Hydrogen-assisted Epitaxial Monolayer Growth of $MoSe_2$ on Sapphire

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Transition metal chalcogenides(TMDs) monolayers such as $MoSe_2$, WS_2, etc. exhibit distinct electronic properties due to direct band gap and promise numerous potential applications for next generation photonic and optoelectronic devices. Despite these unique properties originate from monolayer structure, their fabrication has remained difficult due to several limitations- e.g., multilayer formation, oxide residues from precursors, in CVD process. Here we propose a process to fabricate $MoSe_2$ on sapphire via CVD using to promote monolayer deposition. By varying H_2 flow rate, $MoSe_2$ growth rate can be modulated and detailed Raman microscopy and PL spectroscopy analysis indicates that H_2 plays a key role in precursor reduction, leading to $MoSe_2$ monolayer epitaxy. We hypothesize that the absence of H_2 in the nucleation step leads to the optimal mono- or sub-monolayer deposition of metal oxide precursor on substrate, while H_2 introduction during the growth step results in the complete reduction of oxides and the epitaxial monolayer formation of $MoSe_2$. Our results provide an important information to fabricate large-area monolayer $MoSe_2$ crucial for a variety of electronic applications.