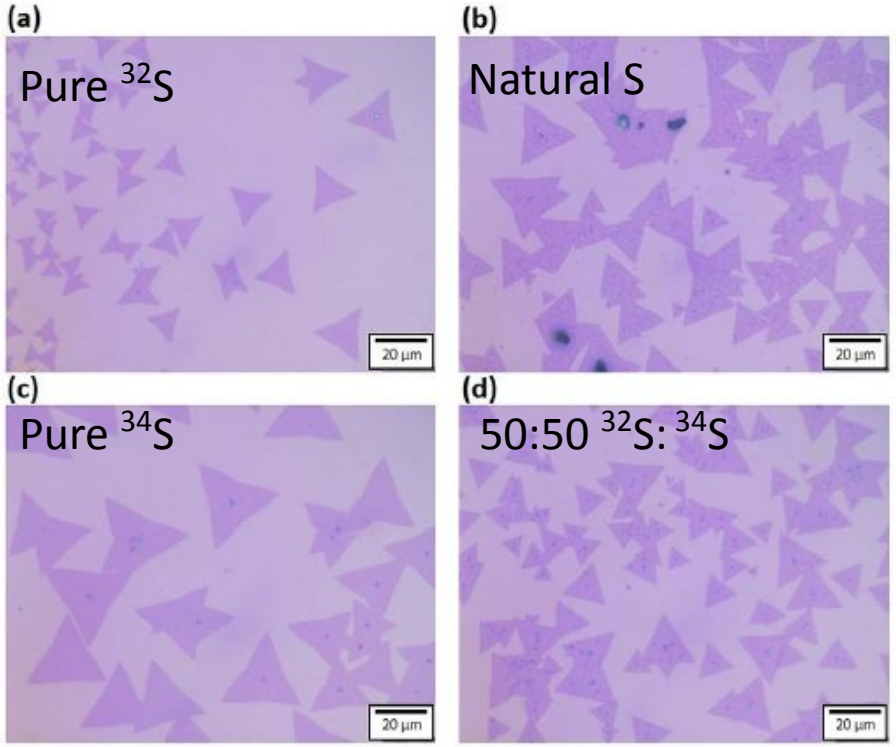


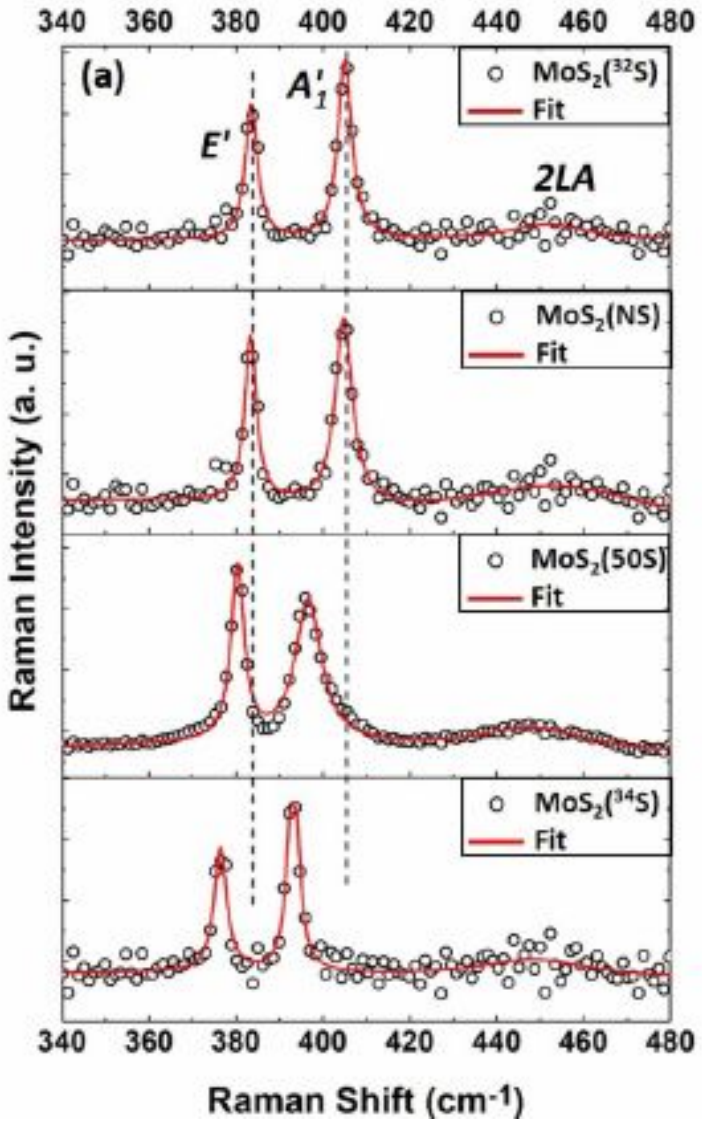


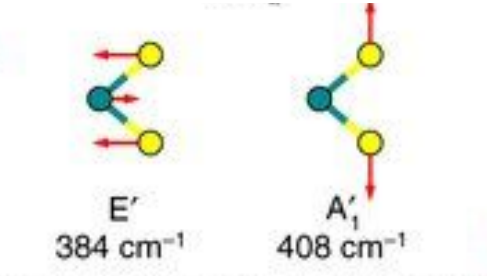
Can we optically probe lattice reconstructed moiré homostructures?

