Vertical 2D Crystal Hetero-structures: The Preparation, Device Application and Selective Growth

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Outline

- **Introduction**
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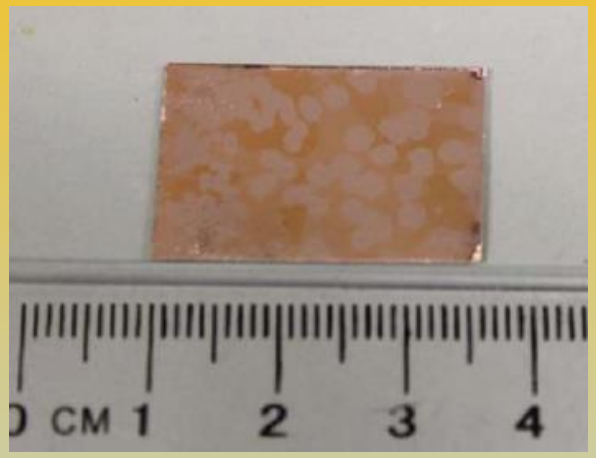
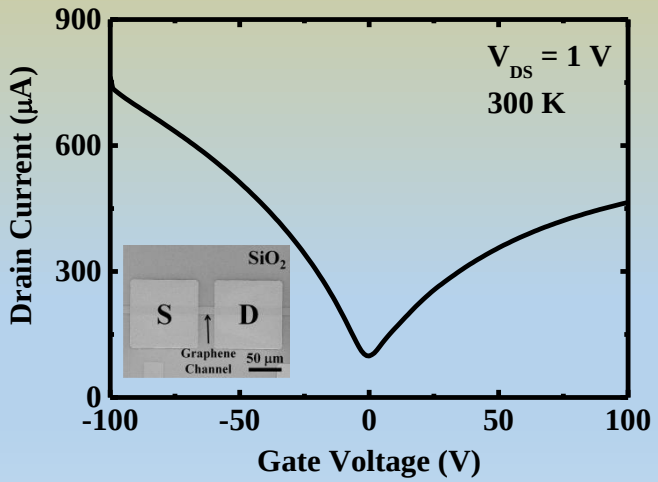
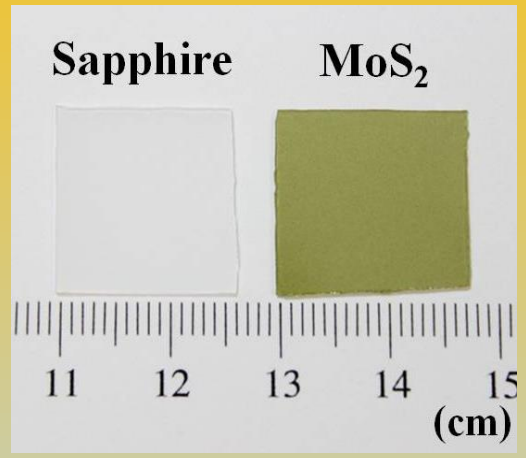
  - Approaches to obtain 2D materials
- **Results and Discussions**
  - The growth mechanism
  - The establishment of 2D crystal hetero-structures
  - Selective growth od 2D crystals
- **Conclusion**

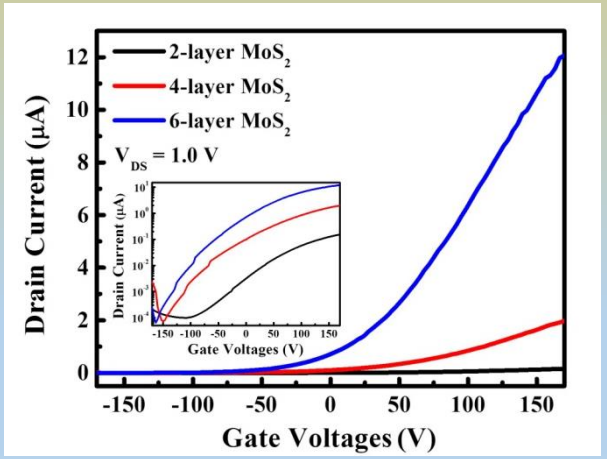
The Development of 2D Materials





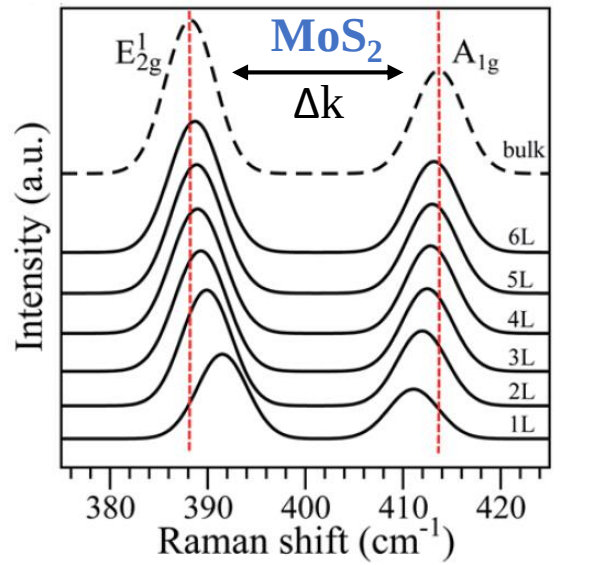
Graphene Transistors
High mobility, low ON/OFF ratios

