Controlled CVD synthesis of single- and few-layered MoS$_2$ crystals

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Two dimensional MoS$_2$ has been intensively studied over the past few years due to its excellent mechanical, electrical and optical properties [1]. Reliable and efficient wafer-scale CVD production methods are prerequisite for the fabrication of 2D-MoS$_2$ based devices. A variety of scalable CVD routes to fabricate 2D-MoS$_2$ have been proposed in the past with the most common involving the sulfurization of MoO$_3$ [1]. Taking place in atmospheric pressure and requiring only MoO$_3$ and elemental sulfur as precursors, it is by far one of the simplest methods used to fabricate 2D-MoS$_2$. Yet, one of its main disadvantages is that the uniformity and nucleation density of the produced crystals is difficult to control. Although other synthetic routes that offer a greater degree of control exist, they tend to be more complex requiring low pressure systems and potentially more expensive or even toxic precursors such as H$_2$S [2,3].

In this work we show that it is feasible to fabricate single- and few-layered MoS$_2$ crystals in a simple, one-step atmospheric pressure CVD synthesis using Na$_2$MoO$_4$ and elemental sulfur as precursors. Na$_2$MoO$_4$ is widely available, water soluble and relatively safe, commonly used as a fertilizer. The thickness and size of the crystals can be controlled by the deposited amount of Na$_2$MoO$_4$ precursor. The fabricated crystals are studied by means of X-ray photoelectron spectroscopy, atomic force microscopy, micro-Raman and micro-photoluminescence spectroscopies, and are compared with single-layer 2D-MoS$_2$ crystals that were exfoliated or transferred to other substrates. Through this comparison various spectral differences are found to arise from residual mechanical strain and/or doping levels induced by the interaction with the supporting substrate as well as the fabrication procedure. These strain and doping levels are quantified using an optical analysis published recently [4].

References

Figures

Figure 1 Photoluminescence intensity image of a CVD MoS$_2$ monolayer. The dark spots are few-layered seed crystals. The average photoluminescence peak position for the monolayer is 1.80(2) eV.