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Study of fabrication and current-voltage characteristics of MoS_2/WSe_2 heterojunction diode

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Abstract

Atomically thin two-dimensional (2D) semiconducting transition metal dichalcogenides (TMDCs) have attracted great attention in recent years. Most studies use mechanic exfoliation method to investigate some TMDC materials, but these samples are small that are hard to form the device. In our work, we demonstrate the Chemical Vapor Deposition (CVD) synthesis of large-area heterojunctions of n-type MoS_2 and p-type WSe_2 with vertically aligned atomic layers. We use the first CVD to synthesize WSe_2 on the sapphire substrate and then using the second CVD directly grow on WSe_2. This direct synthesis of heterojunction opens up some new way to the optoelectronic devices.

1. Introduction

Two-dimensional (2D) materials have been researched widely in recent years, the layers by layers are the van der Waals force bonded. The transition metal dichalcogenides (TMDCs) and graphene are the two-dimensional materials. The TMDCs have different characteristics in different thickness. The TMDCs are interesting because their semiconducting properties [1]. Properties of molybdenum disulfide (MoS_2) and tungsten diselenide (WSe_2) are highly dependent on the film quality, defects, and numbers of layers, which can affect the performance of TMDC devices. MoS_2 is known as an n-type material, since it has shown excellent carrier mobility, great thermal stability, a high on/off current ratio, and can be bent. In contrast to n-type MoS_2, WSe_2 was studied as an ambipolar or mostly a p-type 2D material. The TMDCs have been widely applied to the device like the photodetector, gas sensor, biomedical sensors and solar cell [2].

We show the heterojunction is built up with the bilayer WSe_2 which is directly stacked with MoS_2 on the substrate. The 2D heterojunction p-n diode can have a large area and an excellent current rectification behavior. We hope the fabrication and the device can be helpful to reduce the volume of the device.

2. Experiment

Vertical heterojunctions of WSe_2 and MoS_2 were synthesized from the chemical vapor deposition (CVD) under vacuum pressure. We load the selenium and WO_3 powder in the quartz tube to synthesize WSe_2. We also load the sulfur and MoO_3 in another CVD system to synthesize MoS_2. The Raman spectrum and the photoluminescence (PL) spectrum show the bilayer WSe_2 and MoS_2 stacked successfully on the sapphire substrate. The Raman spectrum as shown in Fig. 1. We observed at 380 and 413 cm^{-1} are the E^1_{2g} and A_{1g} modes for MoS_2, E^1_{2g} is the signal for the in-plane vibration and A_{1g} is the signal for the out-plane vibration, we can probably know the number of layers from these two different frequency [3]. The same way for WSe_2, we observed the peak which is contain E^1_{2g} and A_{1g} for the bilayer WSe_2 is at 250 cm^{-1}, the two peak is almost at the same frequency. Fig. 2 is the PL spectrum from the heterojunction. This figure shows a peak at 1.85 eV for MoS_2 and 1.61 eV for WSe_2, respectively. It can represent the two different band gap energy, and it also indicates the numbers of layers for MoS_2 and WSe_2 with the Raman spectrum. In the voltage-current characteristic measurement, silver plastic was used for the contact electrode to these two materials. We continue to probe the heterojunction which show an ohmic contact between electrodes and heterojunction. We observe a clear current rectification behavior from the WSe_2/MoS_2 heterojunction in the I−V plots as shown Fig. 3. The turn-on voltage was 0.5 V, the heterojunction p-n diode doesn't have the breakdown when it is operated at -5 V. The phenomenon of current rectification clearly demonstrates a p-n junction is formed within the thin WSe_2/MoS_2 heterojunction.

