

Location-Selective CVD Synthesis of Circular MoS₂ Flakes with Ultrahigh Field-Effect Mobility

Presenter:

Chute Chen[†], Anthony Cabanillas[†], Asma Ahmed, Anthony Butler, Yu Fu, Haolei Hui, Hao Zeng, Ajay Yadav, Gabriel Lee, Keith Wong*, Huamin Li*, and Fei Yao*

***Email: keith_wong@amat.com, huaminli@buffalo.edu, feiyao@buffalo.edu**

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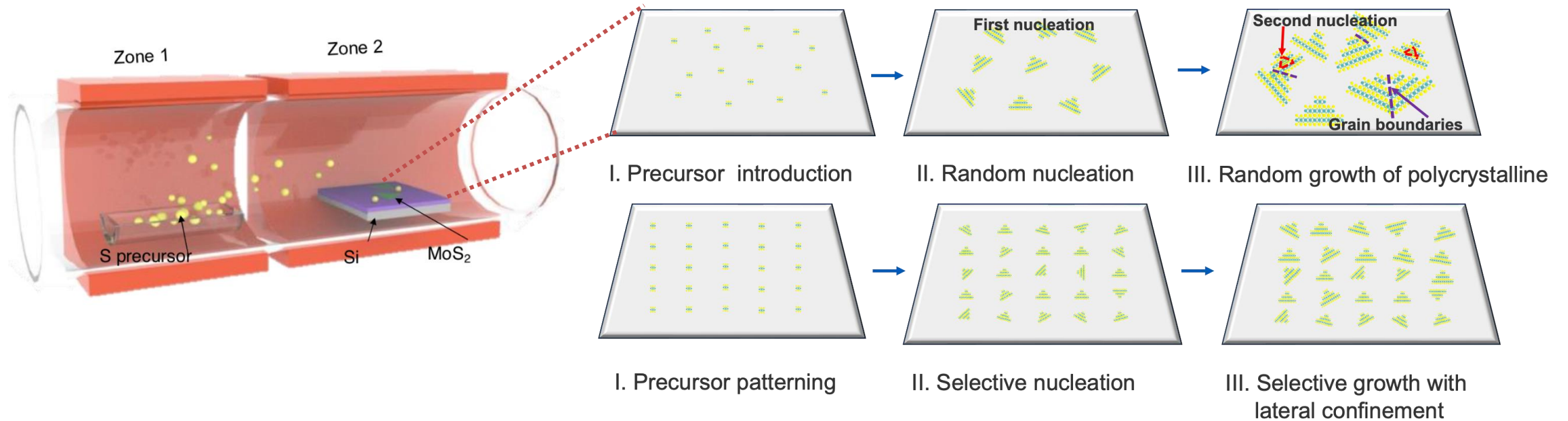
Site-specific synthesis

Introductions

Materials and methods

Results and discussion

Conclusion and highlights



➤ Challenges for **nanoelectronics**:

Despite initial achievements in fundamental scientific research and device demonstrations, the growth of wafer-scale, single crystalline (SC) TMD films is a major obstacle to the advancement of commercially feasible TMD-based nanoelectronics.

➤ Solutions:

Site-specific growth → allows micrometer scale controlled growth at selected locations which can be directly used as channel material for electronic devices.

