Exploring novel materials for future electronic devices
Multi technique approach for synthesis and characterization of 2D TMDCs

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Two dimensional transition metal dichalcogenides (TMDCs) have captured the interest of materials science research due to their outstanding properties and prospective applications in next generation devices.[1] Here we present the growth and characterisation of MoS_2 and WS_2 which are the most well-known TMDC materials.

They are part of the family of the 2D materials presenting a variety of properties.

- energy band gap depending on the structure and the number of layers
- valley polarization due to absence of inversion symmetry and strong spin-orbit interactions
- existence of stable structures

TMDCs
Transition metal dichalcogenides

Two dimensional TMDCs monolayers are atomically thin crystalline materials of the type MX_2,

Where one layer of transition metal (M = Mo, W etc.) atoms is sandwiched between two layers of chalcogen (X = S, Se etc.) atoms.

TMDC-based piezoelectronics
self-powering nano-robots and body-implanted devices[2]

Low-power and high-performance integrated circuits
nanoscale circuits contributing towards green electronics[3]

Sensors
enhanced sensitivity to functionalisation[4]

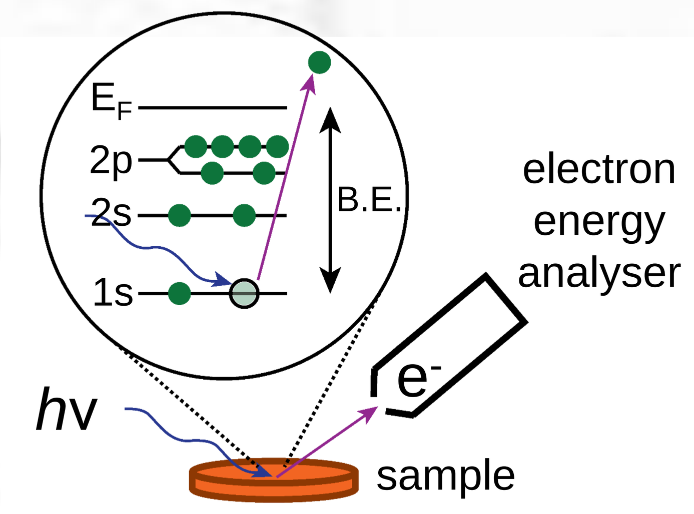
Optoelectronics
direct band gap in near Infrared and visible range[5]

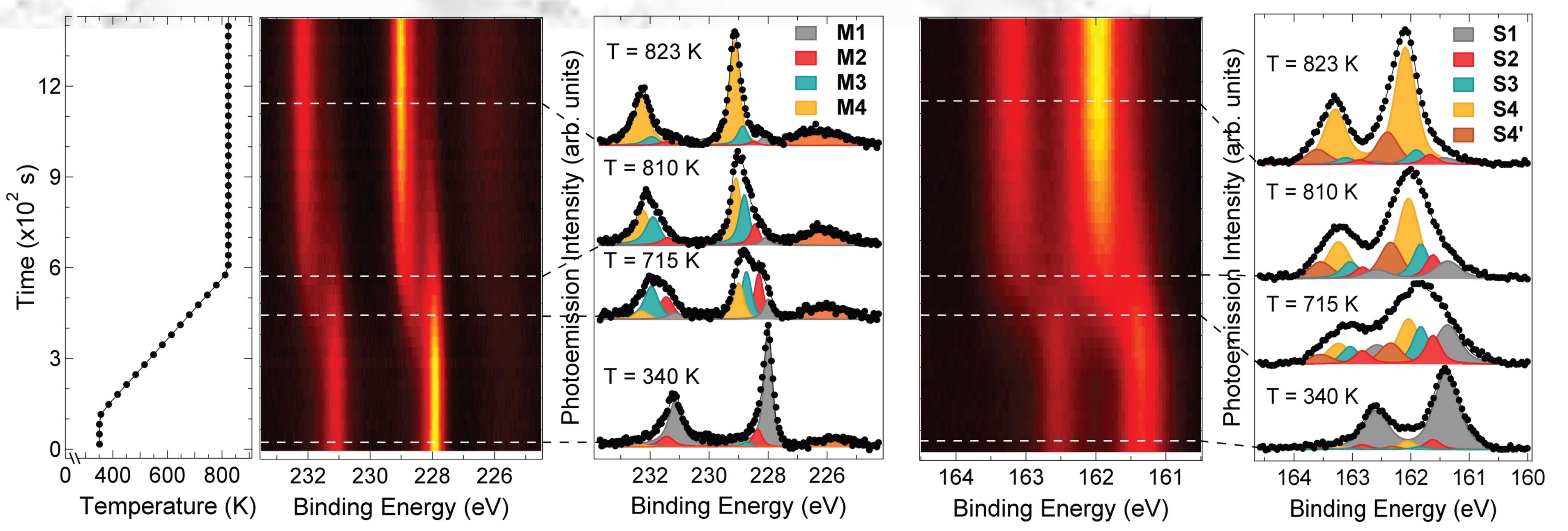
Valleytronics
degenerate valleys of energy bands well separated in momentum space[6]