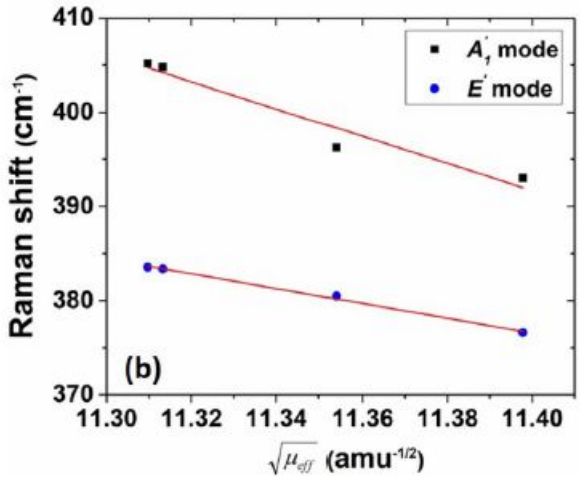


Probing isotopically marked layers



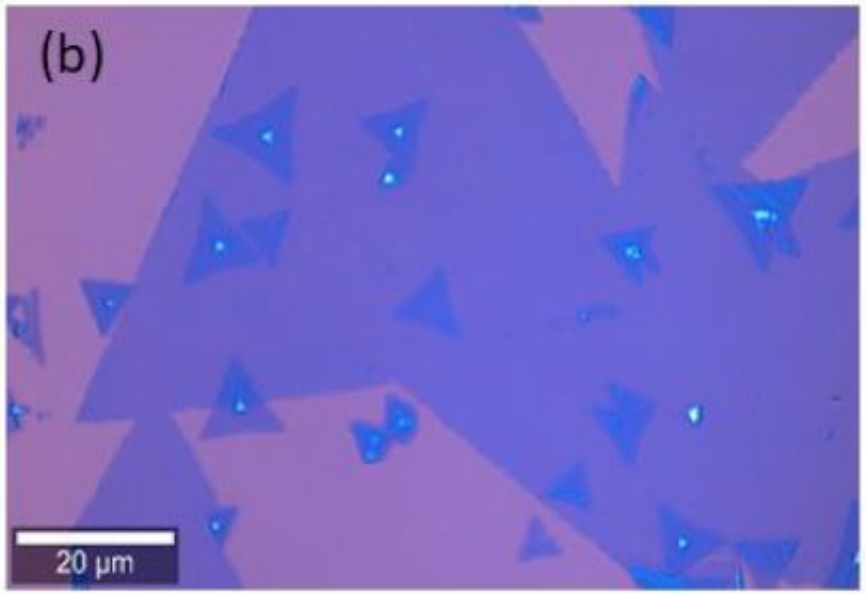


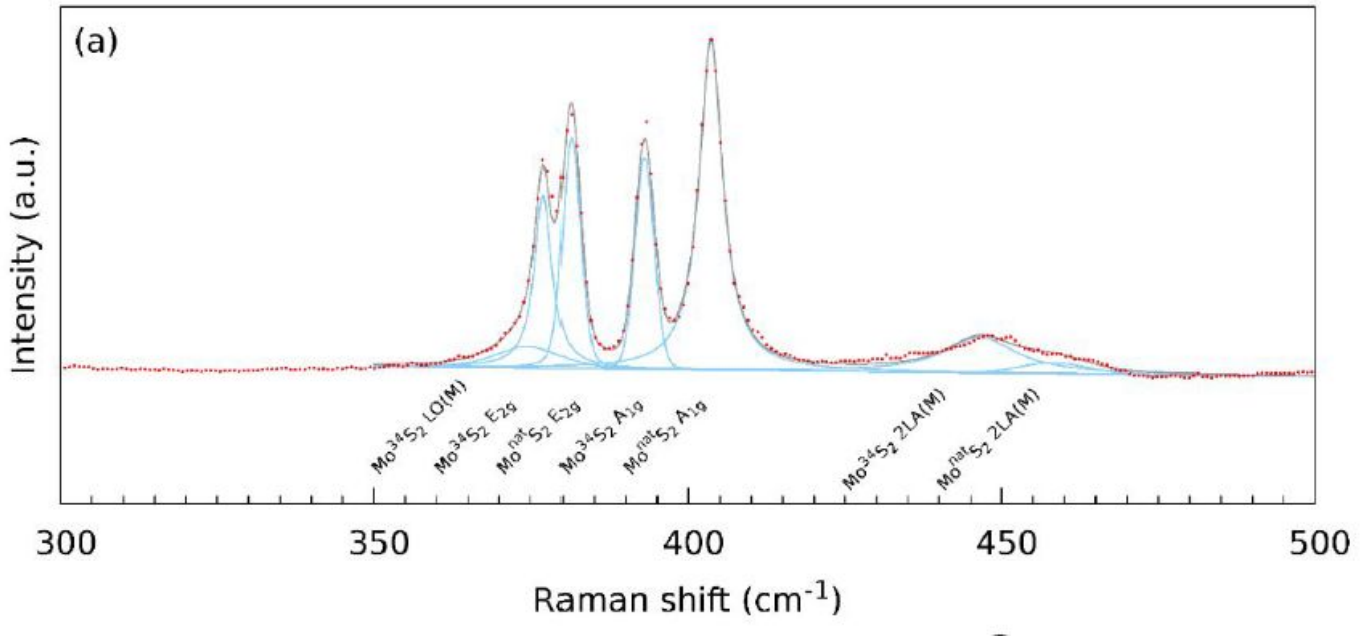