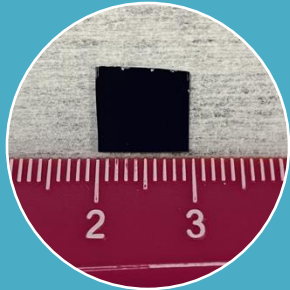
Experiment process

Introductions

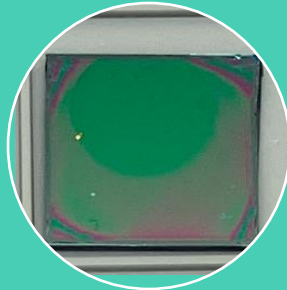
Materials and methods

Results and discussion

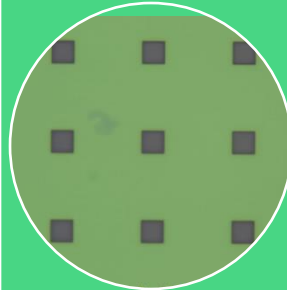
Conclusion and highlights



Substrate
preparation



E-beam
resists spin
coating



E-beam
lithography
patterning



Mo
precursor
loading



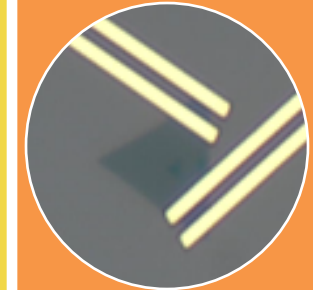
Acetone
liftoff
E-beam
resists



Selective
MoS₂ CVD
synthesis



Materials
Characteriz
ation



Device
fabrication
and
performance
measurement

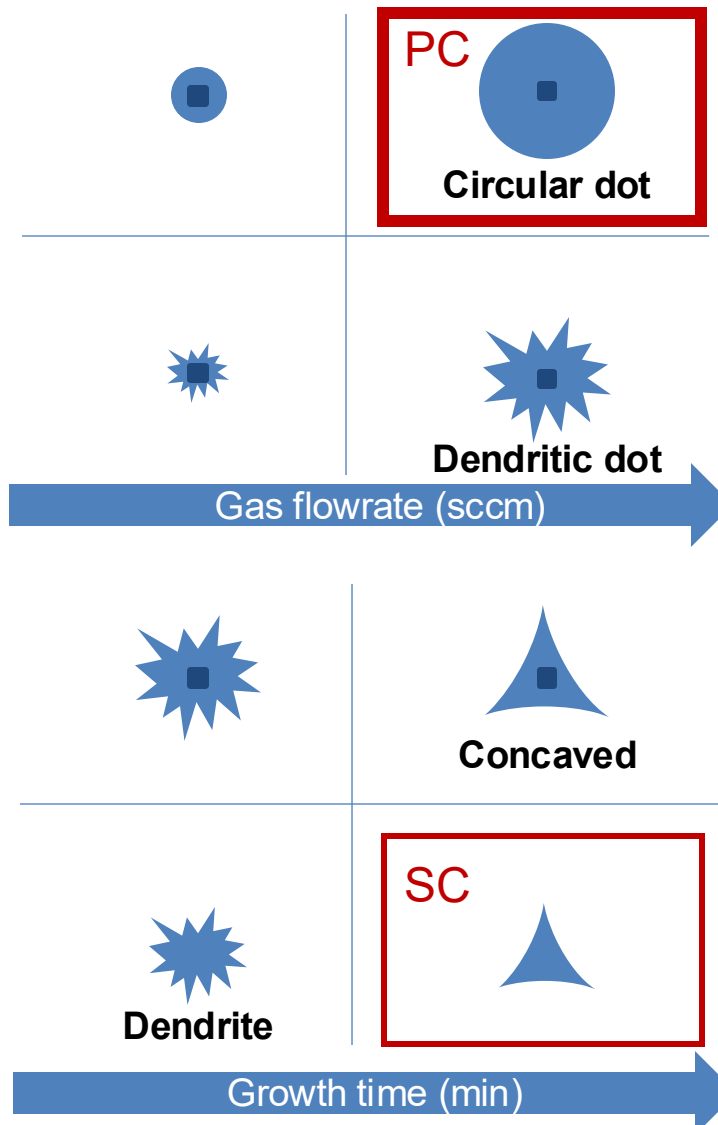
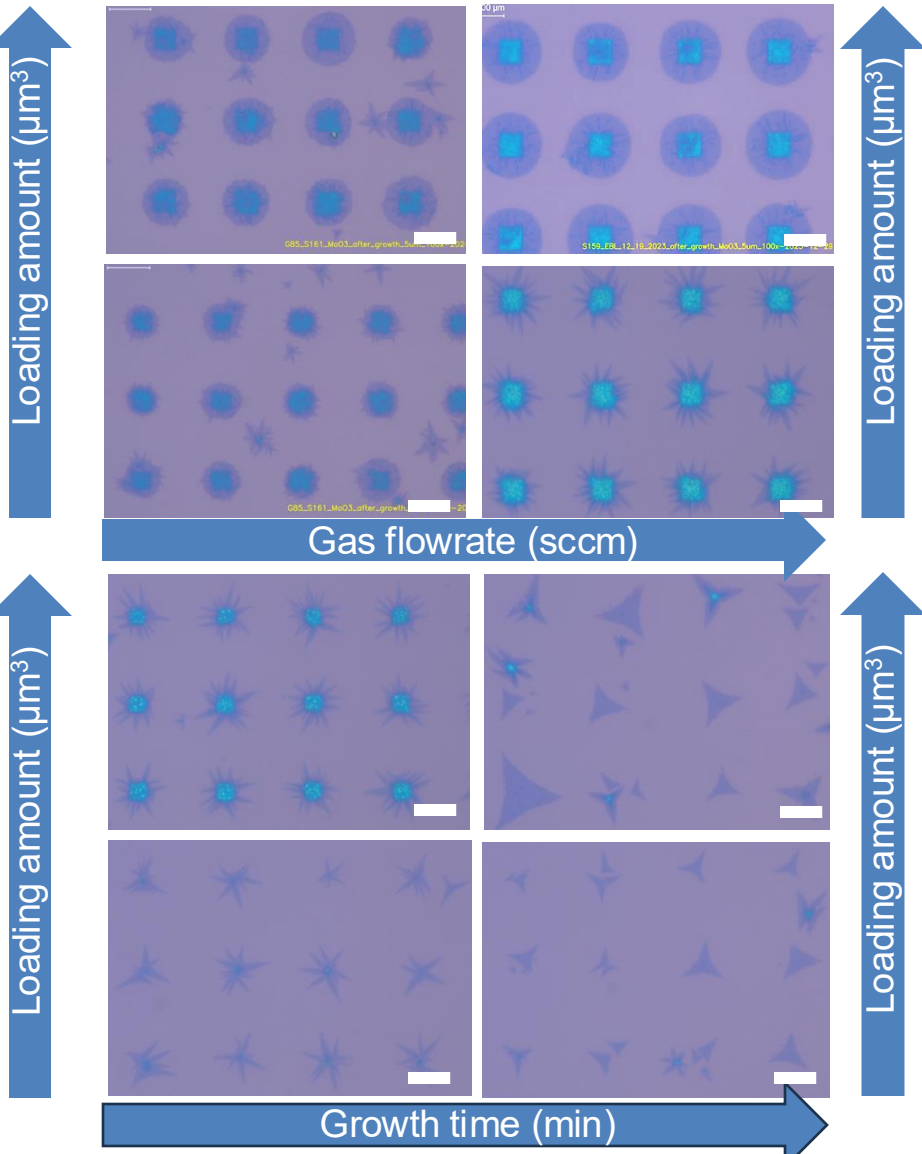
CVD parameter space exploration

Introductions

Materials and methods

Results and discussion

Conclusion and highlights



- Location-specific polycrystalline (PC) and single-crystalline (SC) flakes can be obtained by adjusting the CVD synthesis parameters.
- The electrical properties of monolayer MoS₂ were measured, demonstrating competitive performance compared to published results, though the recipe for equilateral triangle monolayers requires further refinement.
- In contrast, the recipe for circular dots is well-optimized and promising for further investigation.

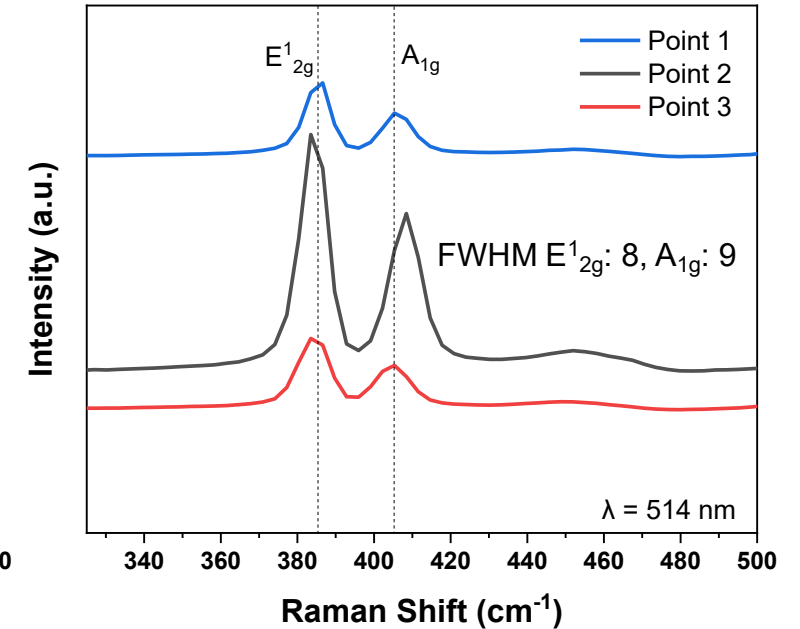
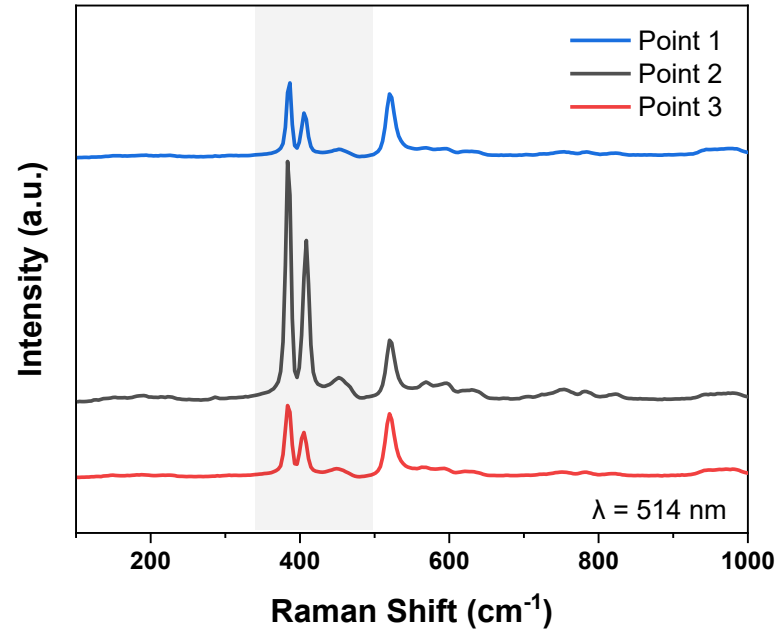
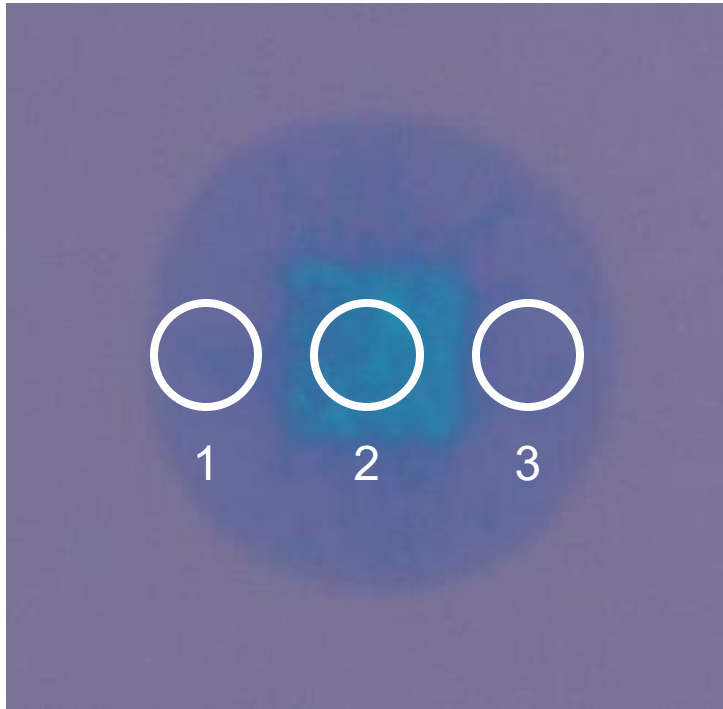
Material characterization - Raman spectroscopy

