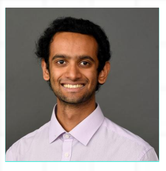
# MOCVD Synthesis & Characterization of 2D Complementary n-type $MoS_2$ and p-type $WSe_2$

From Knowledge to Competitiveness

Portugal-US Partnerships 2026 Summit

MIT Portugal Program

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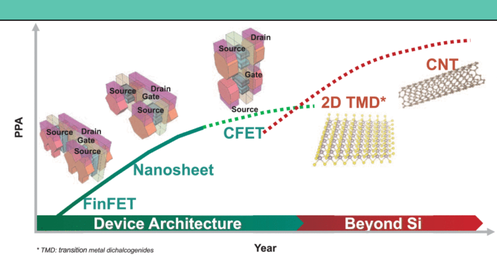
Chips/Nanotechnology

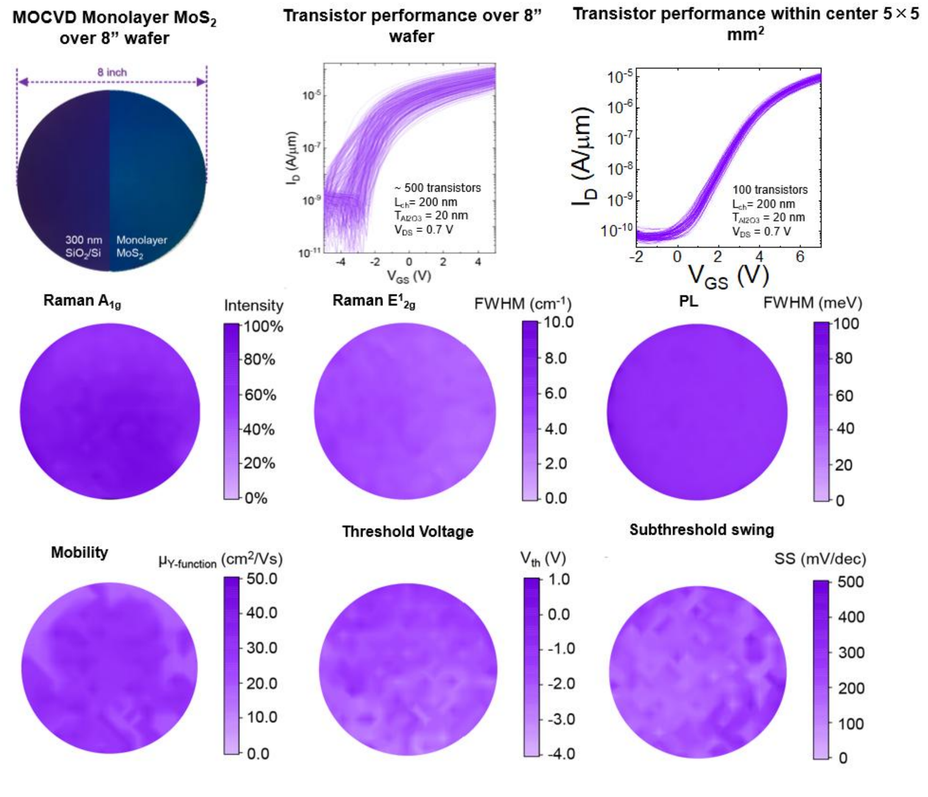
## Introduction

- There is a rising interest in van der Waals materials due to their unique properties and varied potential applications
- However, synthesis remains a key bottleneck to commercializing 2D materials. Amongst the available synthesis methods, **industry-compatible MOCVD** offers a promising route to uniform, large-area films.
- We demonstrate **scalable MOCVD synthesis** of high-quality **n-type $MoS_2$** and **p-type $WSe_2$** films suitable for large-area electronic integration.




*2024 IEEE International Solid-State Circuits Conference (ISSCC)*, San Francisco, CA, USA, 2024, pp. 10-15