Fast XPS - investigation of the growth of MoS_2 on Au(111)

Fast-XPS (X-ray Photoelectron Spectroscopy) allows to
- monitor the sample growth in real time.
- study the growth dynamics.
- avoid the growth of unwanted species by carefully tuning the growth parameters.

Mo 3d and S 2p core level spectra simultaneously acquired for the study of the growth of single layer MoS_2. [7]

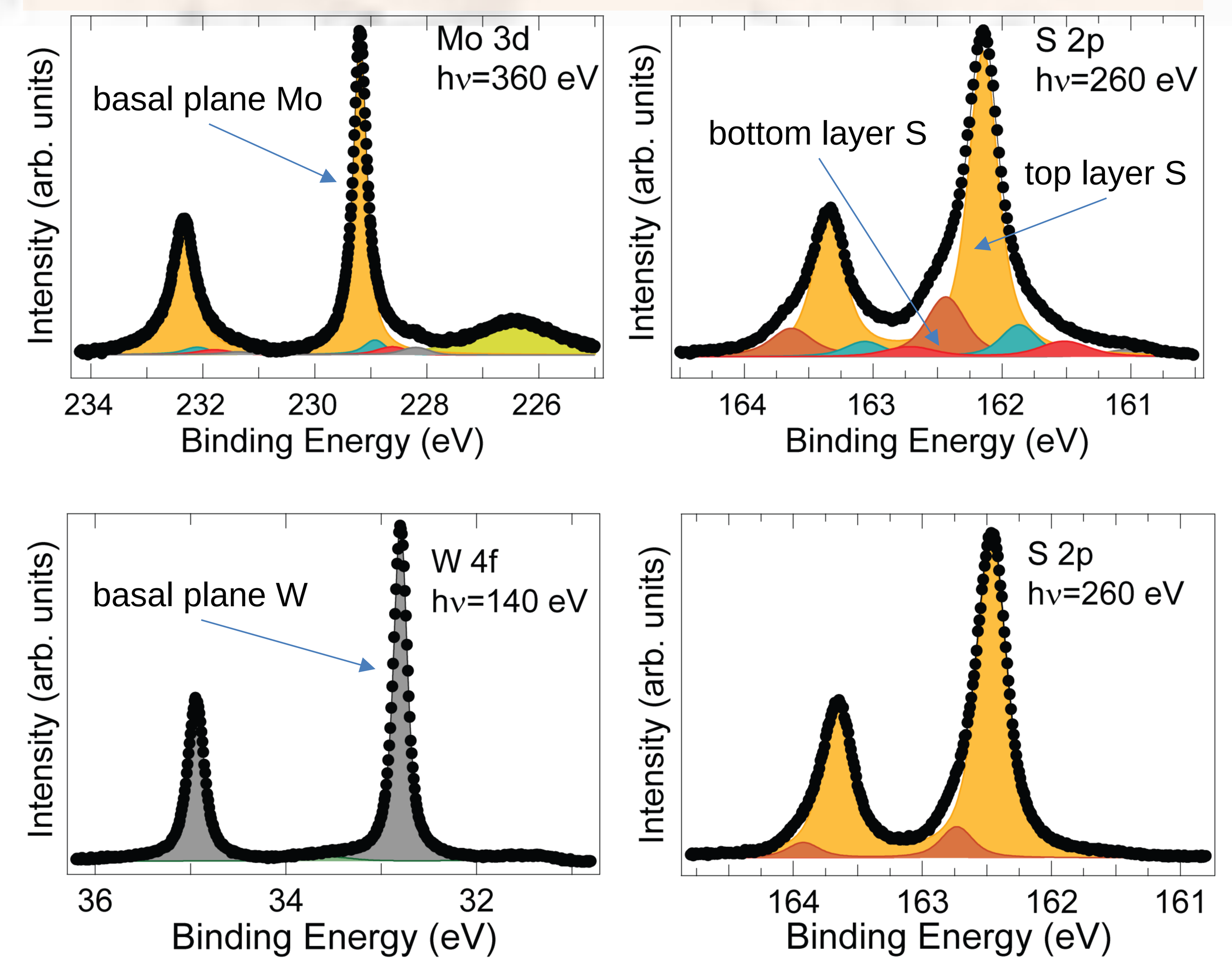




High resolution XPS

HR-XPS is
- element specific and quantitative.
- sensitive to chemical snd structural environment.

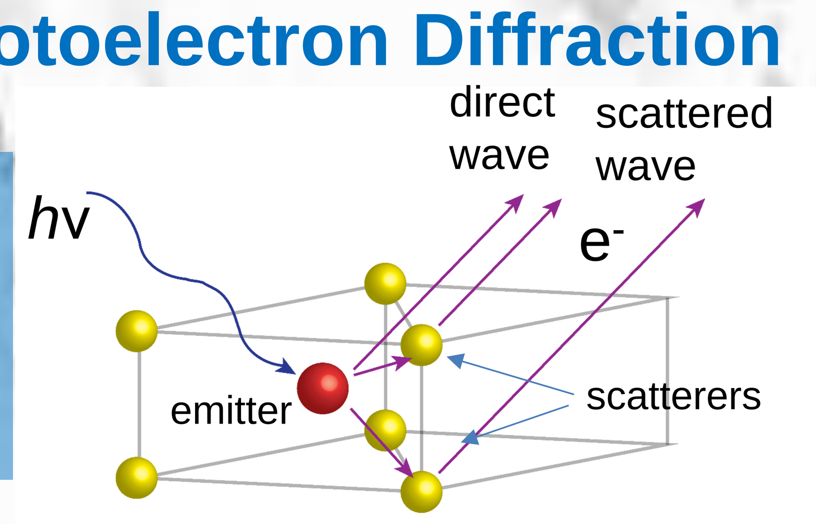
High resolution spectra of Mo 3d, S 2p and W 4f show the core level components of single layer MoS_2 and WS_2.