Introductions

Materials and methods

Results and discussion

Conclusion and highlights



Point	E¹₂g (cm⁻¹)	A₁g (cm⁻¹)	Frequency difference (Δ)	Layers
1	386.5	405.3	20.8	2
2	383.5	408.4	24.9	> 3
3	383.5	405.3	21.9	3

The Raman analysis verifies that the flakes consist of MoS₂, as indicated by the presence of characteristic peaks at 387cm⁻¹ for E¹₂g and 407cm⁻¹ for A₁g.

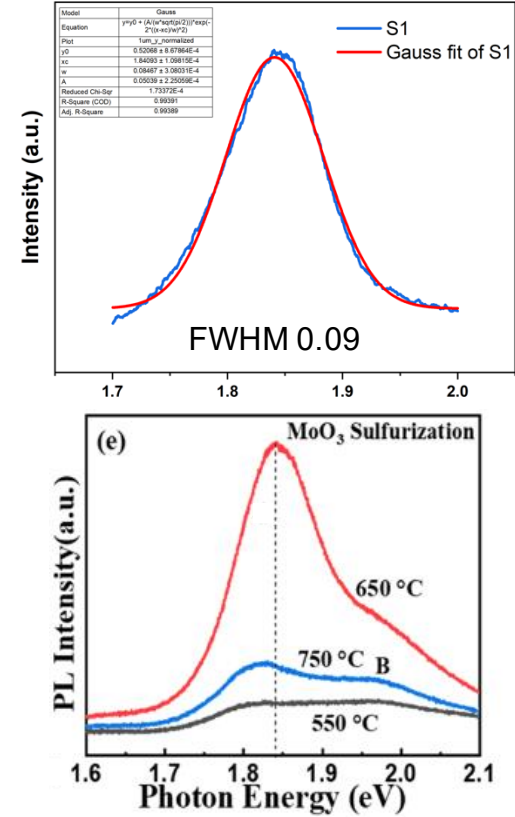
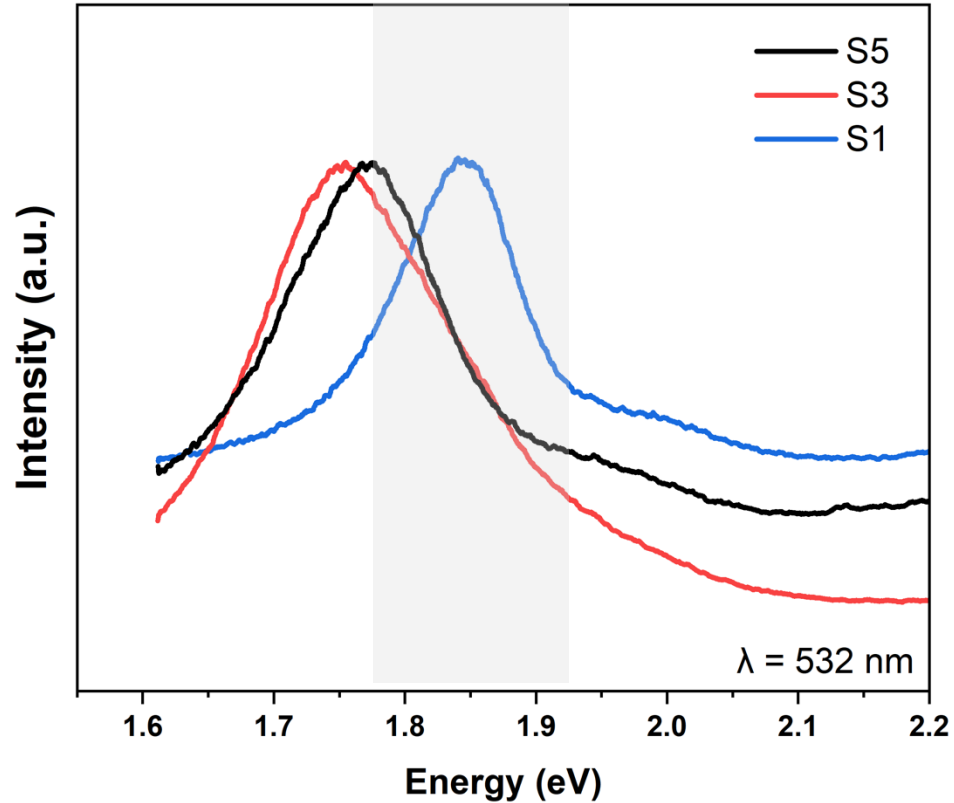
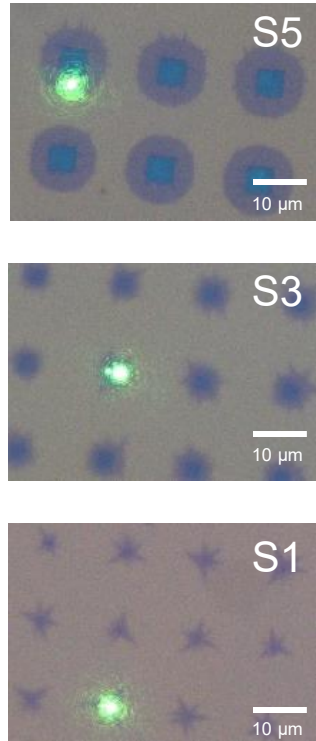
Material characterization - Photoluminescence spectroscopy

