エレクトロニクスおよびオプトエレクトロニクス用の数層 2D 遷移金属ジカルコゲナイドの合成: ミスト CVD の展望

Synthesis of Few-layer 2D Transition Metal-Dichalcogenides for Electronics and Optoelectronics: A Prospective of Mist CVD

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1. Introduction: Two-dimensional (2D) semiconductors; especially transition metal dichalcogenides (TMDCs) are potential candidates in modern electronic and optoelectronic for ultimate device scaling owing to their efficient electrostatic tunability, atomic thickness, and dangling bond-free surface with superior transport properties [1,2]. To explore and realize their full potential for practical applications, the synthesis of large-scale, uniform, and crystalline TMDC films using economical pathways and in a reproducible manner is one of the top challenges today. In this work, we report the growth of the few-layer TMDC films of MoS_2, WS_2, and $WS_{2-x}Se_x$ on the $Al_{1-x}Ti_xO_y$ wafer by a solution processes, simple mist chemical vapor deposition (Mist-CVD). We also demonstrate their application in FETs and in-plane p-n junction solar cells.
2. Experimental: Ammonium tetrathiotungstate $(NH_4)_2WS_4$ and Ammonium tetrathiomolybdate $(NH_4)_2MoS_4$ were used as a precursor of WS_2 and MoS_2 respectively and N-methyl-2-pyrrolidone (NMP) as solvent. The generated mist by 3 MHz Atomizer was supplied into the hot-wall reaction tube by Ar/H_2 (25%) carrier gas at a furnace temperature (T_f) of 400– 600°C on $Al_{1-x}Ti_xO_y$ coated p^+-Si substrate. Subsequent sulfurization (selenization) was executed to further improve the quality of the as-deposited MoS_x (WS_x) films at T_f of 600 °C for 20– 40 min. Finally, the MoS_2, WS_2, and $WS_{2-x}Se_x$ channel MOSFETs were fabricated using UV-lithography and a standard lift-off process with sputtered Au/Pt source and drain electrodes.
3. Results and Discussion: Fig.1 shows the optical microscope, AFM, and TEM images of mist CVD MoS_2, WS_2, and $WS_{2-x}Se_x$. Atomic few-layer thickness with a submillimeter lateral length MoS_2, WS_2, and $WS_{2-x}Se_x$ flakes was obtained at an adjusted deposition time, precursor concentration, substrate surface treatment, and subsequent sulfurization (selenization) condition. In Fig. 1c, the transfer characteristics of WS_2 n-channel FETs with Au S/D electrodes depict the mobility of 40–50 $cm^2V^{-1}s^{-1}$ and an on-off ratio of 2×10^6. Thus, an efficient way of fabrication of 2D TMDCs films with a comparable dimension is realized using mist-CVD. We will discuss the perspective of mist CVD for the synthesis of atomic-layer TMDCs MoS_2, WS_2, and $WS_{2-x}Se_x$ with their electronic and optoelectronic applications [2,3].

[1] J. Li et al. *Small Sci.* 2, 2200062 (2022), [2] A. Kuddus et al. *Nanotechnology* 33, 045601 (2022), A. Kuddus et al. *Semicon. Sci. Technol.* 37, 095020 (2022)

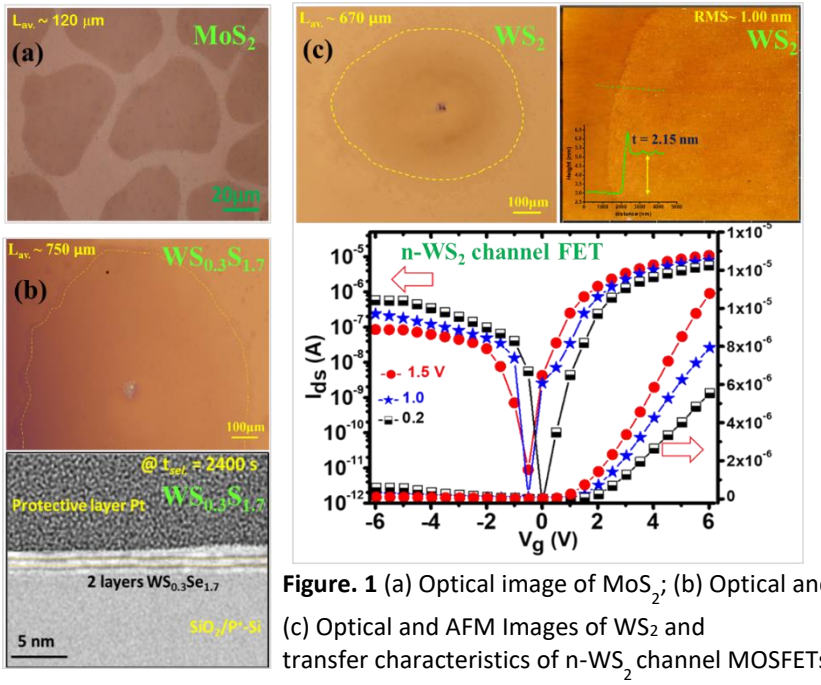

Figure. 1 (a) Optical image of MoS_2; (b) Optical and TEM images of $WS_{2-x}Se_x$; (c) Optical and AFM Images of WS_2 and transfer characteristics of n-WS_2 channel MOSFETs [2,3].