Controlling the growth of metallic and semiconducting 2D-chalcogenide by Chemical Vapour Deposition

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Molybdenum ditelluride ($MoTe_2$) has received increasing amounts of attention over the last five years, mainly due to the interesting layer-dependent properties of its two polymorphs. In bulk form hexagonal 2H-$MoTe_2$ is an indirect gap semiconductor but when it is thinned down to few- and monolayer samples, a direct gap of ~1.1 eV emerges. This bandgap switching is accompanied with a strong photoluminescence signal in the near IR region, making few-layer 2H-$MoTe_2$ a potential candidate for optoelectronic devices [1]. Whereas, the monoclinic 1T'-$MoTe_2$ is a Weyl semi-metal in bulk form and has been investigated for potential applications in fields as varied as energy conversion and surface enhanced Raman spectroscopy (SERS) [2-3]. The polymorphism of $MoTe_2$ provides an opportunity to exploit the influence of crystal structure on the electronic properties without the need for compositional change. The most exciting examples of this include the fabrication of 2H-$MoTe_2$ based field effect transistors that are contacted with the semi-metallic 1T' phase which show improved device performance compared to 2H devices contacted with other metals [4]. However, most methods of forming 1T'-2H homojunctions rely on post-growth modification using techniques such as laser irradiation [5]. In this work we show that the nature of seeding layer determines whether the atomically-thin $MoTe_2$ film grown by chemical vapour deposition (CVD) is 1T'-$MoTe_2$ or 2H-$MoTe_2$. When molybdenum metal is used phase-pure semiconducting 2H-$MoTe_2$ is formed as the sole product. However, using molybdenum trioxide results in the formation of phase-pure semi-metallic 1T'-$MoTe_2$. This control over the phase growth allows for the simultaneous growth of both 2H-$MoTe_2$ and 1T'-$MoTe_2$ on a single substrate during one CVD reaction and without the need for any post growth modification (Figure 1).

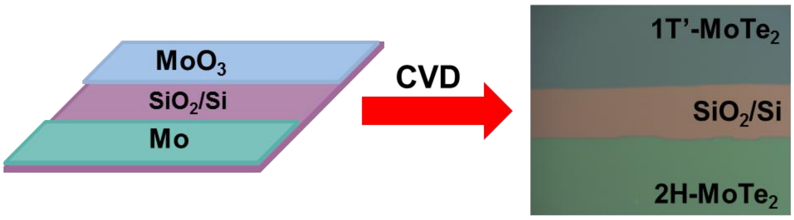

Figure 1: Illustration of the conversion process that allows for the simultaneous growth of both 2H- and 1T'-$MoTe_2$ on a single substrate.

Furthermore, the layer dependent properties of 1T'-$MoTe_2$ were explored by using few-layer and bulk films as SERS substrates. When adsorbed onto few layer films rhodamine 6g dye could be detected at concentrations as low as 5 nM, remarkably the bulk films exhibited no appreciable SERS activity.

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