Introductions

Materials and methods

Results and discussion

Conclusion and highlights



The photoluminescence (PL) spectrum of monolayer molybdenum disulfide (MoS_2) exhibits peaks in the range of approximately 1.85 eV to 2.00 eV. The S1 region displayed monolayer/bilayer (ML/BL) flakes, while the S3 and S5 regions showed multilayer flakes.

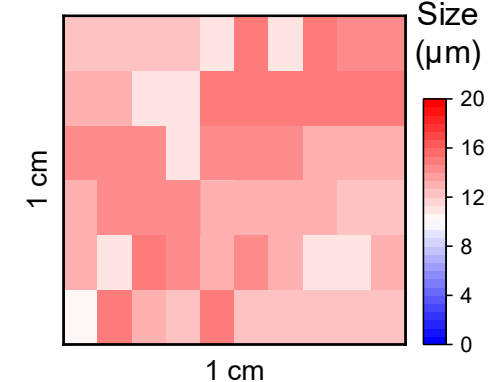
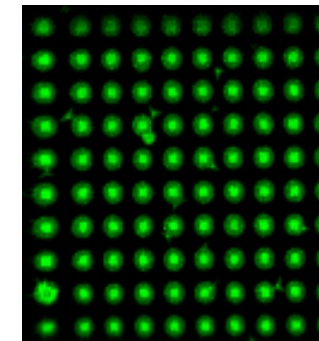
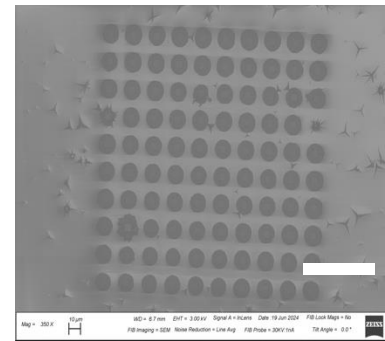
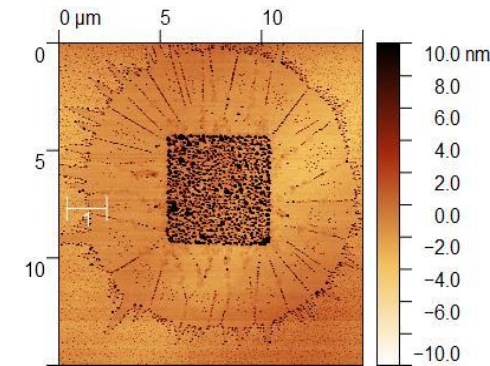
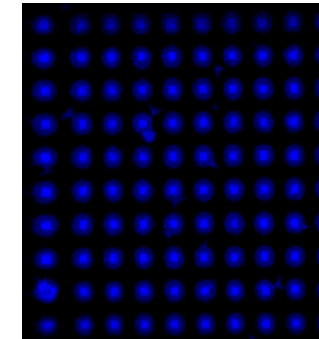
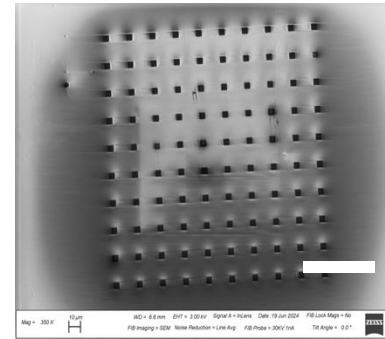
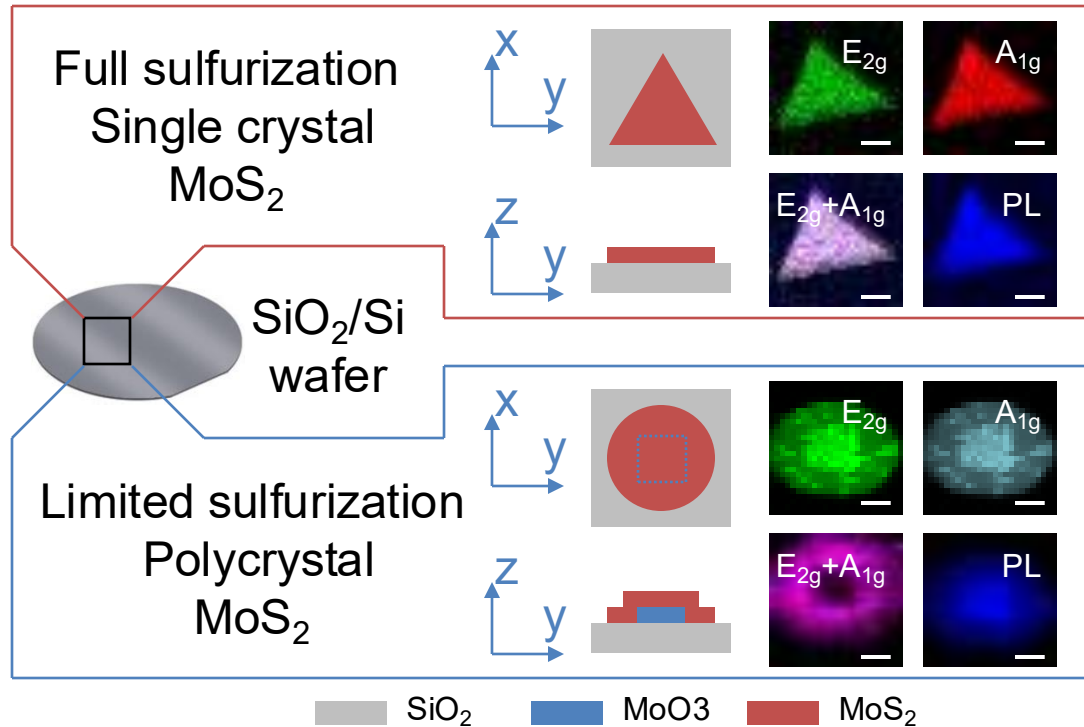
Material characterization - Array scale mapping

Introductions

Materials and methods

Results and discussion

Conclusion and highlights



- The uniformity of the flakes can be assessed using 10 x 10 arrays through various characterization techniques such as SEM, AFM, Raman, and PL mapping.