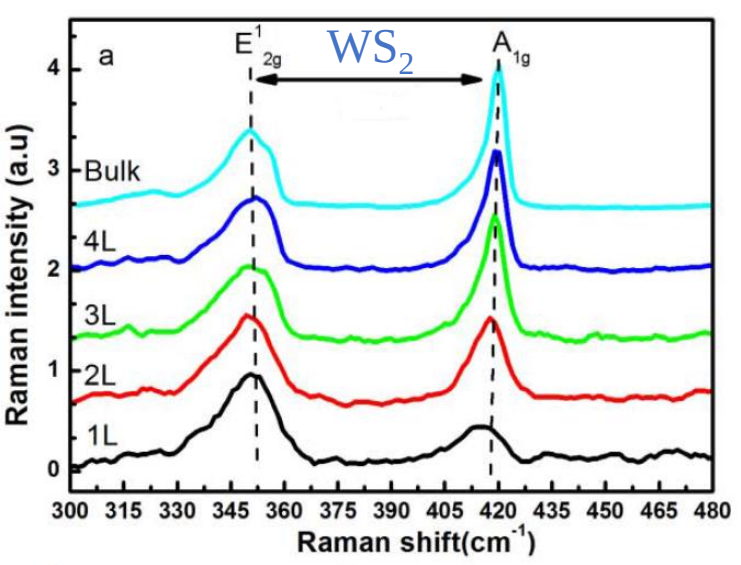


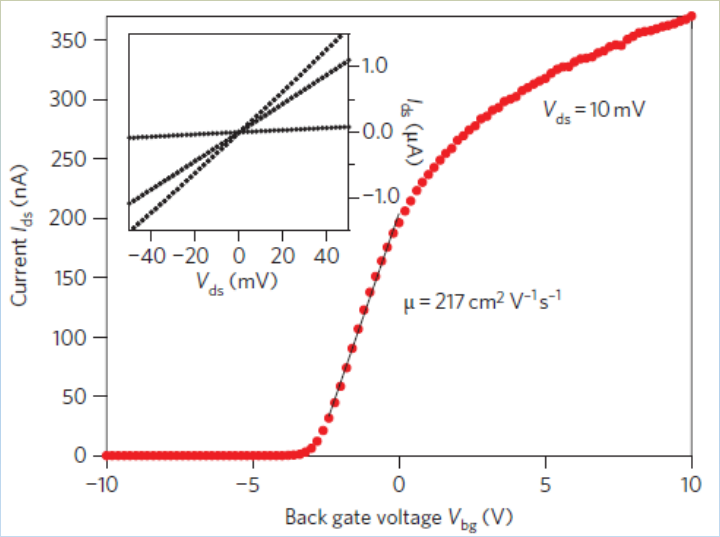


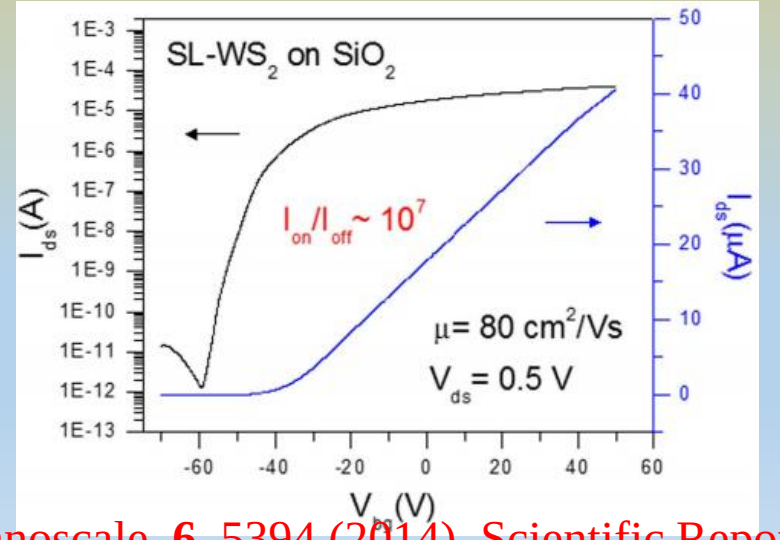
MoS_2 Transistors
Lower mobility, high ON/OFF ratios

Transition Metal Dichalcogenides (TMDs)



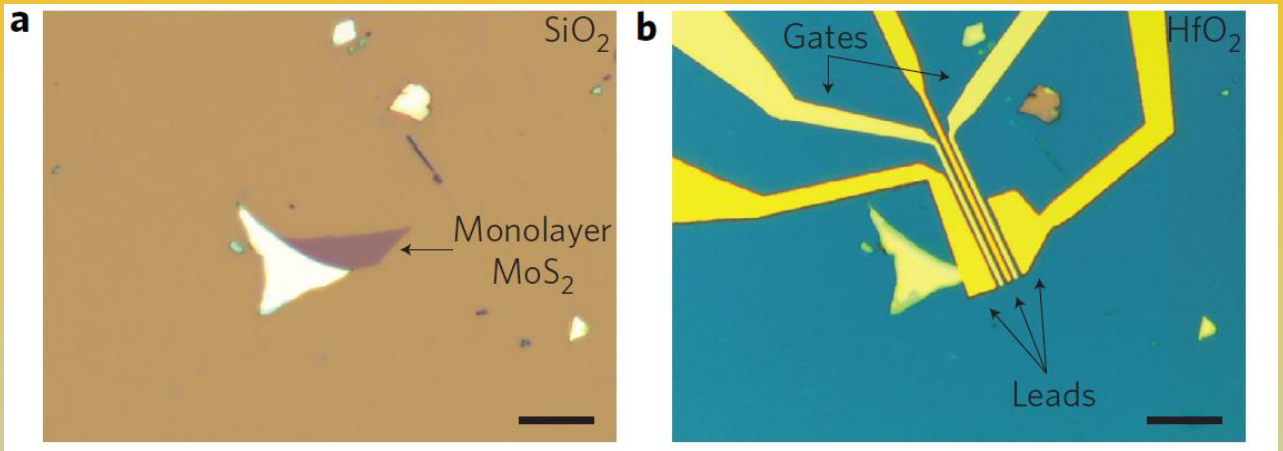






Nanoscale, **6**, 5394 (2014), Scientific Reports, **3**, 1608 (2013), Nature Nanotechnology, **6**, 147 (2011), Scientific Reports, **5**, 10699 (2015)

Approaches to Obtain 2D Materials



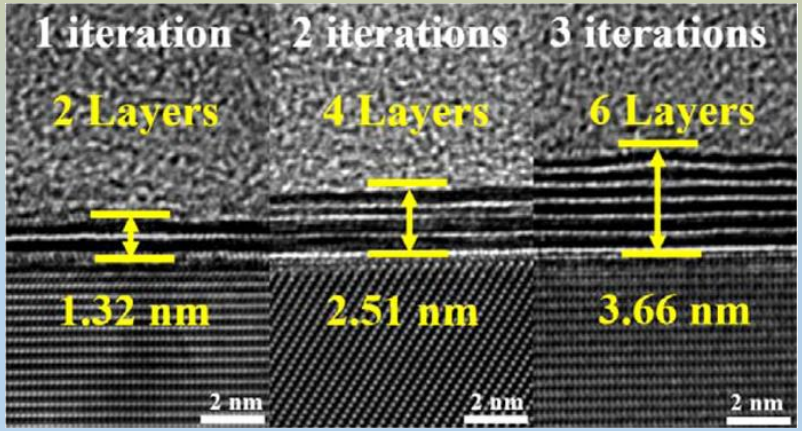
Mechanical Exfoliation

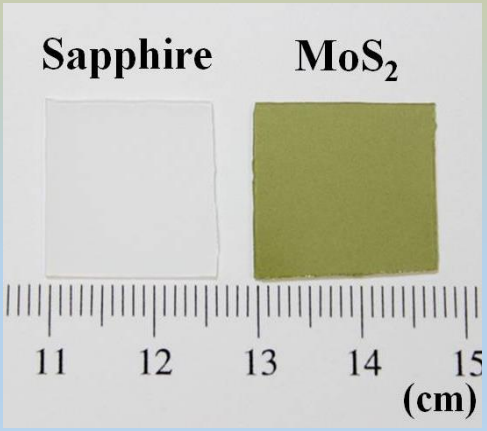
Advantage:

1. **Easy to obtain single-crystal 2D material flakes**
2. **Good device performance**

Disadvantage:

1. **Large-area films are not available**
2. **Difficult to establish hetero-structure**





Chemical Vapor Deposition

Advantage:

1. **Good layer number controllability**
2. **Wafer-scale film growth**

Disadvantage:

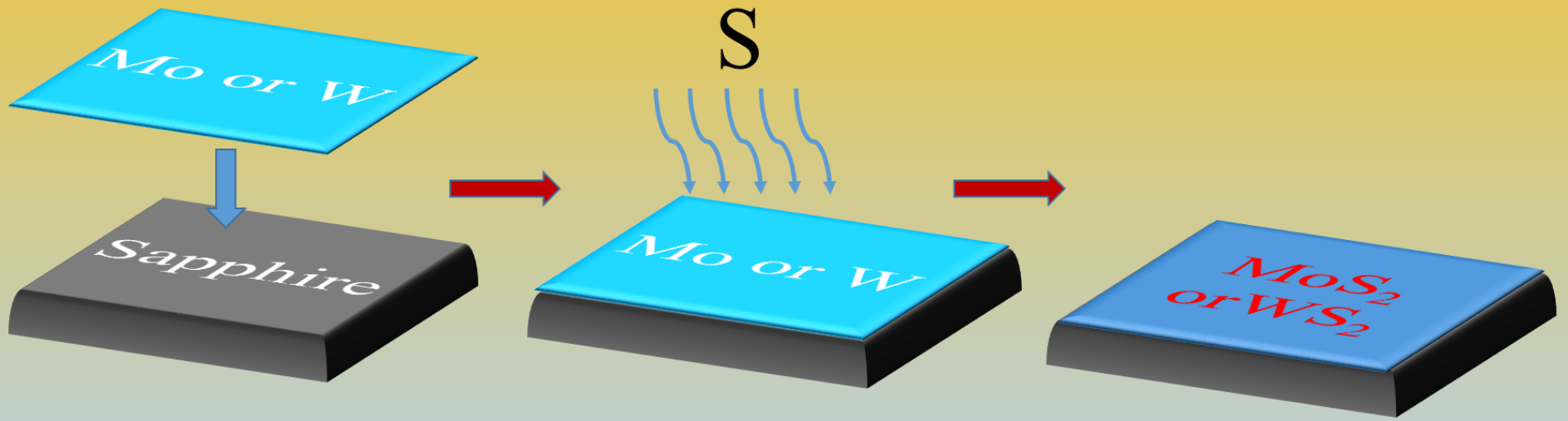
1. **The choices of precursors**
2. **Difficult to achieve selective growth**