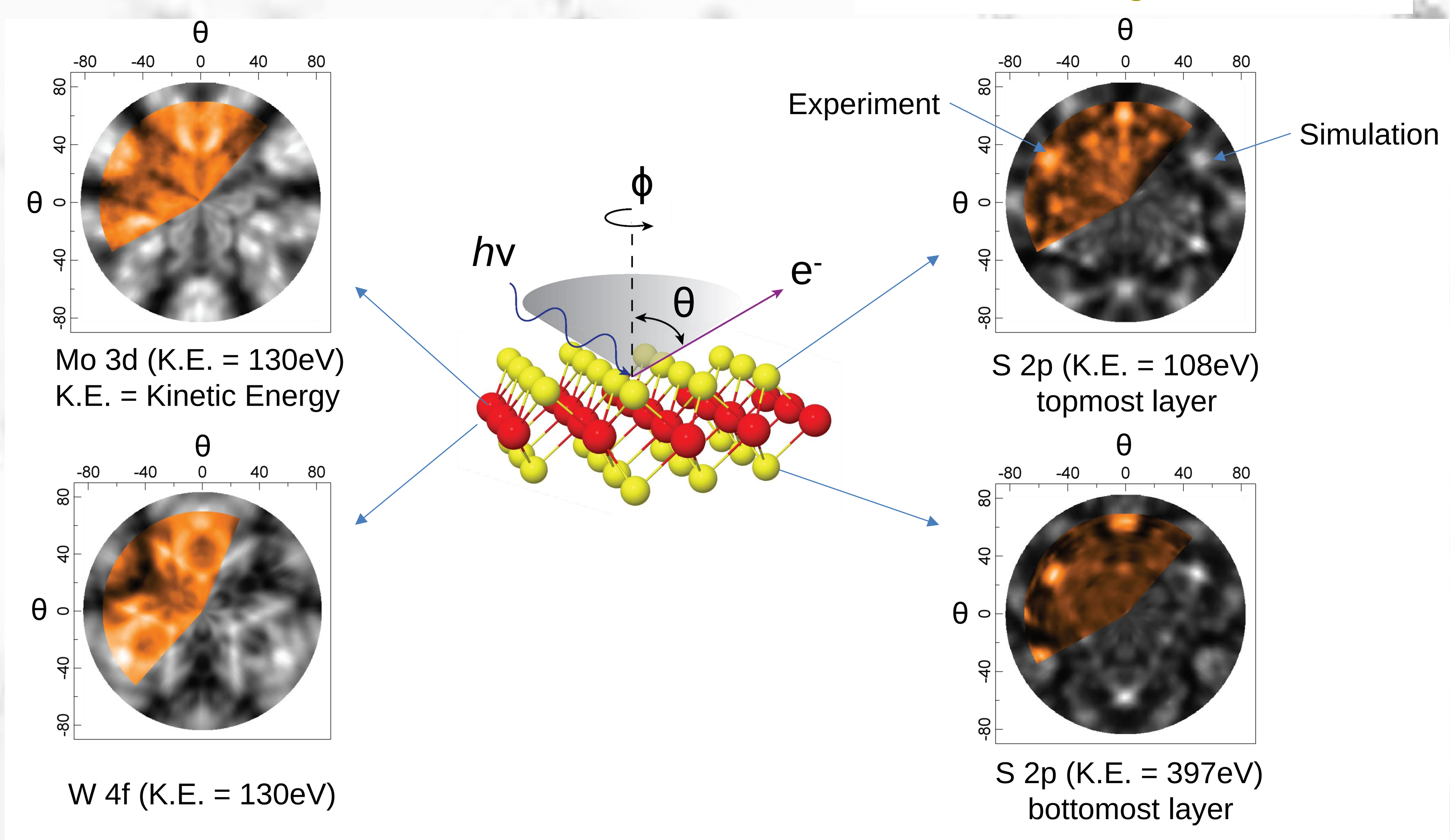


Structure determination: X-ray Photoelectron Diffraction

XPD is a powerful tool to
- examine local order .
- determine crystal structure and orientation .

XPD patterns are in excellent agreement with the simulations for single layer MoS_2 and WS_2.

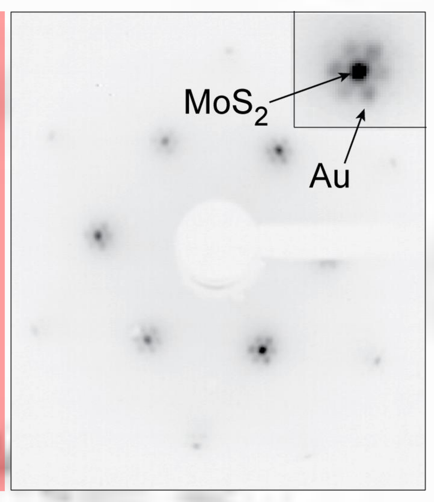




Low Energy Electron Diffraction

LEED is used to
- determine long range order.
- study symmetry and rotational alignment of the adsorbate

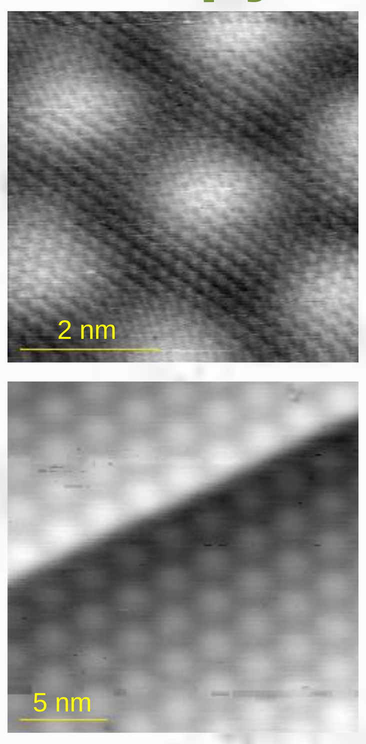
LEED image (at 117eV) for MoS_2 on Au(111) showing the moiré pattern due to lattice mismatch between MoS_2 and the substrate.



Scanning Tunnelling Microscopy

The atomically-resolved STM image on the top shows the topmost S atoms exhibiting moiré periodicity of 3.4 nm, visible in the form of bright hexagonal protrusions.

Image at the bottom shows the single layer MoS_2 nano-island carpeting over an Ag terrace.



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References:

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