CVD growth of atomically thin MoS_2 films for digital electronics

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Two-dimensional (2D) materials receive a great interest because of their unique properties. Molybdenum disulfide (MoS_2) is probably the most prominent member of the large group of transition metal dichalcogenides (TMDs) belonging to even larger family of 2D materials. Due to immunity to short-channel effects, mechanical flexibility and improved electrostatic gate control, 2D MoS_2 is a promising candidate for modern electronics [1], [2].

To achieve fabrication of complex electronic circuits on 2D materials one has to synthesize uniform films on a large scale. One of the well-established techniques is chemical vapor deposition (CVD). In this work, we utilize CVD growth to synthesize cm^2 scale single- and few-layer continuous MoS_2 films with high uniformity. The growth recipe is adopted from [3]. The films are grown from MoO_3 and sulphur precursors in tube CVD furnace at 700^{o}C in argon environment at atmospheric pressure on c-plane sapphire substrates.

We used our films to fabricate logic building blocks and logic circuits from single- and few-layer MoS_2 transistors. One of the recent circuitry we fabricated is a 1-bit implementation of a microprocessor [4]. Our processor consists of 115 transistors and is based on the NMOS logic family. It incorporates a program counter to facilitate program flow, several registers used to store I/O-data, an arithmetic logic unit performing the actual operations and a control unit coordinating the function of the other subunits. It is able to run simple, user defined programs that consist of logical operations and are stored in an external memory. By varying the W/L ratios of the FETs we were able to fabricate logic gates that are easily cascadable into larger, more complex circuits.

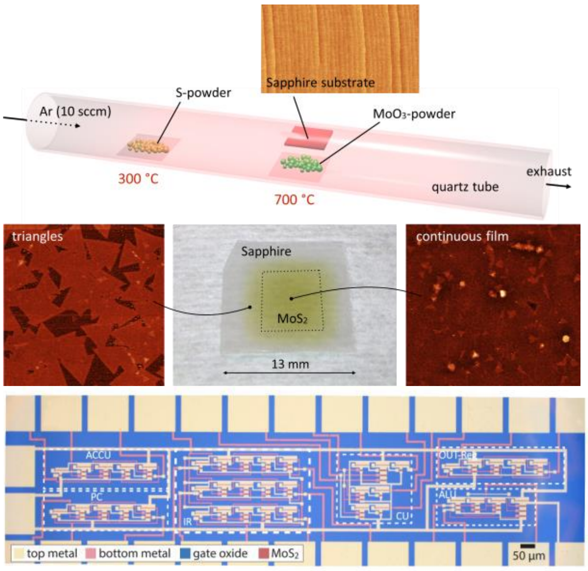

Fig. 1: Schematic of the CVD tube furnace with AFM image of the bare sapphire substrate and the optical microscope images of the grown films on the wafer. On the edge of the grown film triangular shape grains are formed, which then coalesce into continuous film towards the center of the wafer. On the bottom, optical microscope image shows 1-bit microprocessor, consisting of 115 transistors.

A short program of 10 instructions was executed, confirming the correct rail-to-rail operation of our processor. It constitutes the most complex logic device using 2D-semiconductors fabricated to date [5] and is readily scalable to multi-bit data.

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