Varade V. and GH et al. 2D Materials, 2023

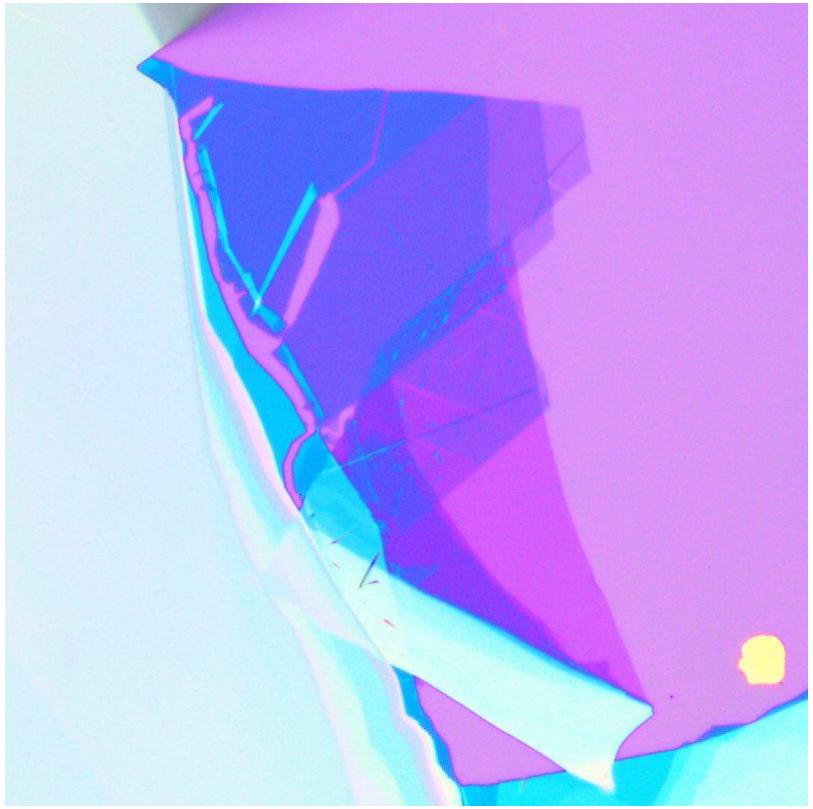
Isotopically marked heterostructures



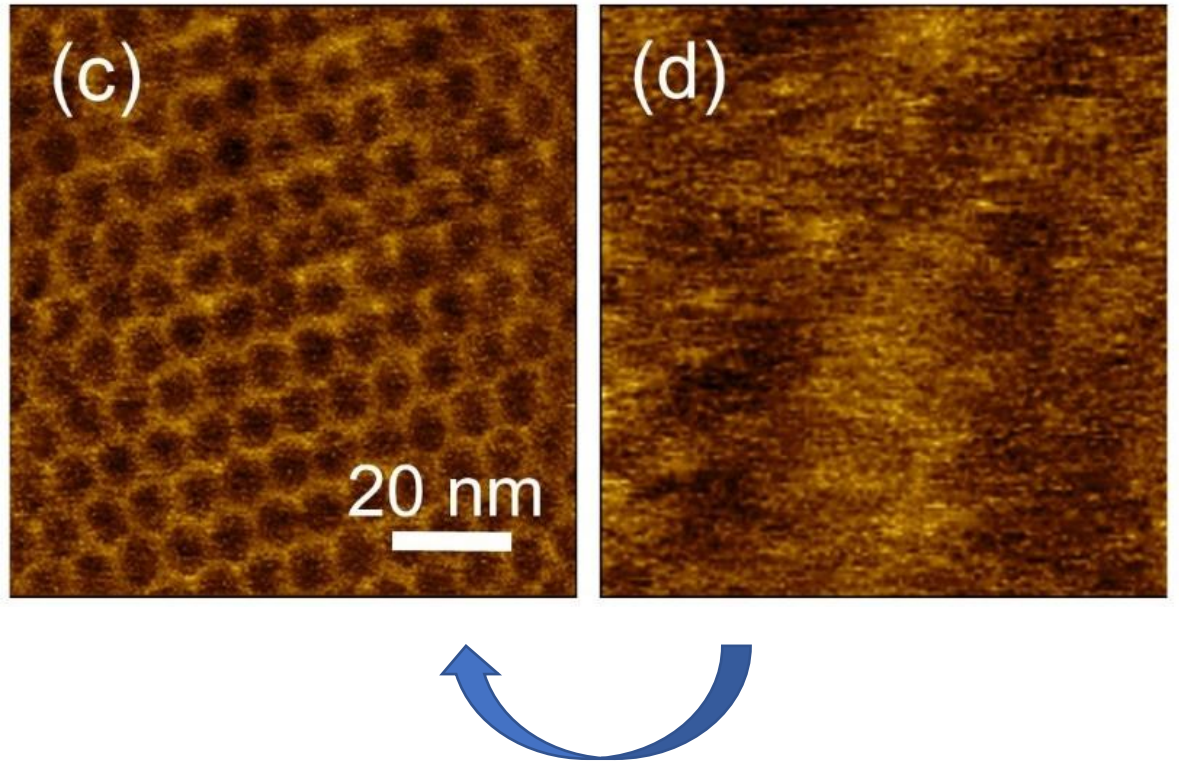


