Duan Xidong et al., J Material Sci Eng 2019, Volume 8
DOI: 10.4172/2169-0022-C6-140

Two dimensional lateral complicated struture

Duan Xidong[1] and **Duan Xiangfeng**[2]
[1]College of Chemistry and Chemical Engineering, Hunan University, China
[2]University of California, USA

Two-dimensional layered materials such as garphene, MoS_2 and WSe_2 have attracted considerable interest in recent times as semiconductor after Si and becoming an important material platform in condensed matter physics and modern electronics and optoelectronics. The studies to date however generally rely on mechanically exfoliated flakes which always be limtited to simple 2D materals, especially 2D lateral complicated structure can not be perpared through exfoliation strategy. Much like the traditional semiconductor technique, complicated structure such as controlling the space distribution of composition and electronic structure of two dimensional semiconductor material is essential to construct all modern electronic and optoelectronic devices, including transistors, p–n diodes, photovoltaic/photodetection devices, light-emitting diodes and laser diodes. And many physics phenomenon can only appear in more complicated structure. To fully explore the potential of this new class of materials, it is necessary to develop rational synthetic strategies of two dimensional lateral complicated struture, such as lateral heterostructure, multiheterostructure, superlattice, quantum well etc., With a relatively small lattice mismatch (~4%) between MoS_2 and $MoSe_2$ or WS_2 and WSe_2, it is possible to produce coherent MoS_2–$MoSe_2$ and WS_2–WSe_2 heterostructures through a lateral epitaxial process (Fig. 1a). Our studies indicate that simple sequential growth often fails to produce the desired heterostructures because the edge growth front can be easily passivated after termination of the first growth and exposure to ambient conditions. To retain a fresh, unpassivated edge growth front is important for successive lateral epitaxial growth. To this end, we have designed a thermal CVD process that allows *in situ* switching of the vapour-phase reactants to enable lateral epitaxial growth of single- or few-layer TMD lateral heterostructures. We used this technique to realize the growth of compositionally modulated MoS_2–$MoSe_2$ and WS_2–WSe_2 lateral heterostructures. From the Fig. 1 b,c,d,e we can see the formation of WS_2–WSe_2 lateral heterostructures clearly. The WS2–WSe2 lateral heterostuctures with both p- and n-type characteristics can also allow us to construct many other functional devices, for example, a CMOS inverter. Fig. 1g is the optical image of the invert constructed using the WS_2–WSe_2 lateral heterostuctures and the curves of the output–input and the voltage gain. The voltage gain reaches as large as 24.

In a typical sequential-growth process for 2D lateral heterostructure, the excessive thermal degradation or uncontrolled nucleation duringthe temperature swing between sequential growthsteps represents the key obstacle to reliable formation of monolayer heterostructure or other lateral complicated structure .We designed a modified CVD system.We used a reverse flow from the substrate to the source during the temperature swing between successive growth steps A forward flow from the chemical vapor sourcewas only applied at the exact growth temperature. With such reverse flow, the existing monolayer materials will not exposure to high temperature and chemical vapor source at the tempreture increasing and decreasing steps to minimize thermal degradation and eliminate uncontrolled homogeneous nucleation. With a high degree of controllability in each step, the integrity and quality of monolayer heterostructures can be well preserved after multiple sequential growth steps. We used our approach initially for the general synthesis of a wide range of 2D crystal heterostructures. We also grew more complex compositionally modulated superlattices or multiheterostructures, the number of periods and repeated spacing can be readily varied during growth. HADDF-STEM analysis of the atomic structure of the lateral heterostructures and Multiheterostructures show the atomically sharp interface can be clearly observed.

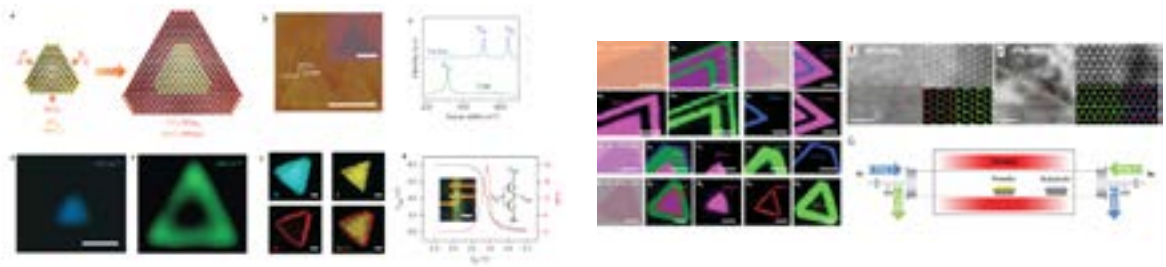

Figure 1: *a.Schematic of lateral epitaxial growth of WS_2–WSe_2 and MoS_2–$MoSe_2$ heterostructures. b.AFM image of a triangular domain with a thickness of 1.2 nm. Inset: optical image of a triangular domain. Scale bars, 5 μm. c. Raman mapping at 419 cm−1 (WS_2 A1g signal), demonstrating that WS_2 is localized at the centre region of the triangular domain. Scale bar, 5 μm. d. Raman mapping at 256 cm−1 (WSe_2 A1g signal), demonstrating that WSe_2 is located in the peripheral region of the triangular*

Recent Publications

1. Xidong Duan, Anlian Pan,Ruqin Yu, Xiangfeng Duan,et,al, Nature Nanotechnology 9,2014,1024-1030.
2. Zhengwei Zhang,Xidong Duan, Xiangfeng Duan,et al, Science, 357, 2017,788–792.

Biography

Xidong Duan is a Professor at the College of Chemistry and Chemical Engineering, Hunan University, China. His current research interests include two-dimensional materials, heterostructures and their applications. He received his BS degree in Chemistry from Hunan University in 1993, his MA degree in Materials from Hunan University in 1996, and his degree in Chemistry from Hunan University in 2016. He was previously a senior engineer at the Changsha Research Institute of Mining and Metallurgy before joining Hunan University.

Notes: