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Ultra-Thin-Body Field-Effect Transistor Array Enabled by CVD Grown Few-Layer MoS_2

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Introduction

- Two-dimensional semiconductor MoS_2, with exceptional properties, has shed light on implementing cutting-edge nanoelectronics and optoelectronics for sub-nano technology applications. Specifically, its atomic-thin structure and intriguing electrical characteristics make MoS_2 a promising contender to drive rapid nanotransistor advancements in the 21st century. Our research, utilizing low-pressure chemical vapor deposition (LPCVD) synthesis, has successfully addressed vital challenges, enabling the production of large-scale, high-quality MoS_2 films. This achievement significantly paves the way for realizing compact and high-performance electronic devices.
- In our research, we introduced a novel approach to fabricate back-gated Field-Effect Transistor (FET) arrays using MoS_2 films on a specific substrate. Through non-destructive analysis and electrical evaluations, we highlighted the characteristics of our multi-layer MoS_2 and effectively engineered ultra-thin-body FET arrays.

Experimental method

- Material synthesis: Utilizing solid sulfur and MoO_3 powders as precursors, we synthesized continuous, high-quality MoS_2 thin films on a 0.5cm x 0.5cm sapphire substrate. The growth was conducted inside a quartz tube, with an Ar flow of 70 sccm as the carrier gas. Optimal conditions were maintained at 780˚C and 10 torr, with a precise growth duration of 30 minutes.
- Material Transfer: 3% polycarbonate(PC)/chloroform was spin-coated onto the MoS_2 as a supporting layer, the supporting layer-capped MoS_2 detached using 2M NaOH ,and collected onto a target substrate. The supporting layer was then dissolved in chloroform over 12 hours to finish MoS_2 transfer.
- Device fabrication: Photolithography involves defining the FET electrode array pattern with precision, using a mask aligner to achieve a detailed array pattern with 4μm channel length. Metal deposition starts with a 2 nm Cr layer for strong adhesion, followed by a 50 nm layer of Au as contact metal by thermal evaporation. After FET array structure formation, Digital Light Processing (DLP) accurately defines isolation regions, and Reactive Ion Etching (RIE) is employed to ensure device isolation. This safeguards each unit from cross-talk

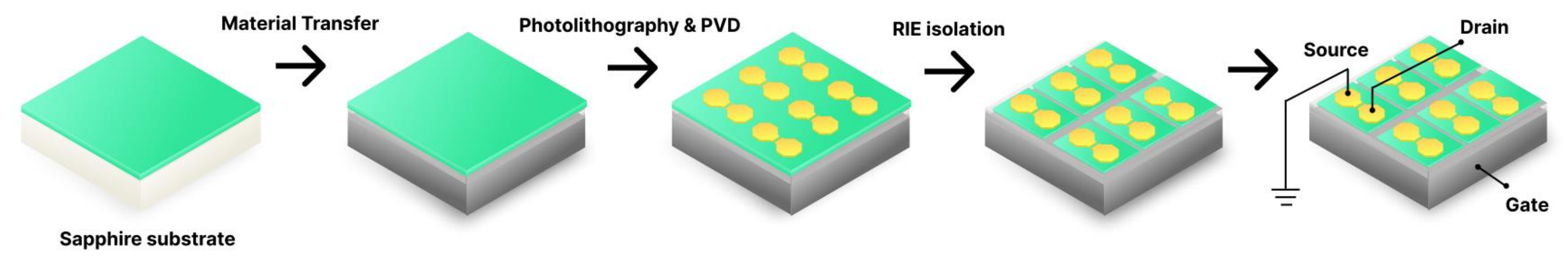

Figure 1: MoS_2 back-gated FET arrays process flow.