Varade V. and GH et al. in preparation

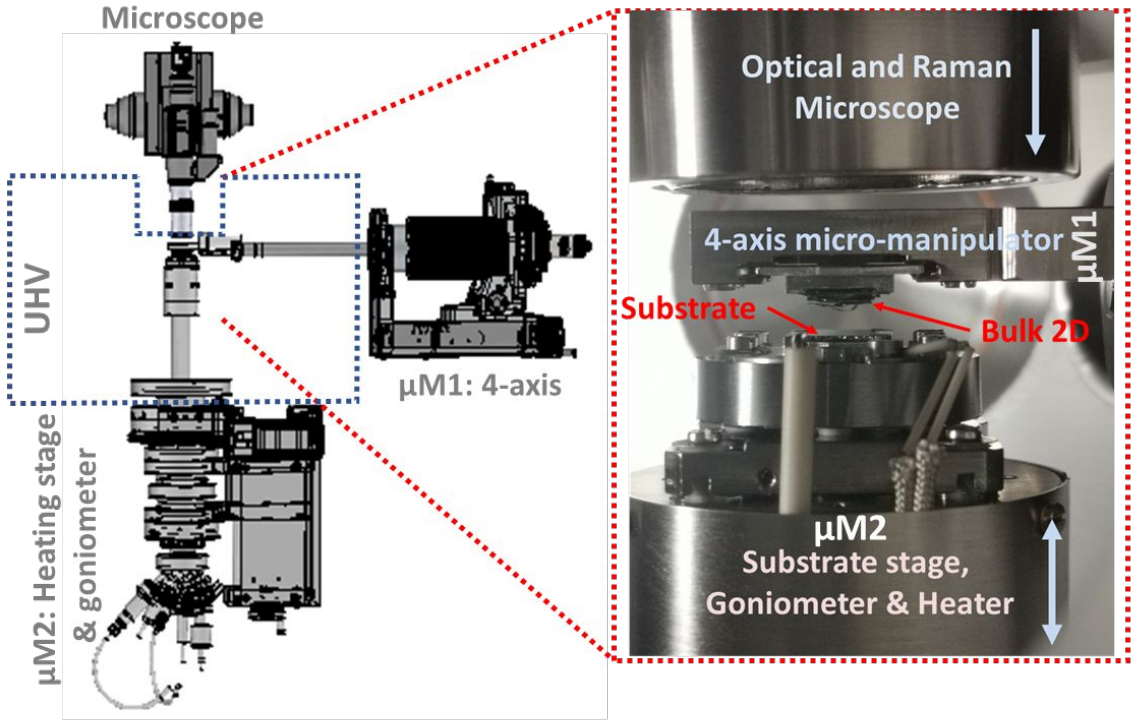
Stacking of 2D layers under ultra-high vacuum conditions