## Low-Temperature (<300 °C) Wafer-Scale $MoS_2$ Synthesis



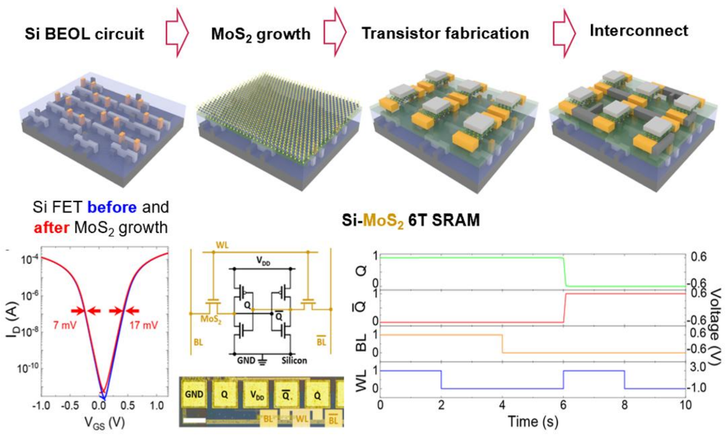

**Good Material Quality**

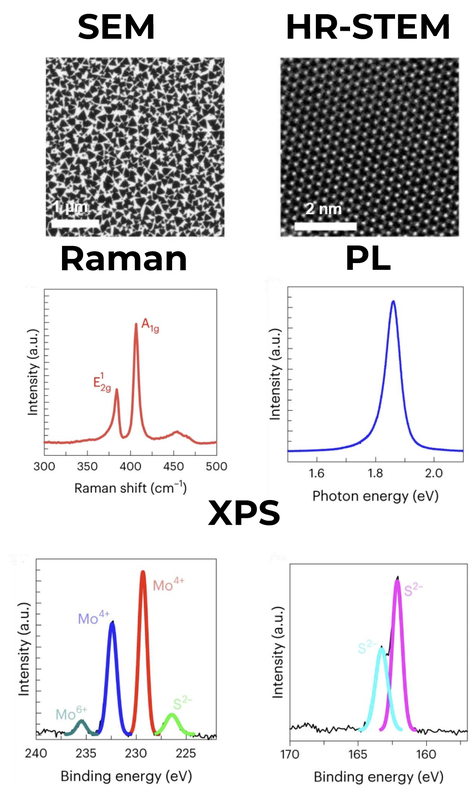
- Grain size ~200 nm
- ~1 hr growth time for continuous monolayer
- Strong Raman, PL, XPS peaks

**Good material Uniformity**

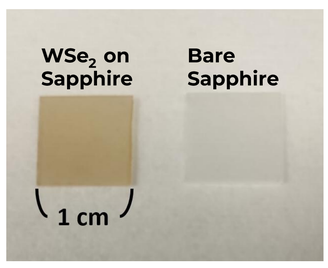
- Full 8-inch wafer coverage
- Excellent wafer-scale uniformity

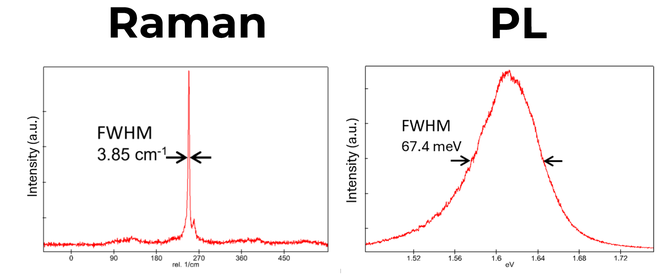
**Small Device-to-device variation**

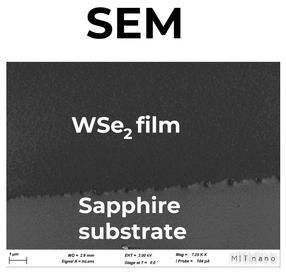


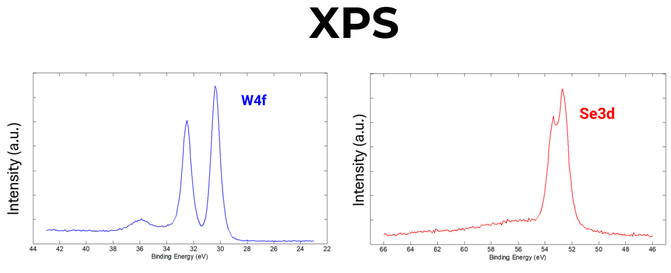




## $WSe_2$ Synthesis




- **Good material quality** with strong Raman, PL, and XPS spectra. SEM shows coalesced film achieved at ~1 hr growth time.
- **Uniform, large-area coverage** over centimeter scale regions achieved.

## MIT/INL Collaboration

- **MIT – Materials & Devices:** MOCVD/CVD synthesis of high-quality $MoS_2$ and $WSe_2$, process engineering, device fabrication, and electrical characterization.
- **INL – Advance Atomic-Scale Characterization:** Aberration-corrected STEM/TEM, AFM, LFM, EELS/EDS, and quantitative mapping of defects, strain, composition, and interfaces.
- **Joint Structure–Property Correlation:** Connect atomic-scale defect and strain distributions with device metrics such as mobility, threshold voltage, contact resistance, hysteresis, reliability, and variability.
- **Closed-Loop Optimization:** Use microscopy and device feedback to guide subsequent synthesis and processing conditions toward improved material quality and device uniformity.
- **Collaborative Goal:** Establish a quantitative **process–structure–property–device** relationship for wafer-scale 2D TMD electronics and identify optimized material/process windows.

## Conclusion

- **High-quality, large-area $MoS_2$ and $WSe_2$** have been synthesized by scalable MOCVD/CVD processes.
- **Wafer-scale $MoS_2$ demonstrates strong material uniformity and promising device performance** with low device-to-device variation.
- **Defects, strain, grain structure, and interfaces** remain key factors governing TMD material and device properties.
- **MIT and INL will combine synthesis, advanced atomic scale material characterization, and electrical characterization** to establish **quantitative process–structure–property–device relationships.**
- **Closed-loop feedback guides material and process optimization toward uniform and reliable 2D electronics.**


Funded by:

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