Results: Material Characterization

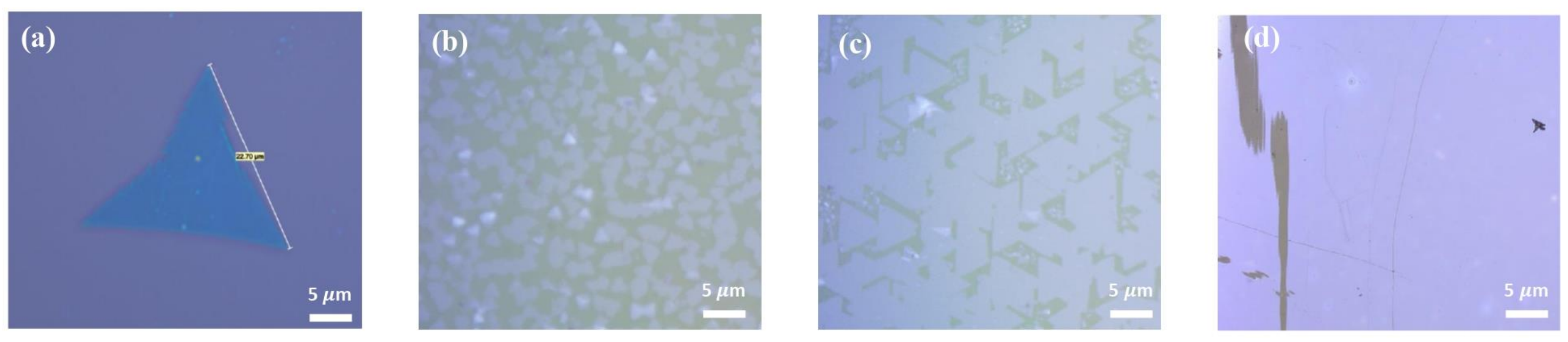

Figure 2: Optical images of (a) ~ (d) Single crystal to continuous film MoS_2

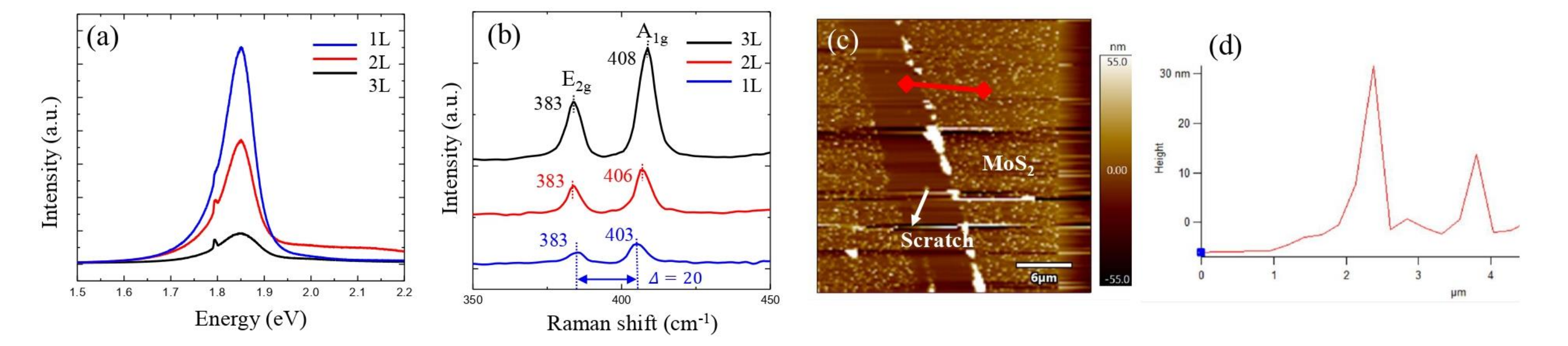

Figure 3: (a) PL spectrum of multi-layer MoS_2. (b)Raman spectra of as-grown multi-layer MoS_2 using 532nm laser excitation. (c) AFM image of continuous MoS_2. (d) Height profile obtained along the red line marked in the AFM image