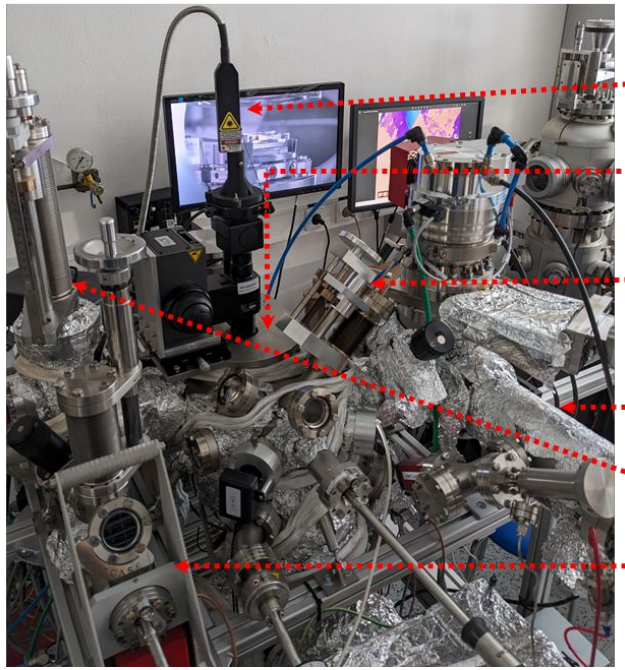


$MoSe_2/MoS_2$ HBL



Ultra-high vacuum exfoliation system

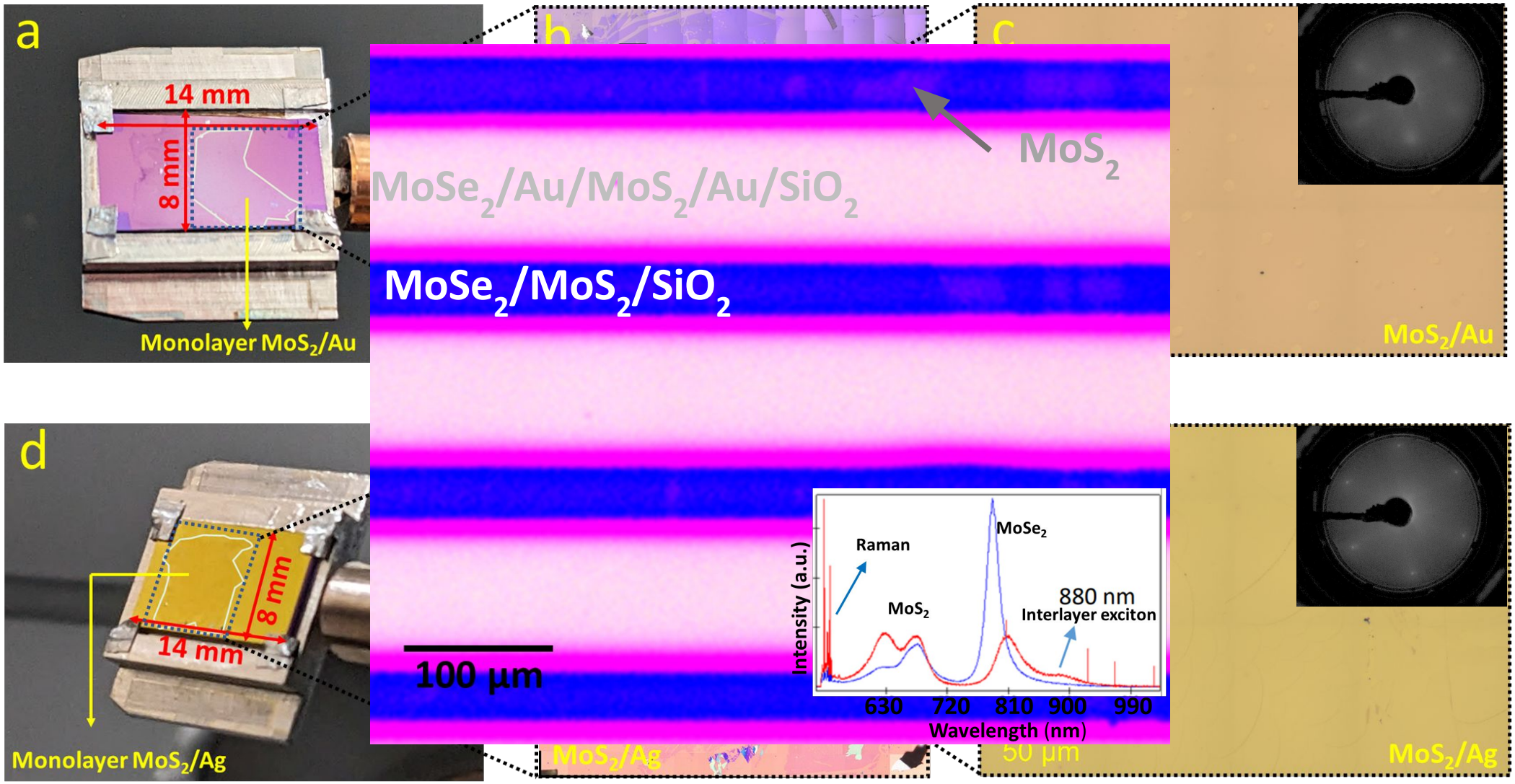




Combine metal- and dielectric-assisted exfoliation

Scalable van der Waals heterostructure

Large-area exfoliation and heterostructure design



Haider G. et al., ACS Applied Electronic Materials, 2024

Summary

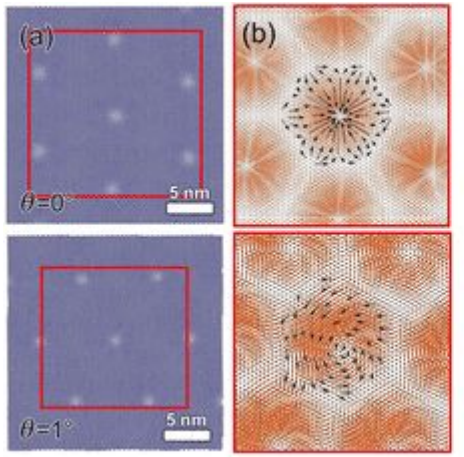
- Our study reveals that **small twist angles (between 0 and 2°) give rise to considerable atomic reconstructions**, large moiré periodicities, and high levels of local strain (with an average value of ~1%).

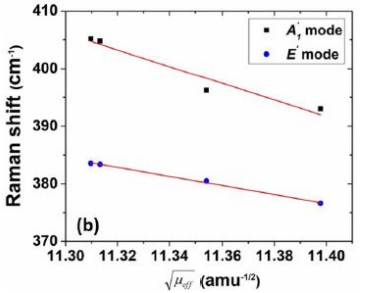
- The formation of **moiré superlattices leads to a complex strain distribution characterized by a combined deformation state of uniaxial, biaxial, and shear components**.

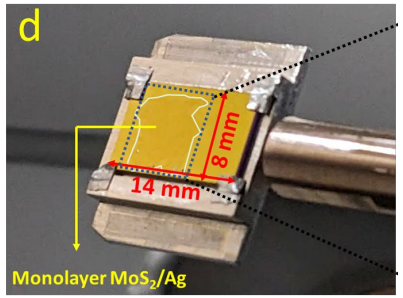
- **Larger twist angles (>10°) hinder lattice reconstruction** and produce moiré patterns of small periodicity and negligible strains.

- **Isotopically marked 2D layers** provide another possibility to investigate constituent layers in 2D heterostructures **optically**.

- Careful manipulation of **2D layers under UHV conditions** may address the scalability and reproducibility issues of functionalities produced in 2D composites.







Role of metal on exfoliation process