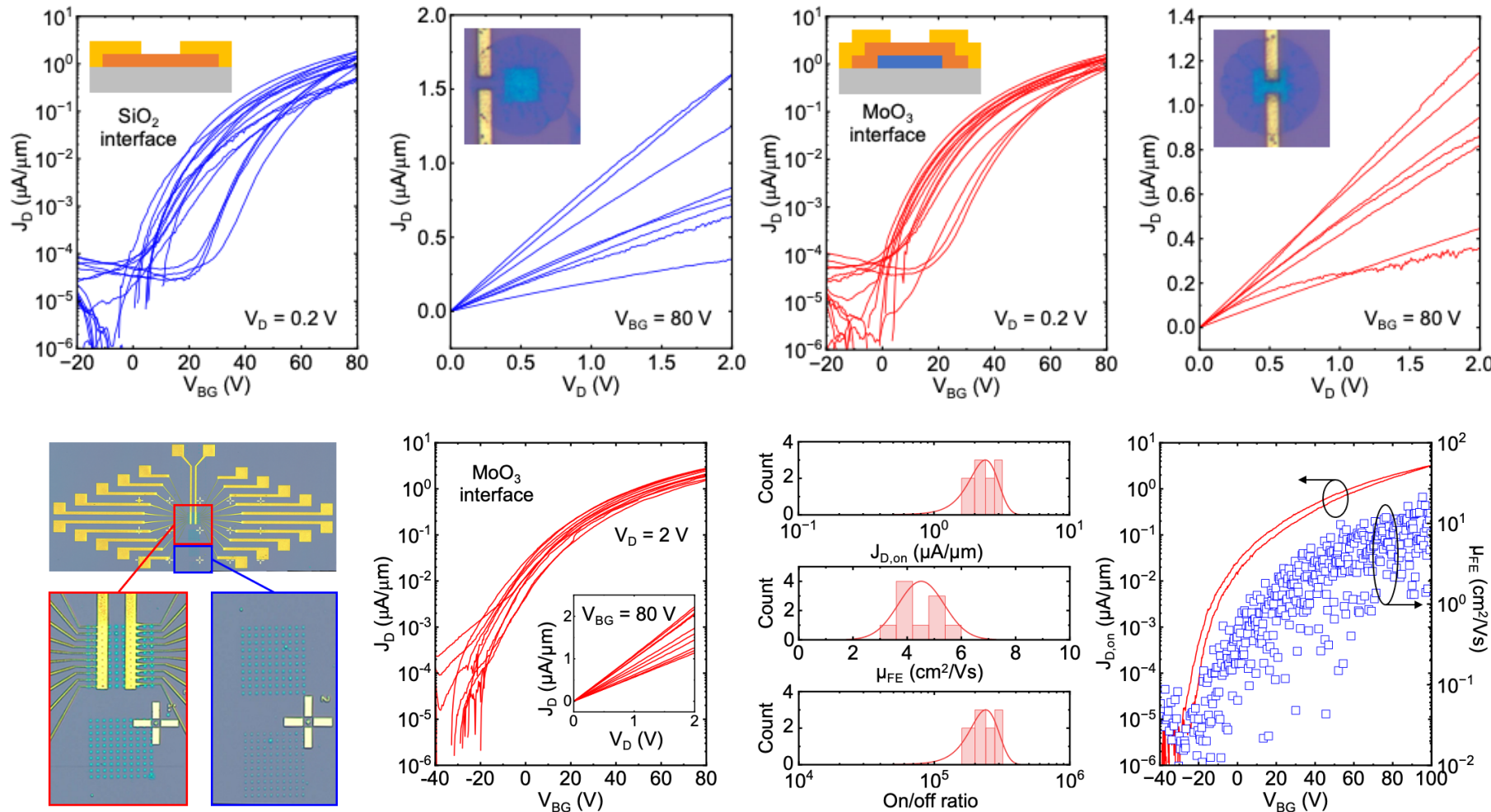
Material characterization - Carrier transport measurement

Introductions

Materials and methods

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Conclusion and highlights



- A comparative investigation of MoS₂ FETs with MoO₃ and SiO₂ dielectric interfaces is performed, focusing on output and transfer characteristics (J_D - V_D and J_D - V_{BG}).
- Both FET types show linear J_D - V_D characteristics, indicating Ohmic contact.
- Optimized MoS₂ FET achieves $J_{D,on}$ of 3 $\mu\text{A}/\mu\text{m}$, μ_{FE} of 20 cm^2/Vs , and on/off ratio up to 10⁶.