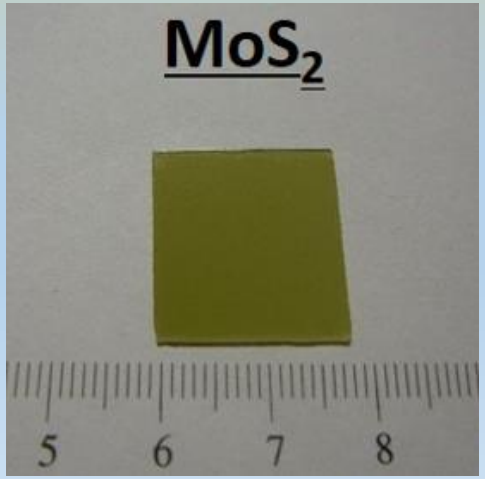
Nature Nanotechnology **6**, 147–150, 2011

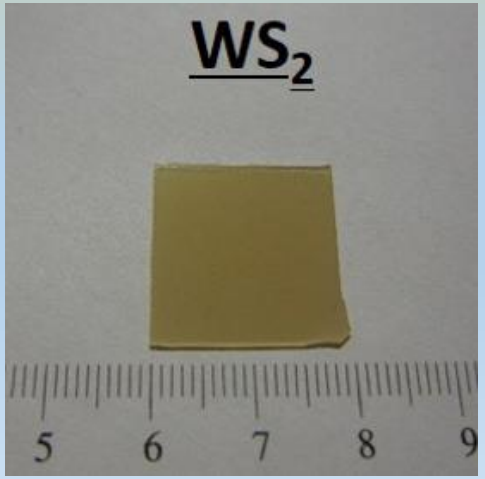
J. Phys. D: Appl. Phys. **48**, 435101, 2015

