Large Area Chemical Vapor Deposition of High-Quality Few-Layer MoS_2 through Modulation of Precursor Source Temperature Profiles

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It has attracted great attention to grow large area 2D-layered transition metal dichalcogenides (TMDCs, such as MoS_2 and WSe_2) for scale-up applications in optoelectronics and nanoelectronics, such as manufacturing commercially-viable TMDC-based photodetectors, photovoltaic cells, ultrasensitive nanoelectronic/optoelectronic biosensors, *etc*.[1,2,3] Extensive studies have been performed to deposit or synthesize high-quality TMDCs by using various physical/chemical methods, including mechanical/chemical exfoliation, bottom-up chemical synthesis, and chemical vapor deposition (CVD).[3] Especially, CVD-based methods have some important advantages in terms of potential controllability of number of layers, average grain size, and growth area.[3] Nevertheless, it is still challenging to quantitatively control and secure the optimized CVD condition for reliably producing uniform and large area TMDC films because of involvement of multiple coupled processing parameters. Although some CVD systems, operated under specific conditions, happen to generate high-quality TMDC layers, the processing society still lacks a quantitative model capable of specifying the CVD performance profile and exploring the processing limits.

Here, we present a progressive CVD trial for achieving high-quality large-area few-layer MoS_2 through specifically modulating time-dependent temperature profiles set for solid-phase precursors, carrier gas flow rates, and substrate positions/orientations. Such systematically and progressively acquired CVD results could be used for constructing a quantitative guideline for producing manufacturing-compatible 2D TMDC films.

Fig. 1 illustrates the lab-made CVD setup for this research, which has two separate heating zones for generating reactive precursor vapors (*i.e.*, MoO_3 and S vapors for growing MoS_2) from their solid sources. Using this setup, the source temperatures of both precursors can be independently controlled for testing the growth results under different heating routes (or time-dependent precursor source temperature profiles). Fig. 2 (a) plots various combinations of temperature profiles for heating/vaporizing S and MoO_3 precursors (here, the heating route for MoO_3 is fixed), and Fig. 2 (b) displays the photos of resulted few-layer MoS_2 films grown under these different heating routes. This test shows that the coverage and uniformity of as-grown MoS_2 films are sensitively dependent on the specific combination of heating routes for S and MoO_3 sources. Additional thermal/fluidic analysis of such MoS_2 growth processes, under the influence of other processing parameters, will be provided in the final presentation.

This work will contribute to realization of comprehensive control of fluidic flows of precursor vapors to the reaction/nucleation sites for reliably producing high-quality TMDC films.

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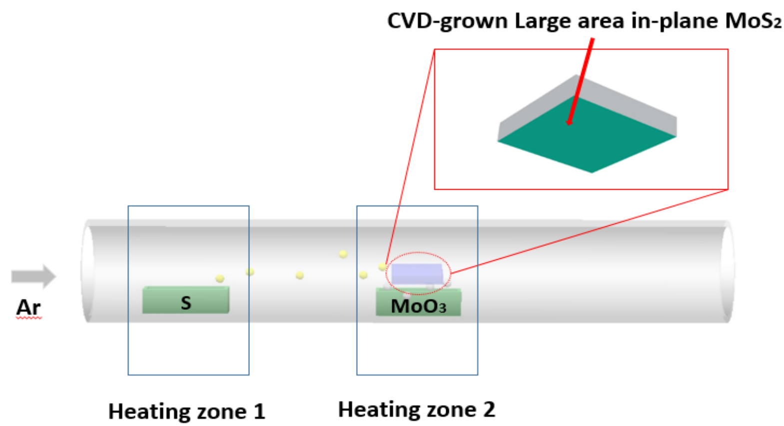

Fig. 1 Schematic illustration of the lab-made CVD setup equipped with two separate heating zones for generating S and MoO_3 vapors

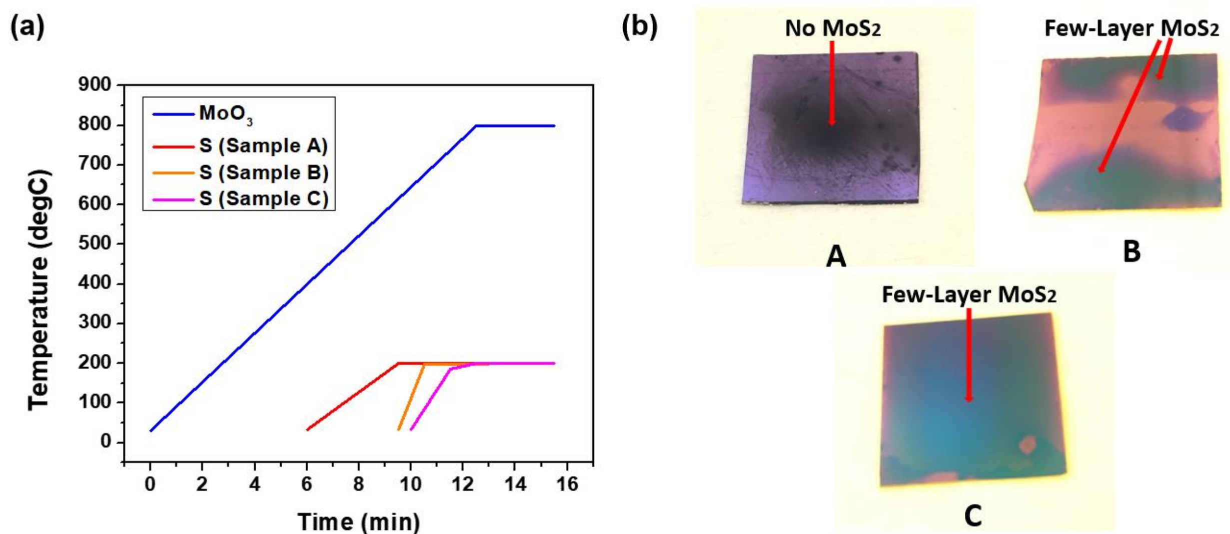

Fig. 2 (a) Temperature profiles for heating/vaporizing S and MoO_3 precursors in CVD experiments, and (b) the corresponding photo images of MoS_2 films on the SiO_2/Si substrate with coverage area difference

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