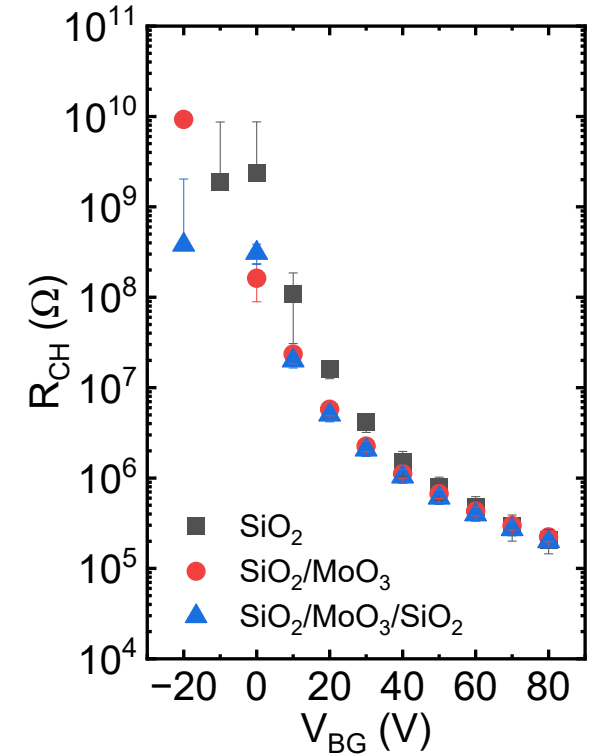
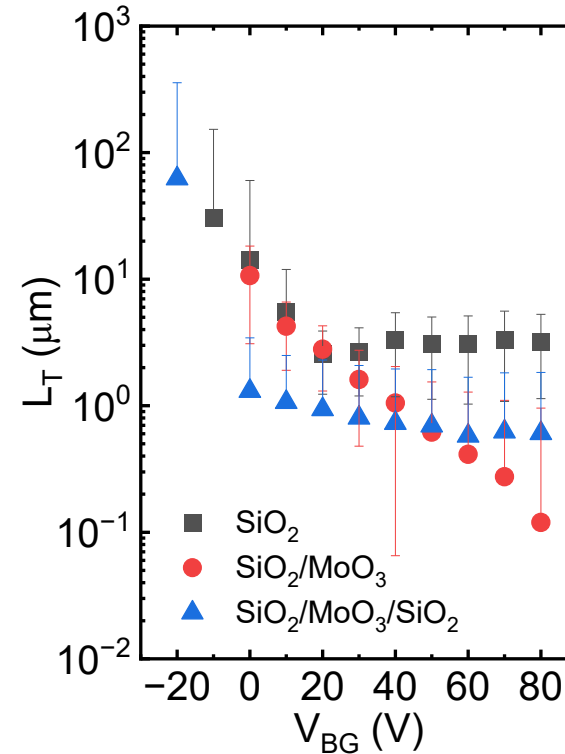
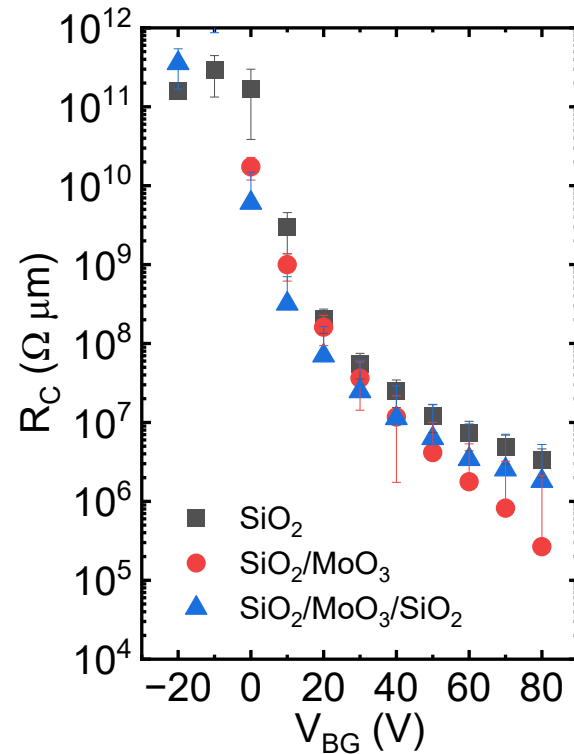
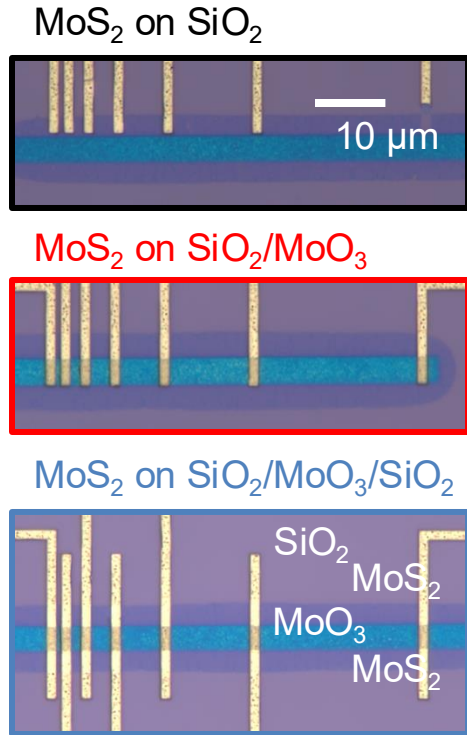
Material characterization - Transmission line measurement

Introductions

Materials and methods

Results and discussion

Conclusion and highlights



- Well-controlled growth enables defining the geometry of as-grown MoS₂ in arbitrary shapes. No need for lithography or etching processes.
- Created a long MoO₃ ribbon (5 μm \times 200 μm) for Transmission Line Measurement (TLM).
- Greater involvement of the MoO₃ interface (compared to SiO₂) improves metal contact conditions. Lower contact resistance (R_c) and transfer length (T_L). Maintains the MoS₂ channel resistance (R_{CH}).