TMD Films Grown by Using Sulfurization of Pre-deposited Transition Metal films

Metal deposition **sulfurization** **MoS_2 or WS_2**

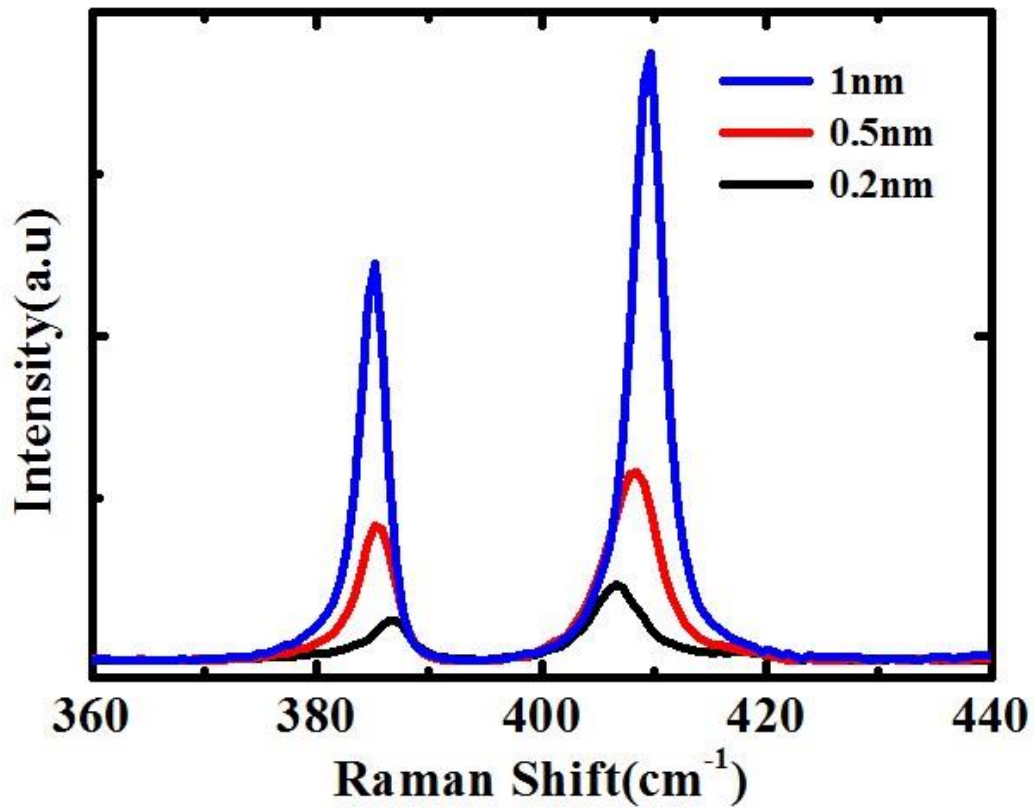


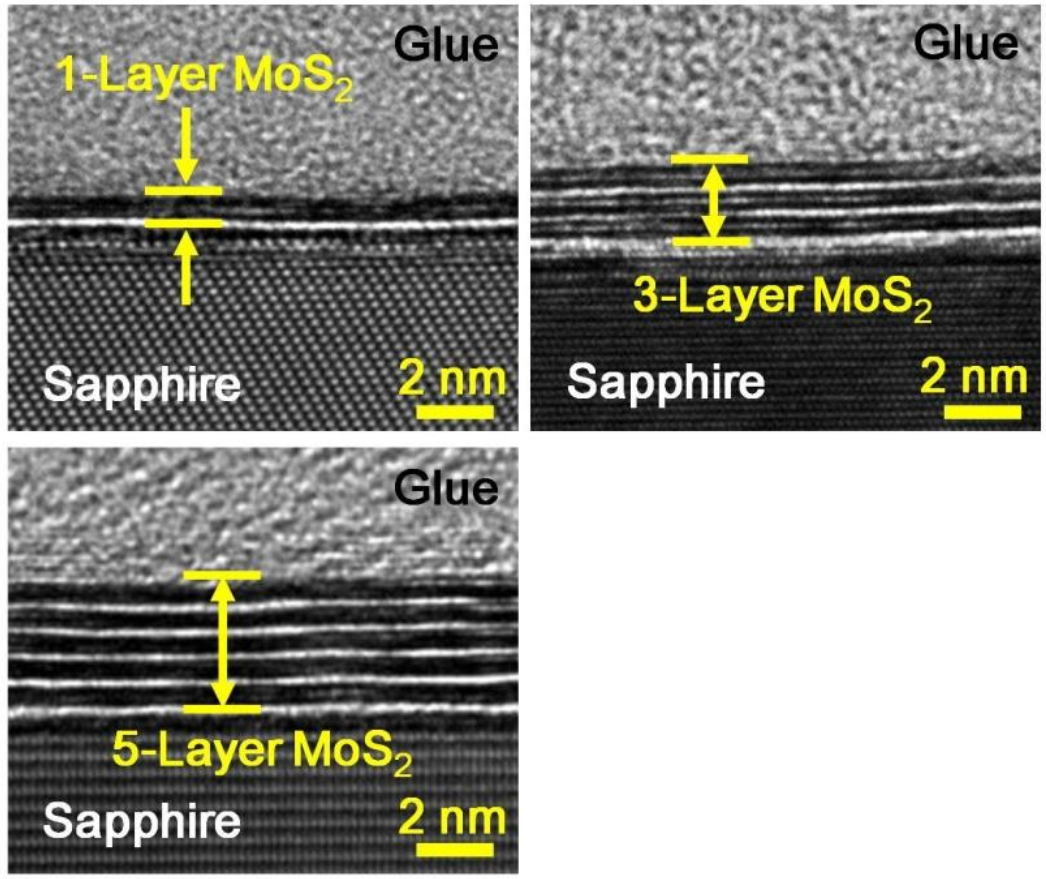




Results and Discussions

Layer Number Controllability of MoS_2

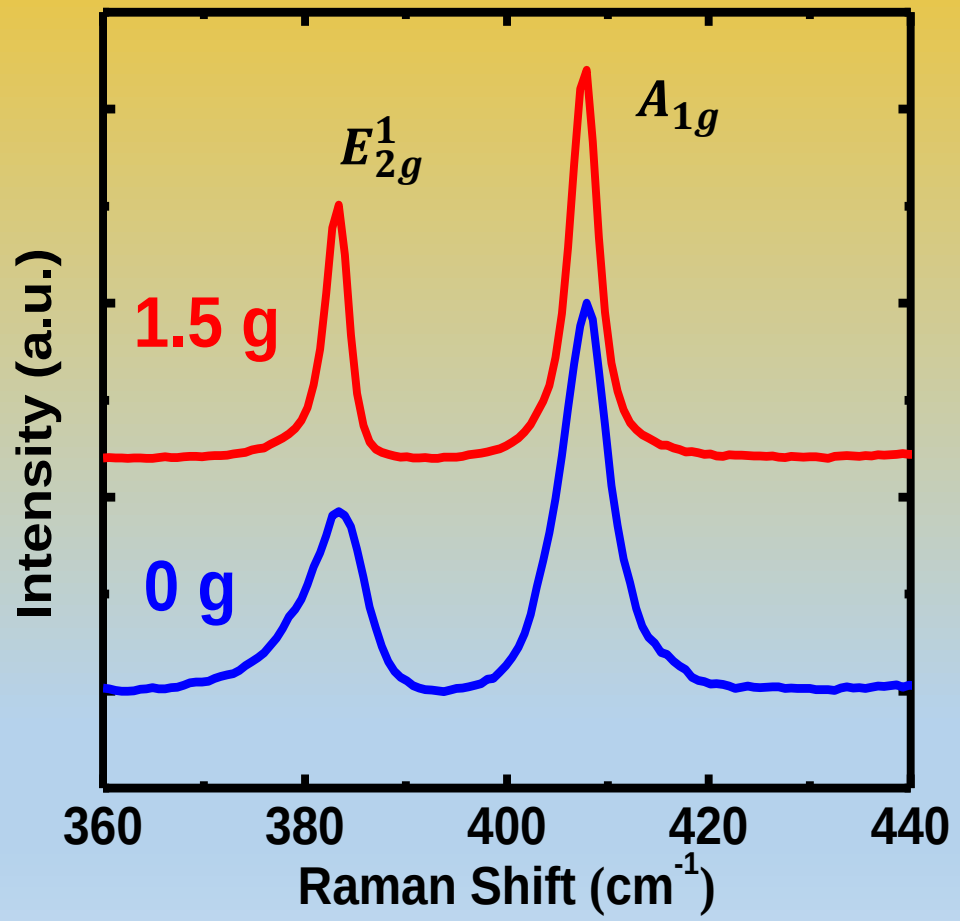




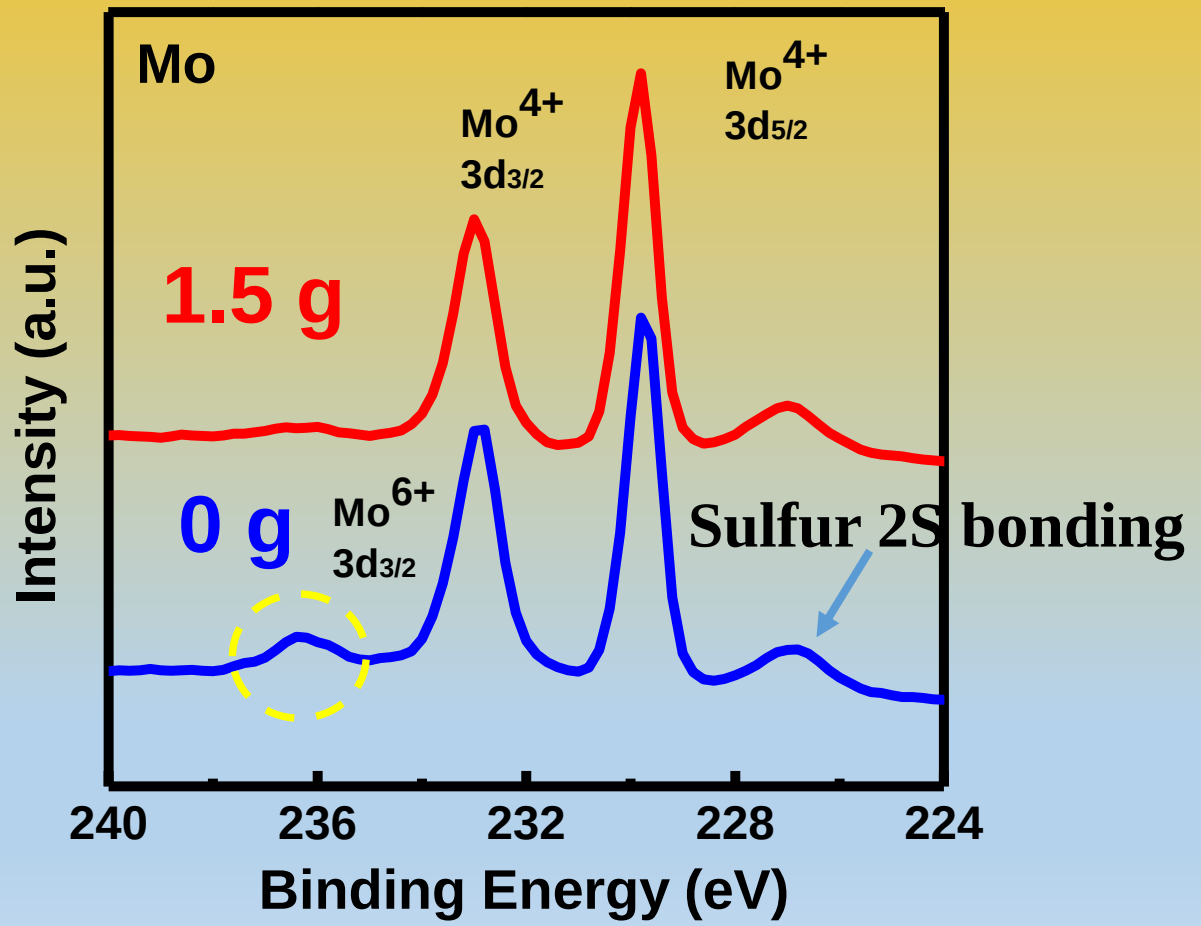
MoS_2 films grown through sulfurization of pre-deposited Mo films with different thicknesses on sapphire substrates