Device structure

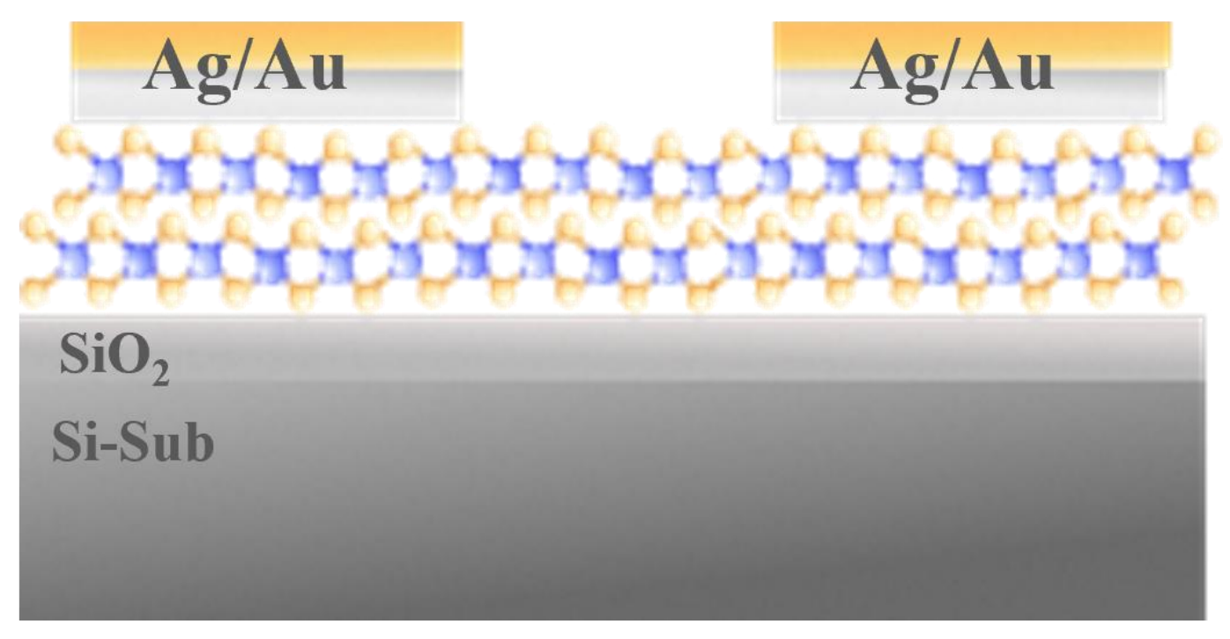

Figure 4: Schematic diagram of multi-layer MoS_2 back-gated FET device

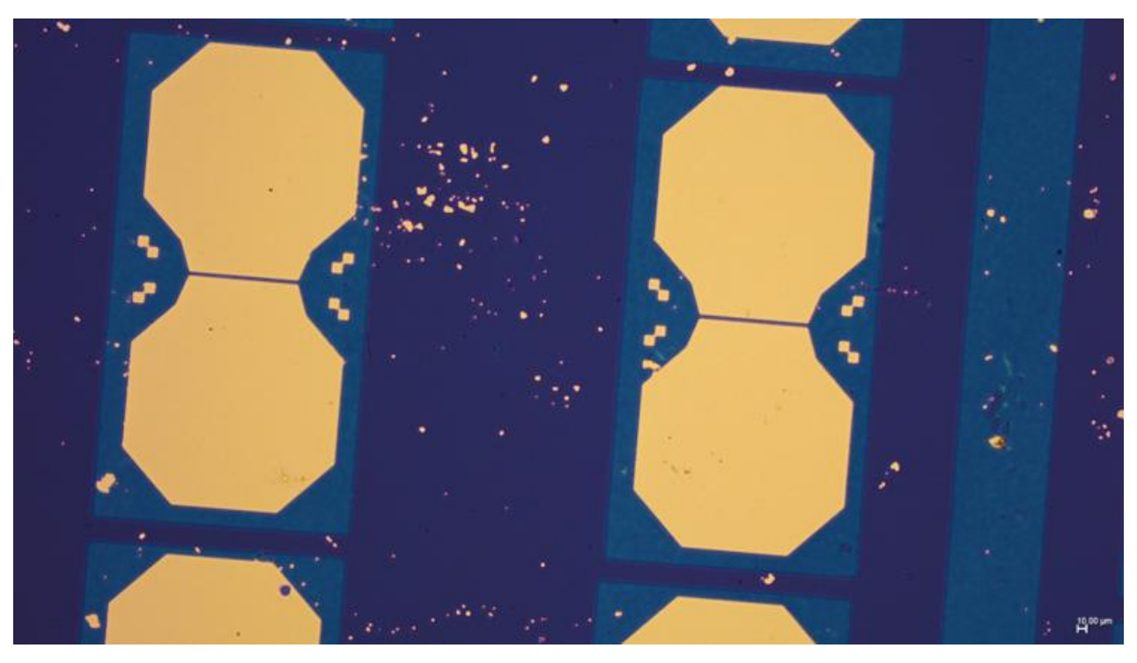

Figure 5: Optical image of MoS_2 back-gated FET array

Results: Electrical properties

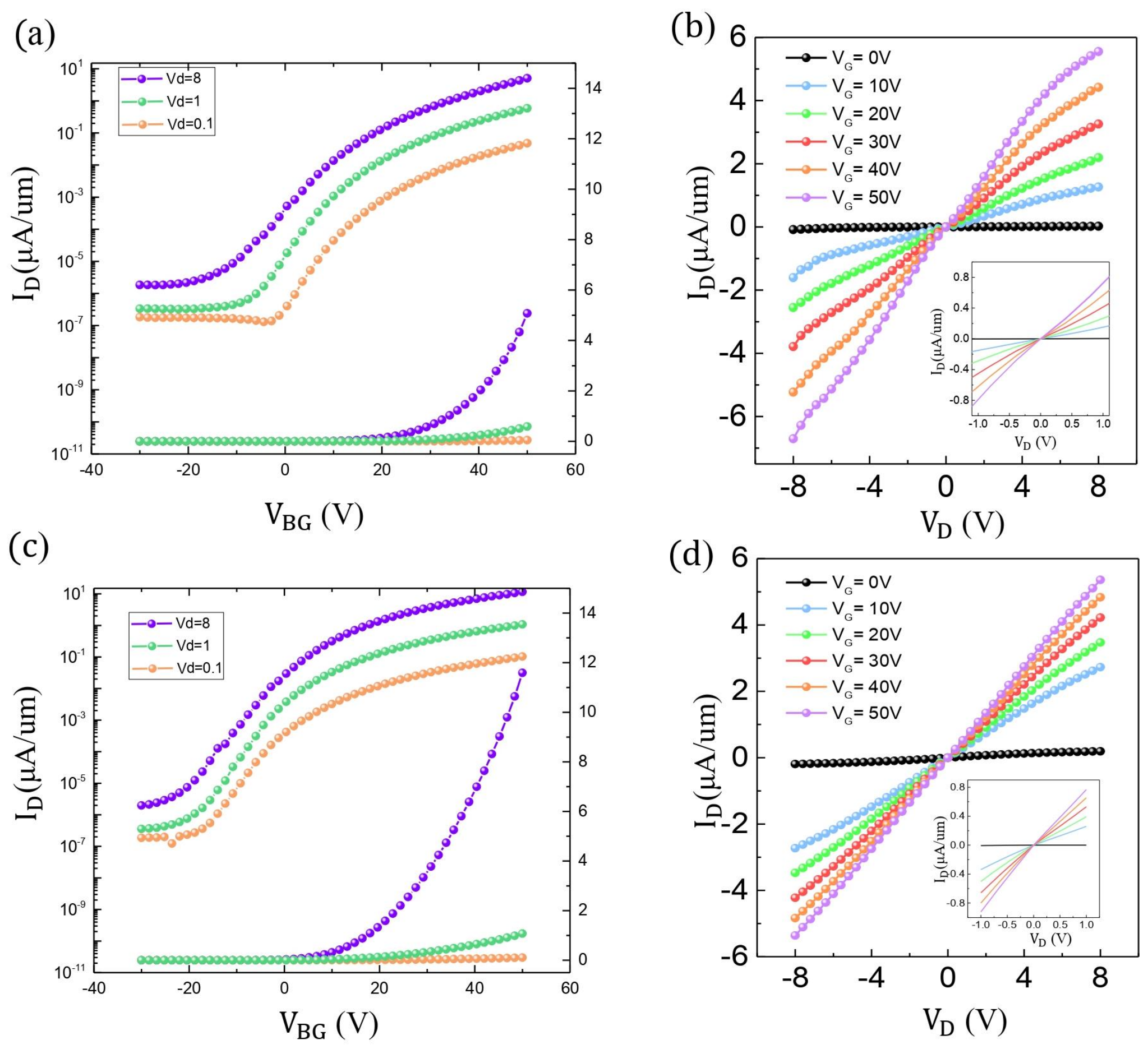

Figure 6:

(a) (b) Transfer & Output characteristics of MoS_2 FET with Cr/Au as contact metal.

(c) (d) Transfer & Output characteristics of MoS_2 FET with Ag/Au as contact metal.

Table 1: Electrical properties of MoS_2 FET .

Contact	μ ($cm^2/V*S$)	S.S (V/decade)	On/Off ratio	V_{th}(V)
Cr/Au	11.67	4.59	1.3×10^7	29.06
Ag/Au	7.75	4.37	5.8×10^6	25.92

Conclusion

- We've adeptly employed the LPCVD method to achieve the synthesis of continuous multi-layer MoS_2 thin films with exceptional coverage. Through rigorous optical characterization, including Raman and PL spectroscopy, we've authenticated the intrinsic quality of the material.
- Our uniquely designed fabrication process allowed for the mass production of ultra-thin-body FET arrays. Impressively, the resulting back-gated FETs demonstrated a remarkable on/off ratio reaching 10^7, underscoring both the efficacy of our approach and the superior electronic attributes of the synthesized material. This sets a promising trajectory for advancing the realm of nanoelectronics in the future.