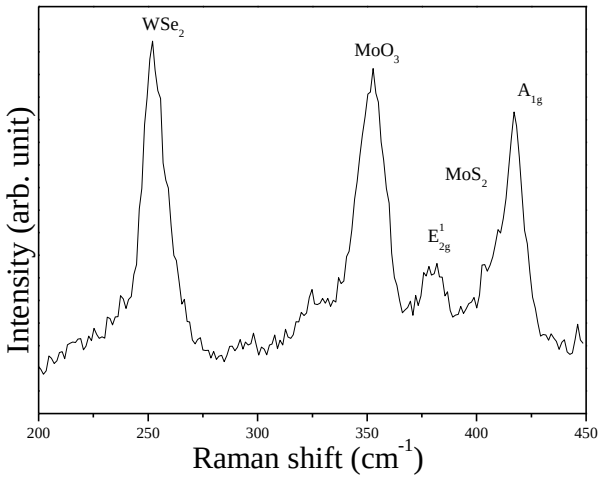

Fig. 1 Raman spectrum for the MoS_2/WSe_2 heterojunction.

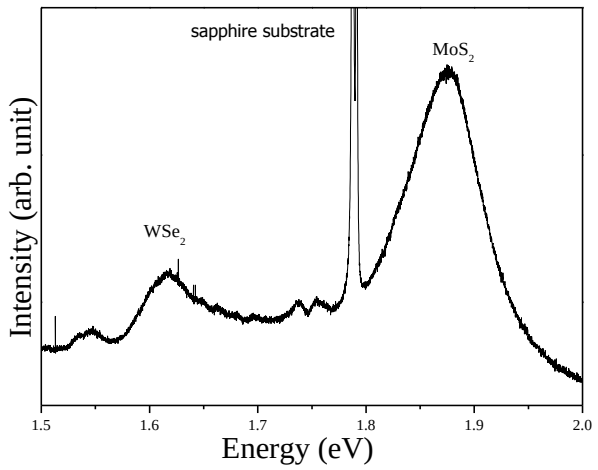

Fig. 2 PL spectrum for the MoS_2/WSe_2 heterojunction.

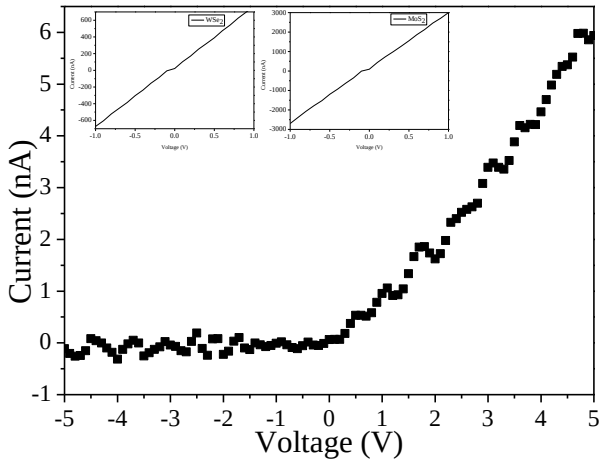

Fig. 3 Current−voltage characteristic of the MoS_2/WSe_2 heterojunction.

3. Conclusions

In summary, we successfully synthesis the vertical heterojunction of MoS_2/WSe_2 on sapphire substrate from the CVD, and the success of the production device. The MoS_2/WSe_2 heterojunction thin films were characterized by Raman spectroscopy and PL spectroscopy. We also demonstrated a current rectification behavior with the p-n heterojunction. The turn-on voltage is 0.5 V, and the current approach 6 nA when it is operate at +5 V. We expect this heterojunction will extend to new devices.

References

[1] J. -H. Yu, H. -R. Lee, S. -S. Hong, D. -S. Kong, H. -W. Lee, H. -T. Wang, F. Xiong, S. Wang, and Y. Cui, "Vertical Heterostructure of Two-Dimensional MoS_2 and WSe_2 with Vertically Aligned Layers," Nano Lett, vol. 15, pp. 1031-1035, Feb 2015.

[2] R. Cheng, D. H. Li, H. L. Zhou, C. Wang, A. X. Yin, S. Jiang, Y. Liu, Y. Chen, Y. Huang, and X. F. Duan, "Electroluminescence and Photocurrent Generation from Atomically Sharp WSe_2/MoS_2 Heterojunction p-n Diodes," Nano Lett, vol. 14, pp. 5590-5597, Oct 2014.

[3] C. Lee, H. Yan, L. E. Brus, T. F. Heinz, J. Hone, and S. Ryu, "Anomalous Lattice Vibrations of Single- and Few-Layer MoS2," Acs Nano, vol. 4, pp. 2695-2700, May 2010.