Sulfurization under Sulfur Deficient Condition

Raman spectrum

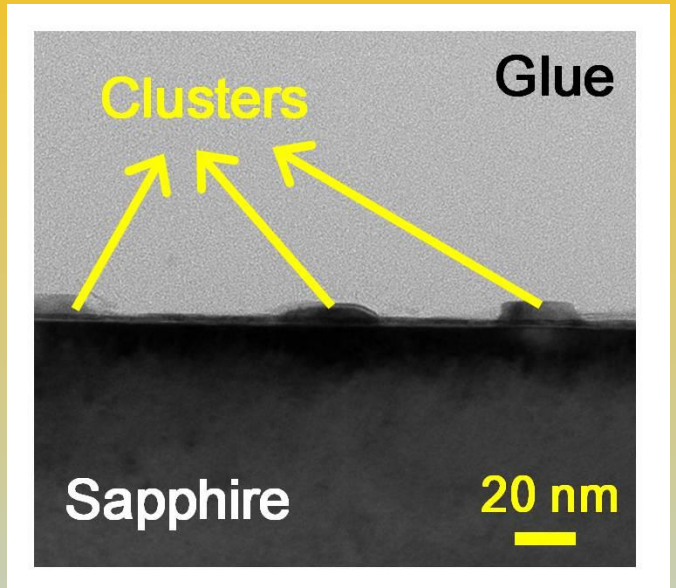


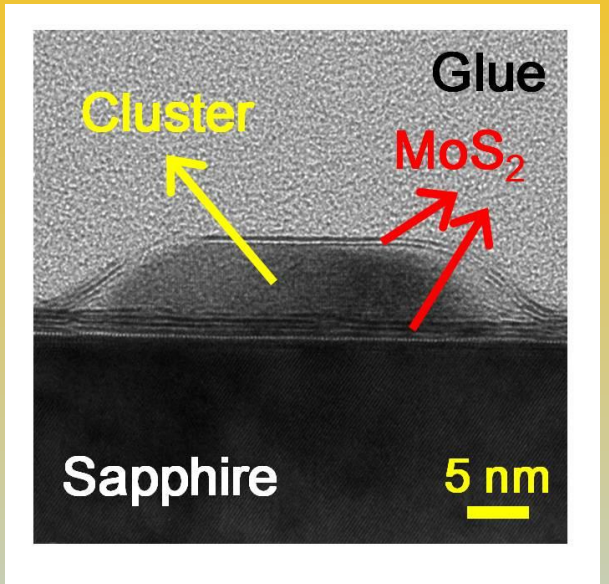
XPS spectrum



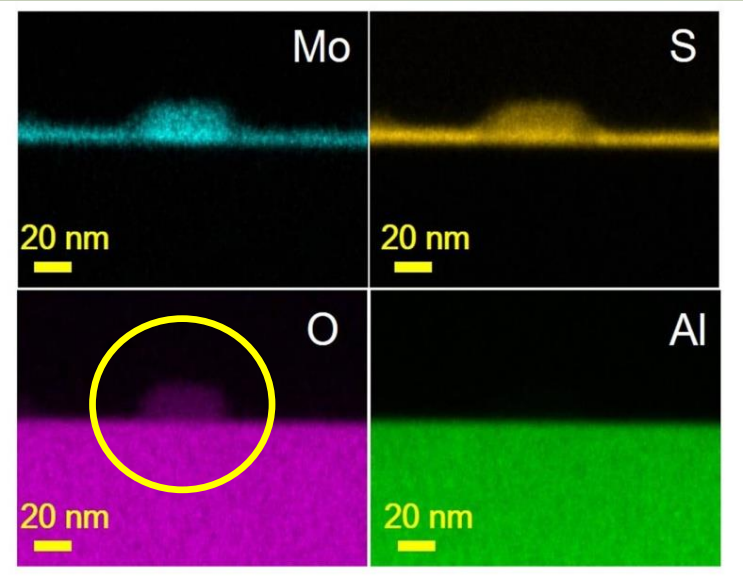
Sulfurization under Sulfur Deficient Condition

