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Quasi-One-Dimensional Molybdenum Disulfide Nanoribbons

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One-dimensional (1D) materials, such as nanowires, nanotubes, and nanorods, have been studied intensively recently due to their unusual structural characteristics and novel physical properties[1–3]. Similarly, 1D structures of transition metal dichalcogenides (TMDs), such as WS_2 nanorods, have been shown to exhibit striking functionalities compared to their two-dimensional (2D) counterparts, such as enhanced photovoltaic effect in bulk, in the absence of a p-n junction[1]. These findings lead to many exciting opportunities for their utilization in optoelectronic devices, such as solar cells, photodetectors, laser diodes, and light-emitting diodes.

This paper will discuss a novel approach for synthesizing MoS_2 nanostructures with tunable dimensionality ranging from 2D to 1D. In our process, epitaxial precursors of transition metal oxides, i.e., ultra-thin films of MoO_x ($x<3$) grown by Pulsed Laser Deposition (PLD), serve as precursors [2,3]. We will show that the addition of halides during sulfurization leads to the unidirectional growth into quasi-1D MoS_2 nanoribbons. The morphological and atomic resolution imaging studies reveal an anisotropic growth of epitaxial quasi-1D nanoribbons in either 2H or 3H stacking orientation. Tip-enhanced photoluminescence (TEPL) spectroscopy reveals a photoluminescence (PL) emission from the edge of the nanoribbons and no emission from the core of the quasi-1D structures. Moreover, we observe an edge-enhanced secondary harmonic generation (SHG) of the quasi-1D MoS_2 nanoribbons, which will be discussed in detail during the talk. Finally, we will report the first ultrasensitive photodetector based on a single 1D MoS_2 nanoribbon. The highly crystalline quasi-1D ribbon device exhibits a high photocurrent response under light illumination and outstanding stability. Photocurrent measurements of single-ribbon photodetector made on SiO_2/Si substrate exhibit a photoresponsivity above 500 AW^{-1} at a wavelength of 532 nm, which exceeds that of graphene, MoS_2, or other nanoribbon-based devices. The experimental results show that single-crystalline quasi-1D MoS2 nanoribbons have immense potential for high-performance photodetector applications.

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