Asia Pacific Nano Congress 2019: Two dimensional lateral complicated struture

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Abstract

Two-dimensional layered materials such as garphene, MoS2 and WSe2 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 MoS2 and MoSe2 or WS2 and WSe2, it is possible to produce coherent MoS2???MoSe2 and WS2???WSe2 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 MoS2??? MoSe2 and WS2???WSe2 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 WS2???WSe2 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.

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