small clusters spreading over the sample surfaces

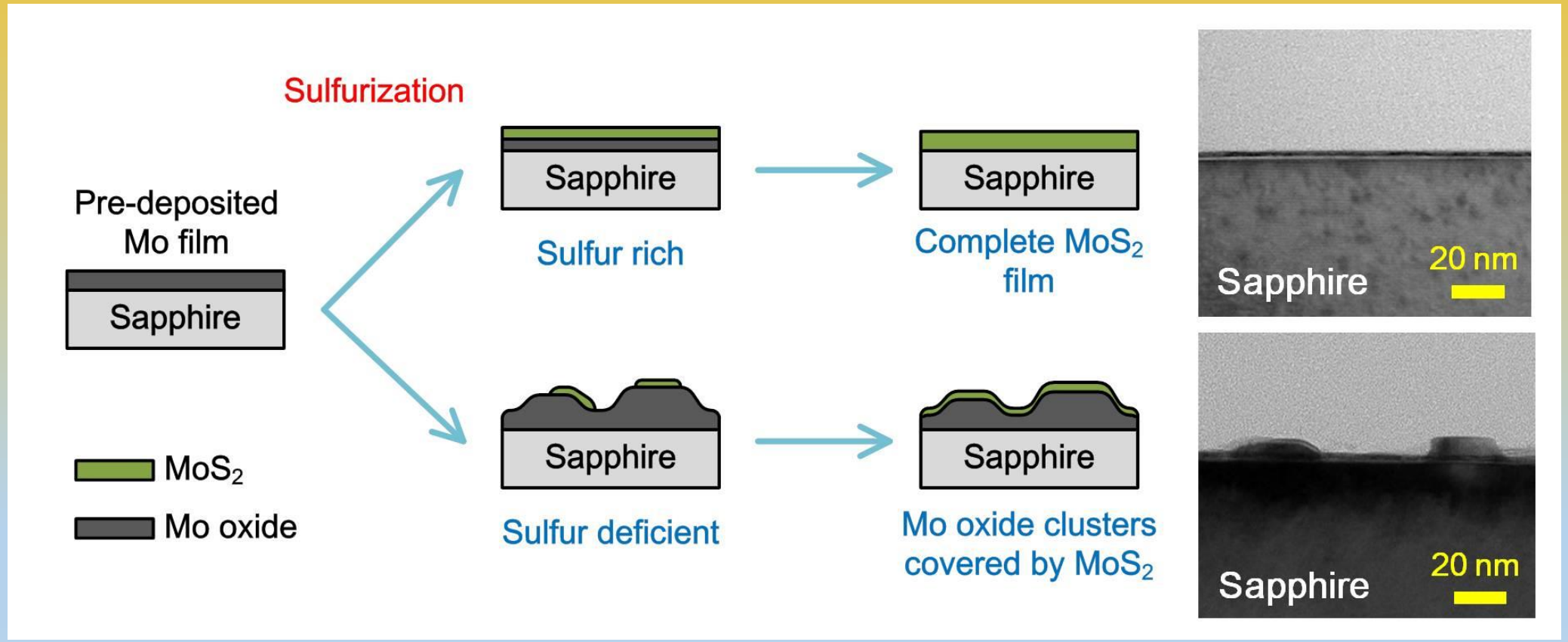




the cluster are covered with layered MoS_2 films



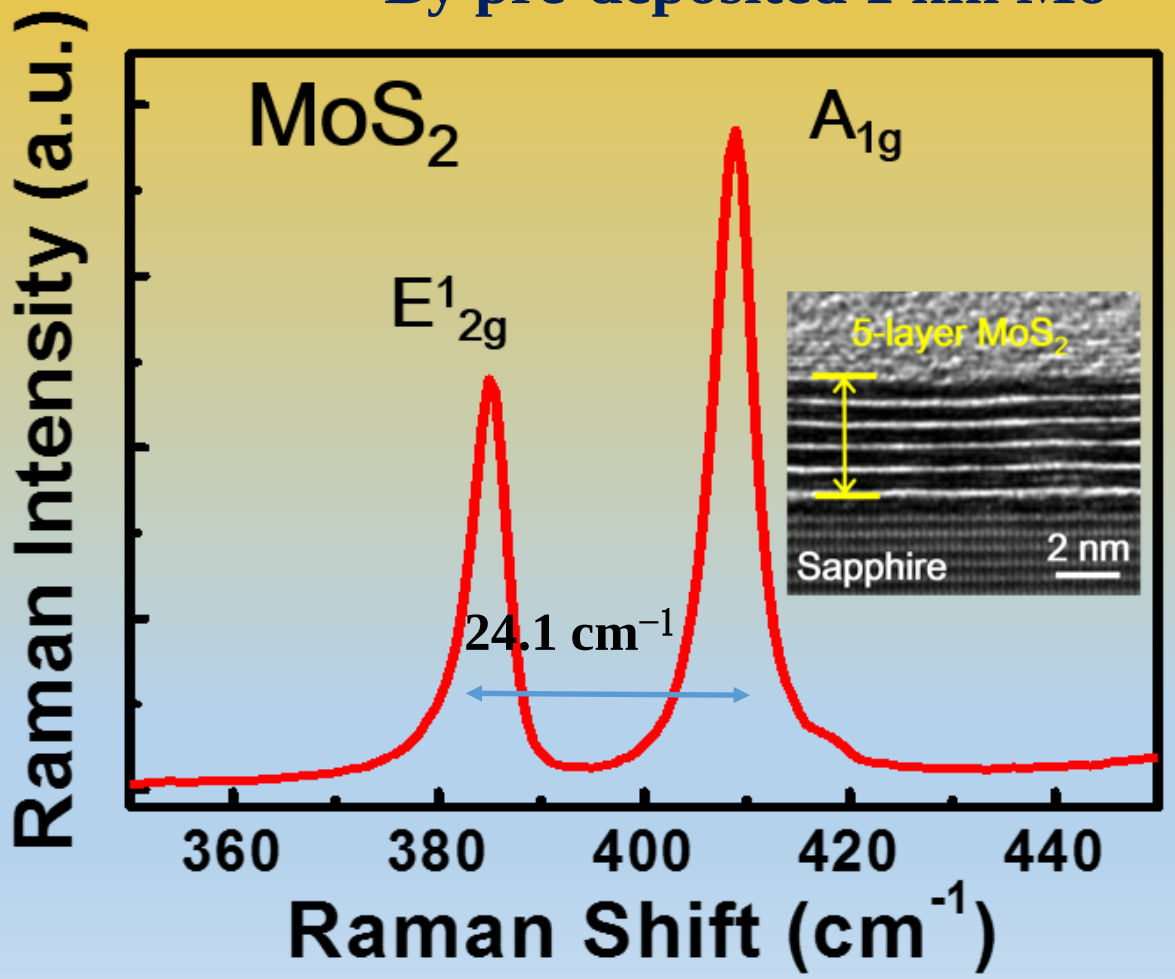
The Growth Model of Transition Metal Sulfurization