Research highlights

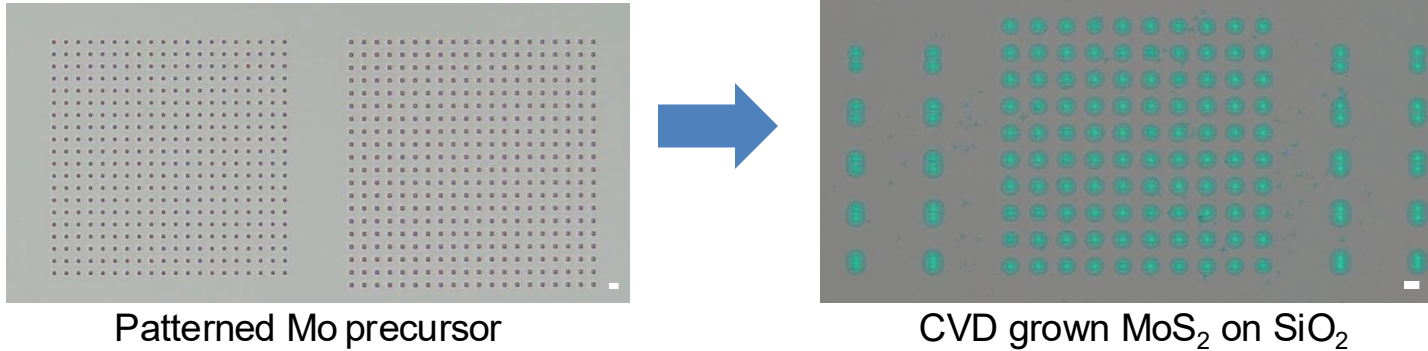
Introductions

Materials and methods

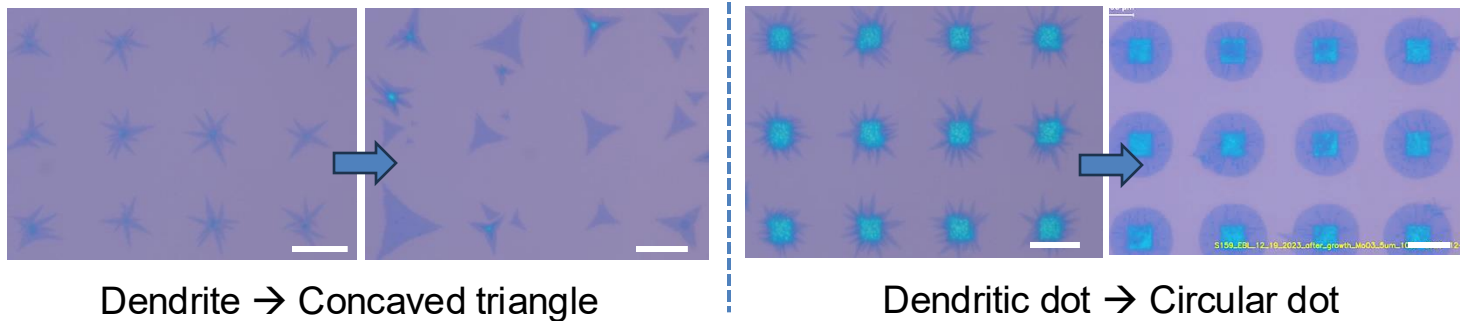
Results and discussion

Conclusion and highlights

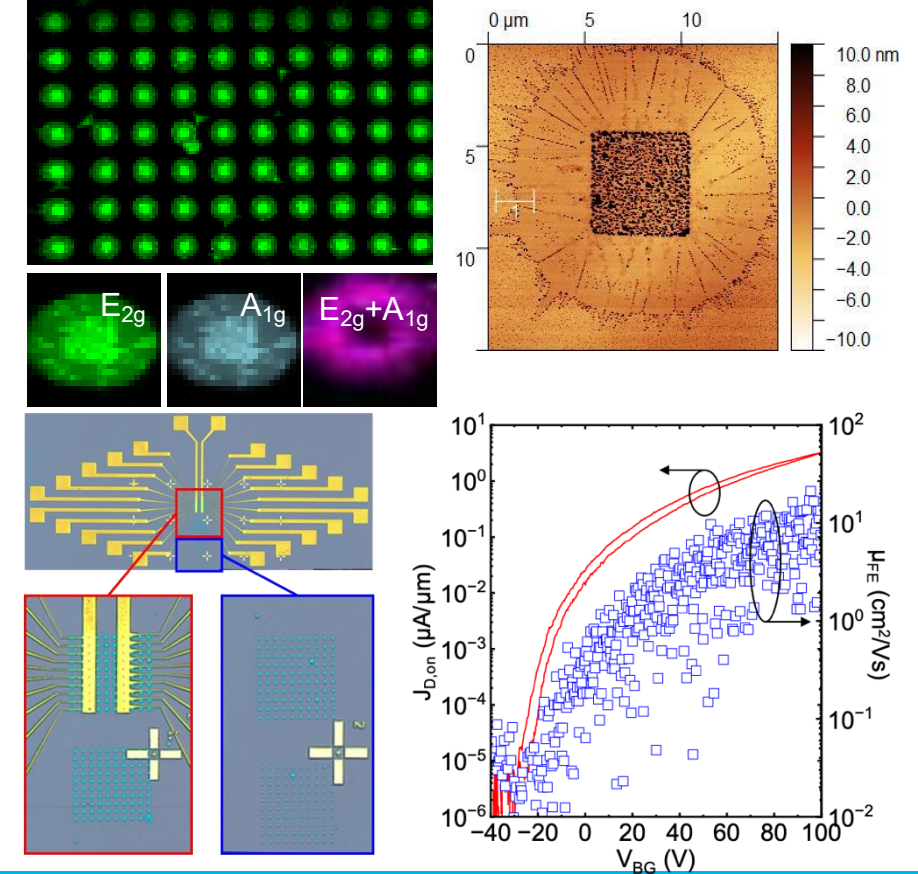
□ Location-selective growth of MoS₂ on SiO₂ (scale bar: 10 μm)



□ Controlled MoS₂ morphology evolution (scale bar: 10 μm)



□ High performance MoS₂ transistors

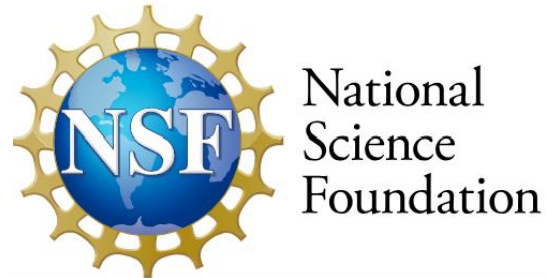
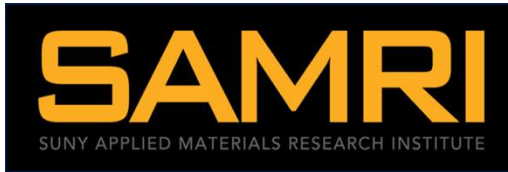
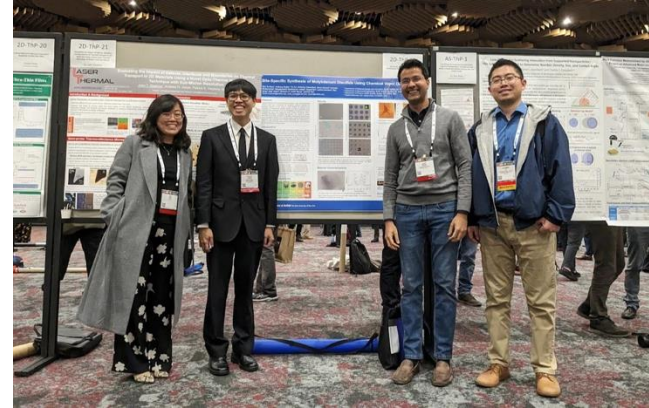


Successfully demonstrate the selective CVD growth of 2D MoS₂ arrays directly on SiO₂ substrates with controlled morphologies and excellent electronic quality (~20 cm²/Vs electron mobility).

Acknowledgement

Team members

- [Nano Energy Technology Laboratory](#)
- [Emerging Nanoelectronics Research Group](#)



