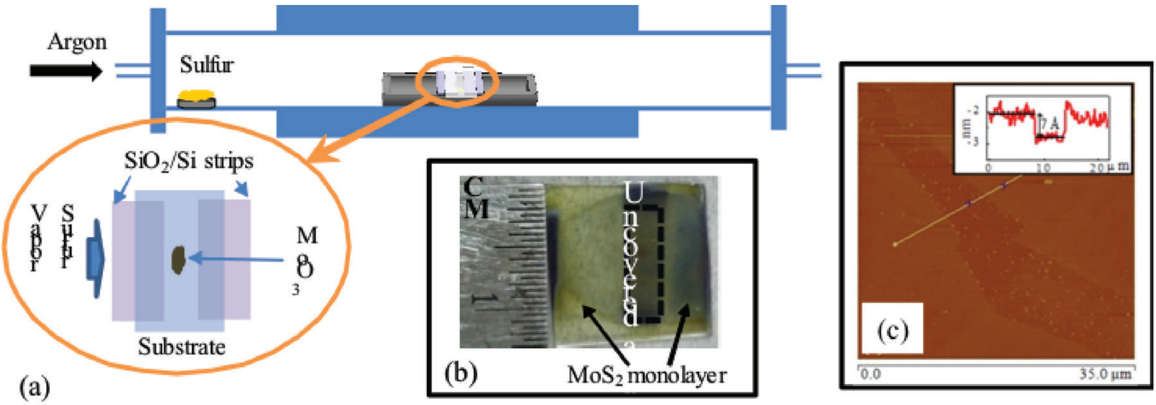
Growth of strictly monolayer large continuous MoS_2 films on diverse substrates



(a) Schematic depiction of the growth process: Sulfur boat is placed in the cold zone. While, the boat containing MoO_3 and the substrate is kept in the hot central part of the furnace. Placement of the substrate and SiO_2/Si strips, which is a very crucial step in this technique, is also highlighted. (b) A sapphire substrate after the growth. Deposition of MoS_2 can only be seen on the portions of the substrate which were covered by the Si/SiO_2 strips during growth. (c) Atomic force microscopy (AFM) image of a continuous MoS_2 monolayer film grown on a sapphire substrate. Inset: The line scan profile across a step, showing the step height of MoS_2 monolayer (~7Å).

Despite a tremendous interest on molybdenum disulphide as a thinnest direct band gap semiconductor with a huge potential for application in optoelectronics and plasmonics, single step synthesis of a large area purely monolayer MoS_2 film has not yet been reported. We have adopted a chemical vapour deposition (CVD) route to synthesise a continuous film of strictly monolayer MoS_2 covering an area as large as several mm^2 on a variety of different substrates without using any seeding material or any elaborate pre-treatment of the substrate. This is achieved by allowing the growth to take place in the naturally formed gap between the pieces of SiO_2 coated Si wafer and the substrate, when the latter is placed on top of the formers inside a CVD reactor. In this process, the gap that is formed between the substrate and the wafer, acts as a natural reactor cavity, resulting in the formation of continuous MoS_2 monolayer, occupying the entire region of the substrate covered by the wafer. The highlight of this method is that it results in the synthesis of strictly monolayer films. Multiple layers have never been found in any of the samples grown by this technique, even when the samples are grown with a wide range of growth parameters. This result is thus a significant step forward for the realisation of MoS_2 monolayer based integrated devices, which can utilise certain unique features of this 2D semiconductor. Moreover, this particular technique could be extended for the growth of other 2D dichalcogenide semiconductors such as WS_2, $MoSe_2$ and WSe_2.

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