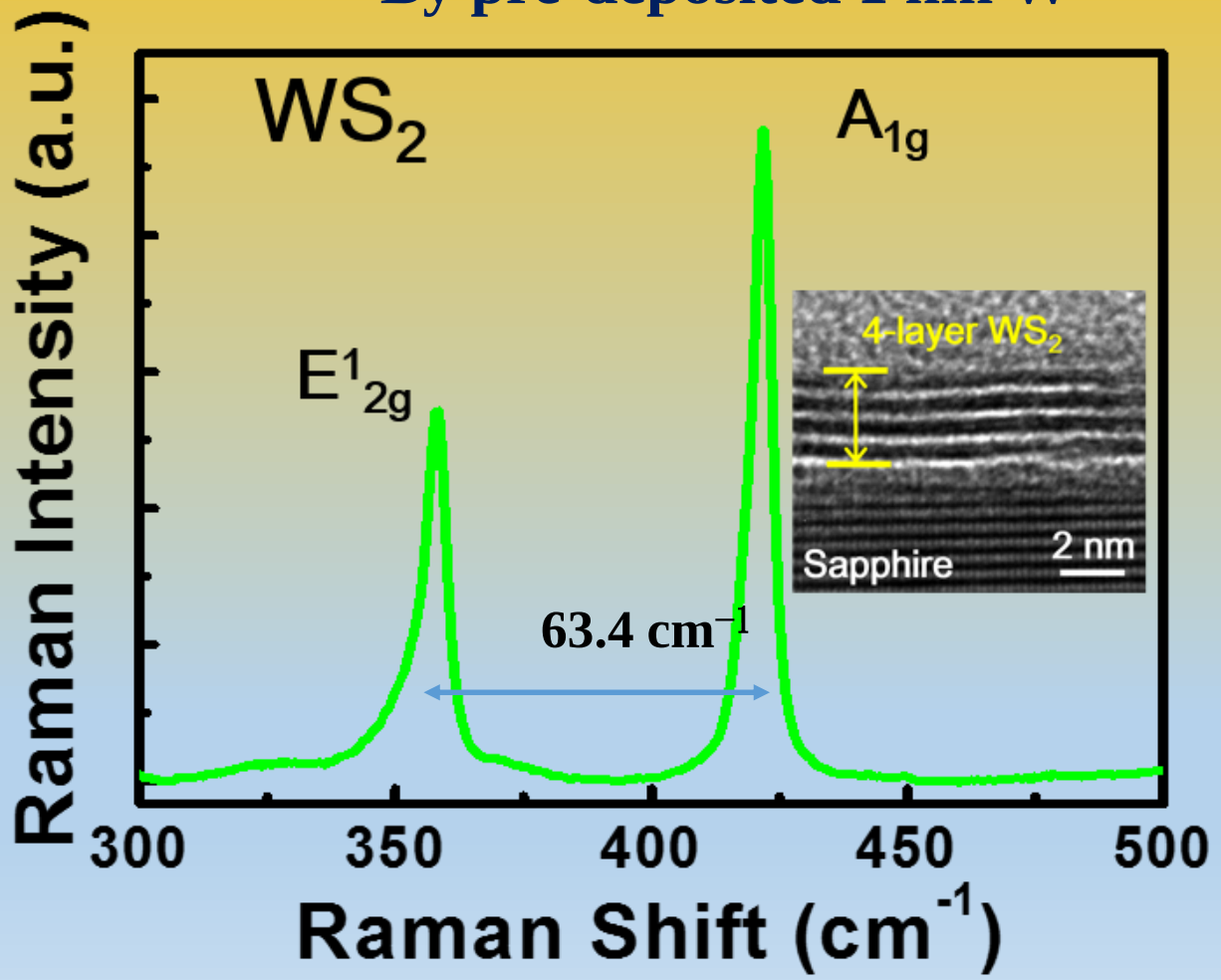
Sci. Rep. **7**, 42146, 2017

The Establishment of 2D Crystal Hetero-structures

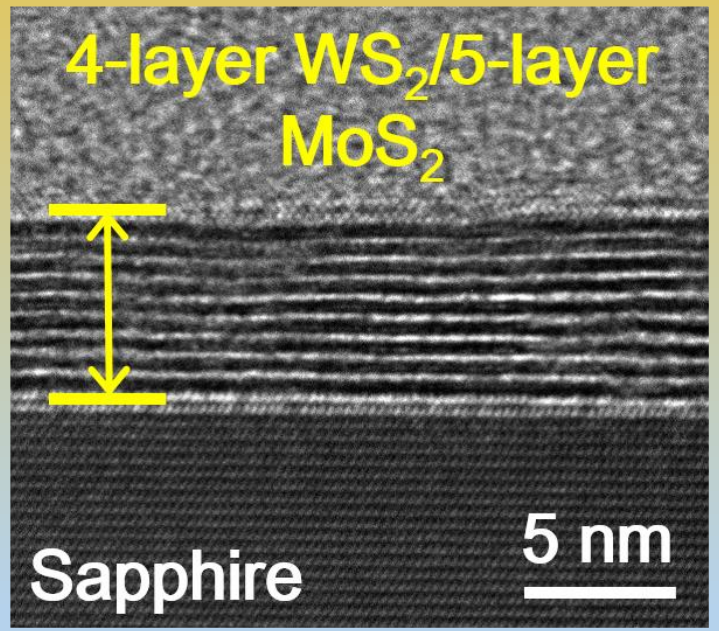
By pre-deposited 1 nm Mo

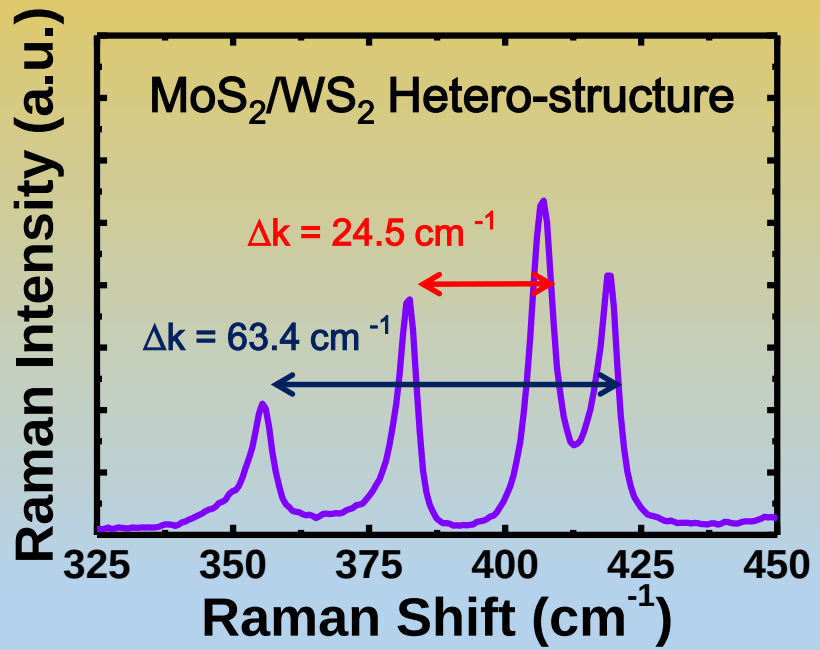


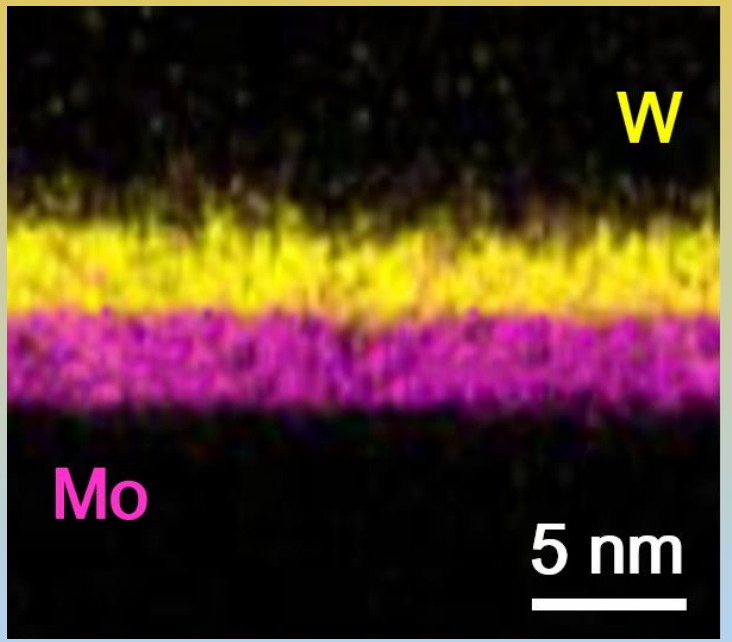
By pre-deposited 1 nm W



The Establishment of 2D Crystal Hetero-structures

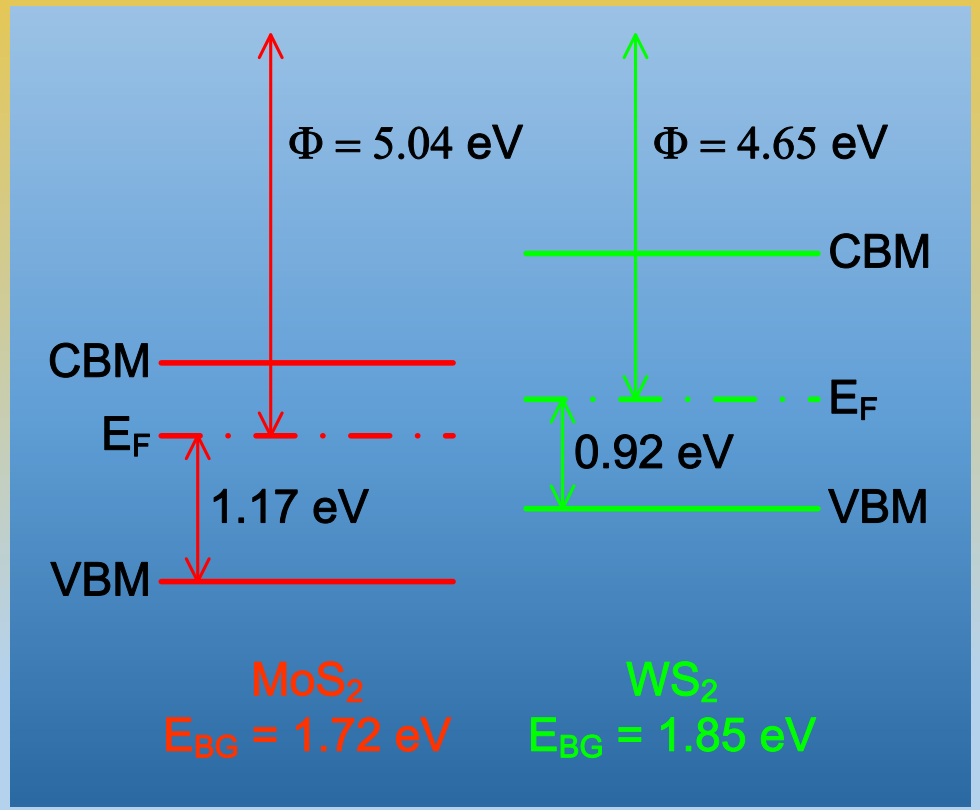


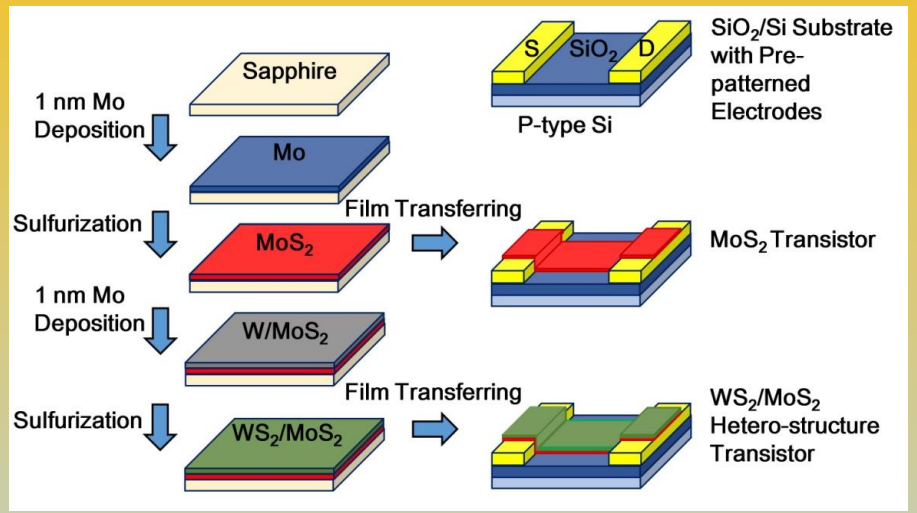


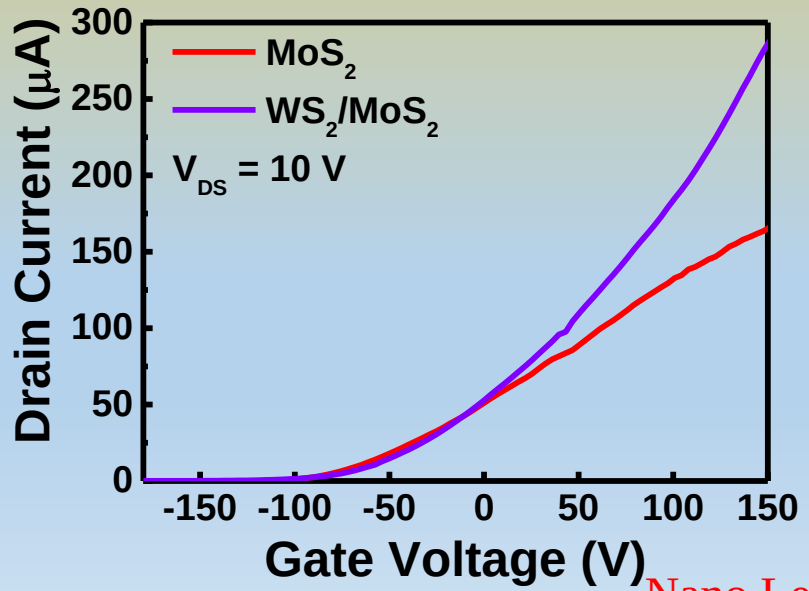


Nano Lett. **16**, 7093, 2016

The Band Diagram and Device Fabrication of WS_2/MoS_2 Hetero-structures

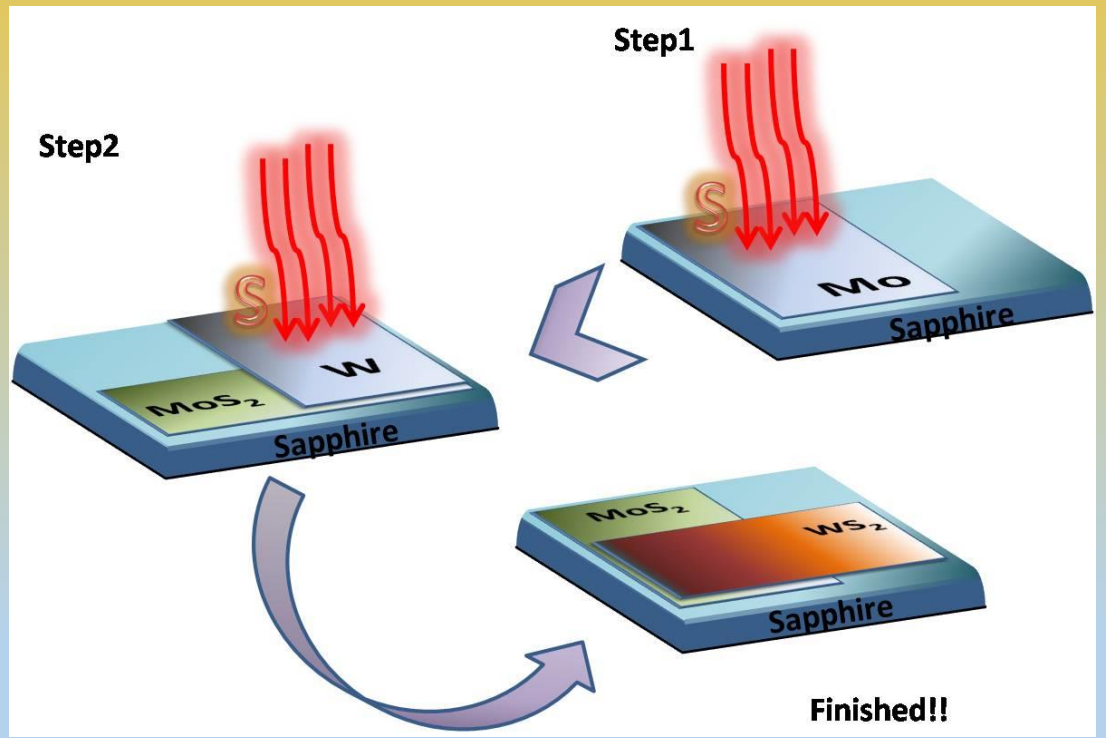