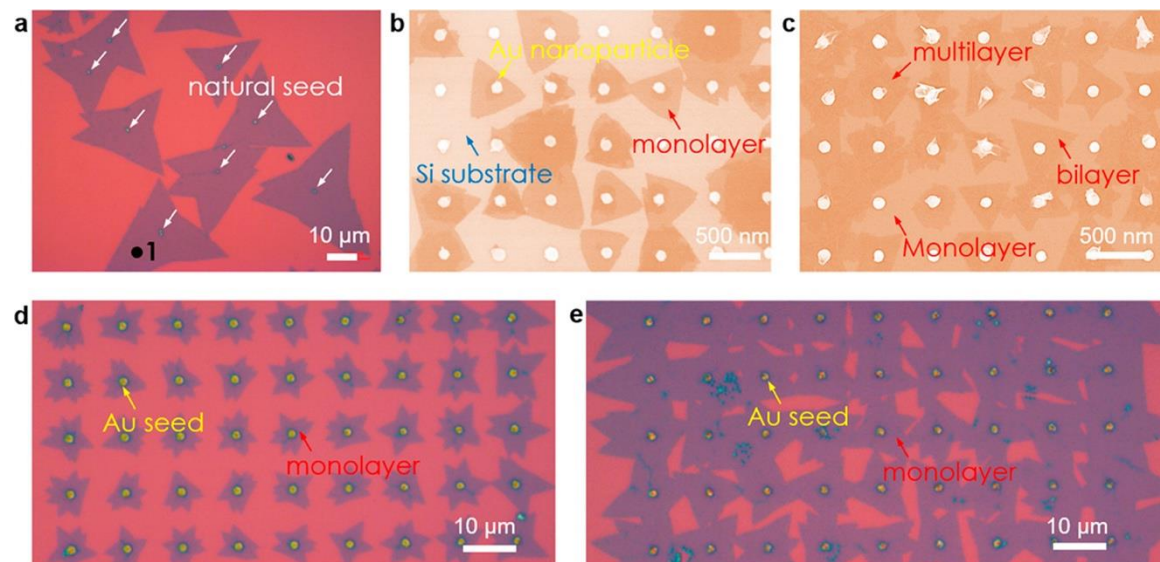
THANK YOU



SUPPORTING INFORMATION



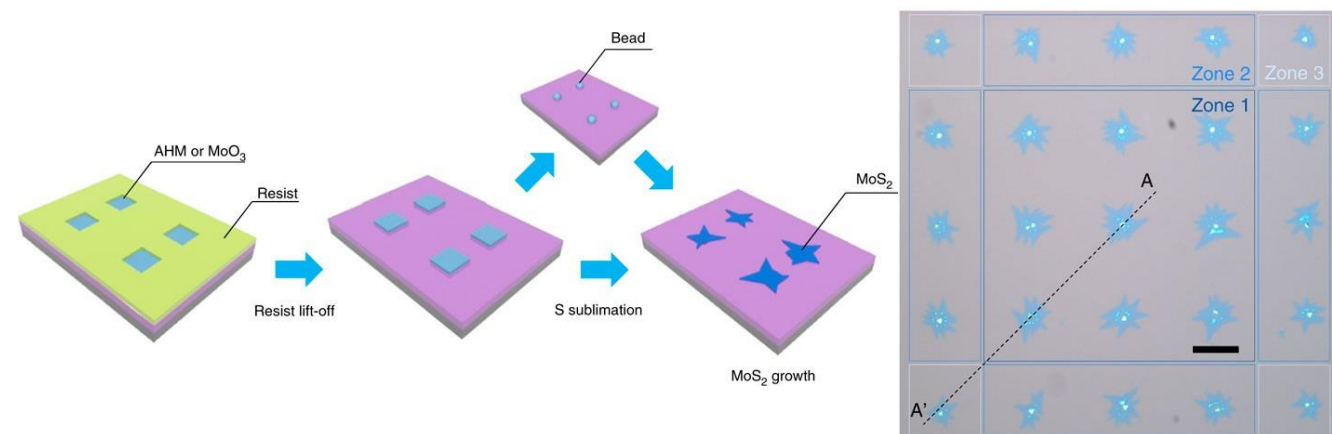
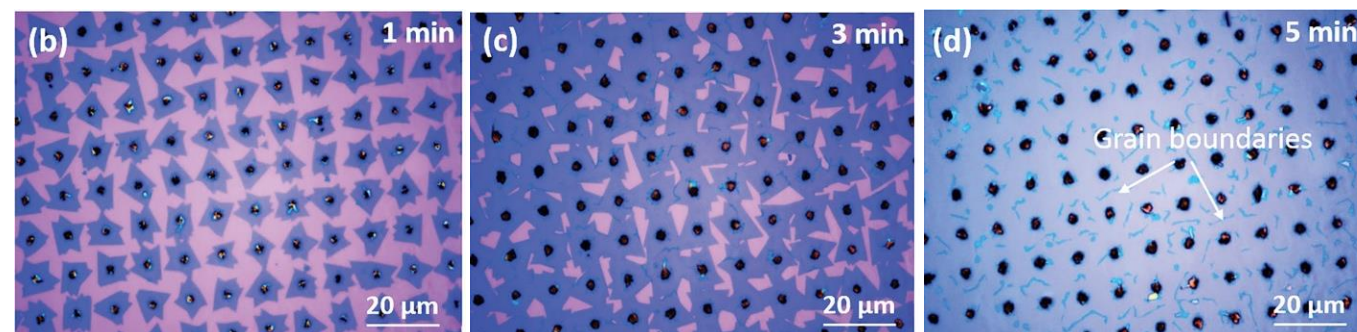
State of the art: site-specific synthesis



- Metal (e.g., Au) nanoparticles to seed the growth of MoS₂ monolayers and thereby provide a means to achieve controllable synthesis.

Issues

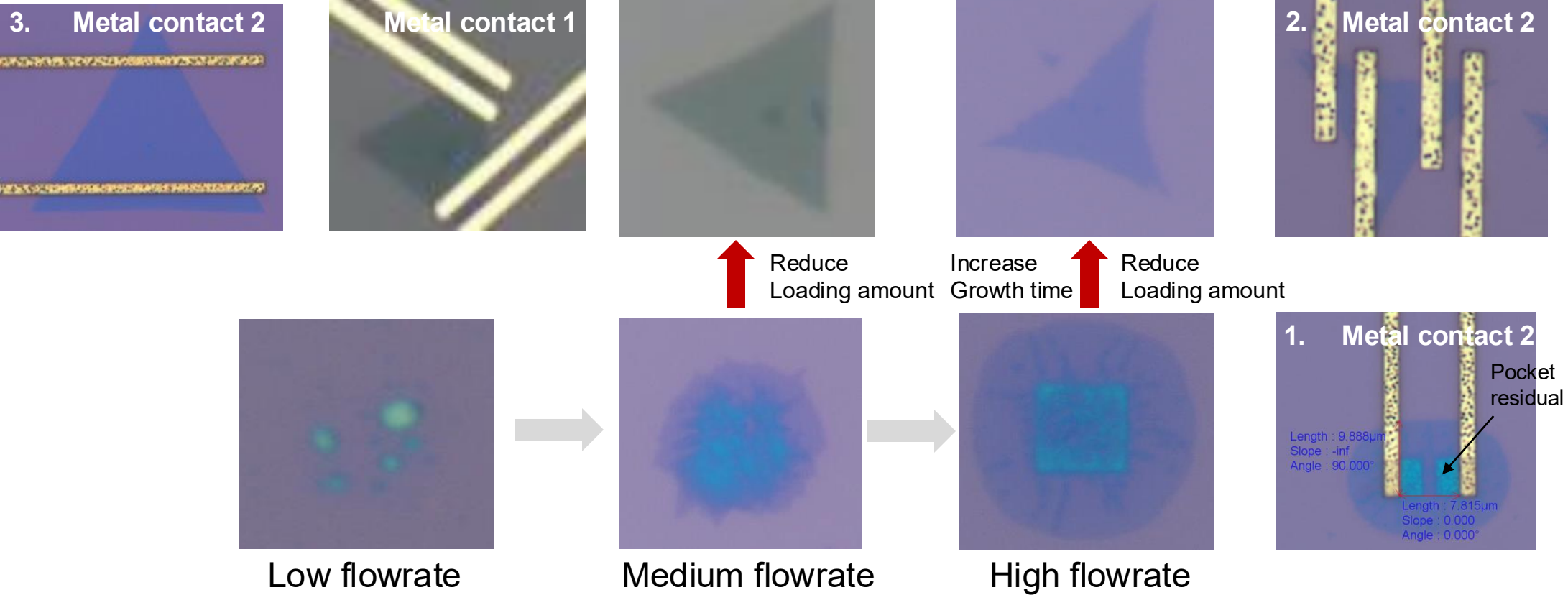
- Conventional photolithography crafts relatively large seed area \rightarrow polycrystalline
- The metal seeds residuals will need extra steps to be removed during the fabrication



Our approaches

- Exploit Electron beam lithographic patterning of the Mo precursors to enable micrometer scale MoS₂ nucleation at predefined locations on SiO₂ substrates

Process-Morphology-Carrier Transport Diagram



Contact	1. Circular	2. Concaved	3. Triangle
Metal contact 1	1	-	< 1
Metal contact 2	20	1 ~ 10	1 ~ 10