Sodium assisted CVD growth of large area two-dimensional WS_2 and MoS_2 crystals

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Molybdenum and tungsten disulfides (MoS_2, WS_2), are two of the most well studied semiconductors of the two-dimensional transitional metal dichalcogenides (TMDCs) family of materials. They possess interesting optical properties, exhibiting a unique indirect to direct bandgap transformation as the crystals' thickness is decreased from bulk to the monolayer limit [1, 2]. Moreover, due to quantum confinement, strong coulomb screening and large spin-orbit coupling, a wealth of physical phenomena emerge ranging from a plethora of excitonic effects to the controllability of valley degrees of freedom [3-5].

Significant effort has been made so far to refine and develop efficient production methods of 2D-TMDC crystals. By far, the most scalable and appropriate for the industry appears to be the atmospheric pressure Chemical Vapor Deposition method (CVD). In a typical reaction scheme, a transition metal precursor, commonly a metal oxide reacts in vapor phase with sulfur at elevated temperatures (800°C).

In this work, an atmospheric pressure CVD method for the production of large area MoS_2 and WS_2 crystals is presented. The method is based on the reaction between a sodium metalate precursor (Na_2MO_4, M = Mo, W), predeposited on the growth substrate, and sulfur vapors at high temperatures. As has been recently observed, the presence of sodium enhances the growth rate of the crystals due to a vapor-liquid-solid growth scheme [6]. We find that by this method continuous MoS_2 films with monolayer and few layer domains, isolated triangular MoS_2 monolayers or very large WS_2 monolayers with lateral dimensions exceeding 300 μm can be readily obtained. The impact of the growth conditions on the crystal shape is studied and it is shown that the chalcogen concentration can significantly affect the crystal's growth. Moreover, the possibility of combining the precursors to produce ternary alloys of the $Mo_xW_{1-x}S_2$ is discussed. The grown crystals are studied by means of XPS to verify their stoichiometry and atomic force microscopy. Micro-Raman and Photoluminescence spectroscopies are employed to identify and quantify the presence of growth induced strain and doping [7].

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