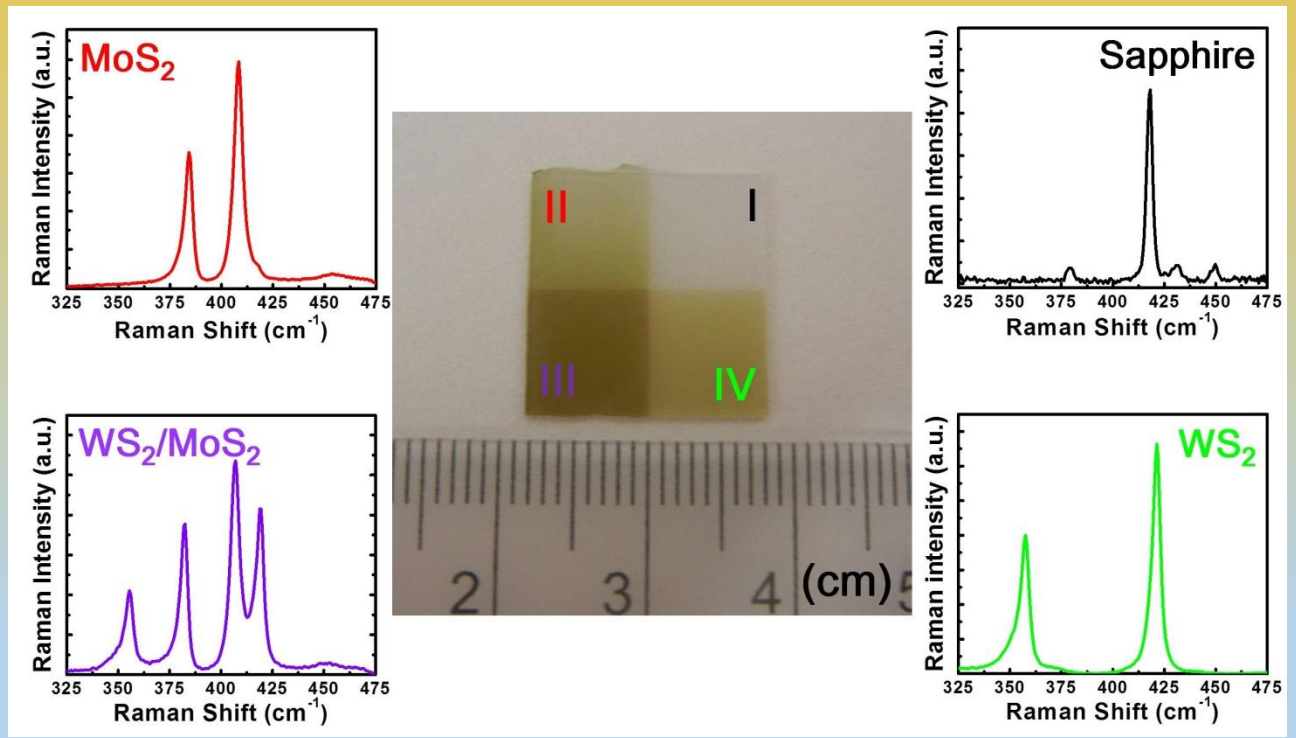




Nano Lett.**16**,7093, 2016

Selective Growth of 2D Crystals





Conclusion

- Large-area TMD films can be obtained
- Good layer number controllability
- The growth model for this growth technique
- The establishment of large-area 2D crystal hetero-structures and their device applications
- Selective growth of 2D crystals

Thank you for your attention

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1. National Taiwan University (Taiwan)
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3. TSMC (Taiwan)

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