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Versatile two-dimensional transition metal dichalcogenides

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Two-dimensional transition metal dichalcogenides (2D-TMDCs), such as MoS₂, have emerged as a new class of semiconducting materials with distinct optical and electrical properties. The availability of 2D-TMDCs with distinct band gaps allows for unlimited combinations of TMDC monolayers (MLs) and enables engineering of van der Waals (vdW) heterostructures with characteristics fundamentally different compared to the conventional 3D-covalently bounded heterostructures. Although various 2D materials have been successfully synthesized by mechanical exfoliation or chemical vapor deposition (CVD), a strategy for the fabrication of 2D heterostructures must be developed. Here we demonstrate a novel approach for the bottom-up synthesis of TMDC monolayers, namely Pulsed Laser Deposition (PLD) combined with a sulfur evaporation beam. PLD relies on the use of a pulsed laser (ns pulse duration) to induce material transfer from a solid source (such as a sintered target of MoS₂) to a substrate (such as Si or sapphire). The deposition rate in PLD is typically much less than a monolayer per pulse, meaning that the number of MLs can be controlled by a careful selection of the number of laser pulses. In the paper, we will discuss the growth of high-quality MoS₂ in the form of one or several MLs over large areas and several substrates, such as sapphire, SiO₂/Si and indium tin oxide (ITO). This approach allows the synthesis of 2D-TMDCs without the use of catalyst and with a good control of the sulfur vacancies. We have found that the absorption spectra

of the MoS₂ films exhibit distinct excitonic peaks at ~1.8 and ~2 eV when grown in the presence of a sulfur evaporation beam as compared to those deposited in vacuum. The structure of the PLD-grown MoS₂ films will be further discussed based Raman spectroscopy analysis, photoluminescence, as composition/thickness determined by Rutherford backscattering (RBS). Some challenging issues and future directions on the use of PLD for the synthesis of complex heterostructures by PLD will be discussed.