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MoS_2 nanostructures with tailored dimensionality

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The ability to manipulate the electrical, optical and magnetic properties of two-dimensional (2D) transition metal dichalcogenides (TMDs) via substitutional doping, defects, electrostatic doping, and charge transfer has led to many exciting opportunities for their utilization[1–3]. This includes fundamental studies and integration in optoelectronic devices, such as solar cells, photodetectors, laser diodes, and light-emitting diodes[4,5]. Similarly, one-dimensional (1D) structures of TMDs, such as WS_2 nanorods, have been shown to exhibit striking functionalities compared to their 2D counterparts, such as enhanced photovoltaic effect in bulk and the absence of a p-n junction[5,6].

Currently, there are no synthetic methods to control the shape of TMDs from 1D to 2D and, finally, 3D. This paper will discuss a novel approach to synthesising TMD structures with tunable shapes via the growth of transition metal oxide, such as MoOx, by Pulsed Laser Deposition (PLD) followed by conversion to 1D, 2D, or multi-crystal MoS_2. This synthesis procedure is a similar approach described in our previous work[7,8], except that alkali was added during the conversion. The morphological studies based on scanning electron microscopy (SEM) and atomic force microscopy (AFM) images reveal an anisotropic growth quasi-1D and highly stacked MoS_2 crystals with preferred (AA(A-…) stacking orientation on (0001) sapphire. AFM images of the MoS_2 nanoribbons disclose the formation of monolayers at the edges of the nanoribbons, particularly at a high sulfurisation temperature ($800^{O}C$). At moderate temperatures (~$600^{0}C$), the extension of the 2D structures outward of the nanoribbons is less pronounced, indicating that nanoribbons probably emerge from 1D ribbons. The conversion/formation mechanism of 1D/3D MoS_2 will be discussed via temperature-dependence studies under an S-rich environment.

The 1D- MoS_2 and (AA(A-…) stacked- MoS_2 crystals exhibit a high second harmonic generation (SHG) signal, which is an indication of a preferential non-centrosymmetric stacking orientation in MoS_2. Similarly, the Raman spectra in 1D and 3D-stacked crystals have distinct peak positions and ratios of the out-of-plane (A_{1g}) and in-plane (E_{2g}^1) phonon frequency modes. Similarly, the Raman spectra of the 1D and 2D- MoS_2 show distinct signatures as a function of the polarisation of the light. Finally, we will discuss that the 1D-MoS_2 devices offer a strong photocurrent response under light, which is highly tunable as a function of the laser power and polarization.

The experimental results reveal the growth of single-crystalline quasi-1D MoS2 nanoribbons and their potential use in future optoelectronic applications.

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