UDC 548.522

CHEMICAL VAPOR DEPOSITION GROWTH OF WS_2 CRYSTALS

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The synthesis and characterization of WS_2 single crystals grown by chemical vapor deposition (CVD) method thru sulfurization of tungsten oxide thin layer on quartz substrate studied. Synthesis of WS_2 carried out at 800-1000 °C in CVD system. The sulphur vapor transported by argon gas (500 sccm). Obtained WS_2 single crystals characterized by optical microscope, Raman and photoluminescence analysis. Optical microscope analysis demonstrated that triangular WS_2 domains with single-phase crystal structure formed. The thickness of WS_2 is 6 layers, which determined by Raman spectroscopy. Photoluminescence spectroscopy analysis revealed a strong peak between 600-660 nm, typically for a monolayer WS_2 crystal, where the band gap is equal to 1.96 eV.

Keywords: transition metal dichalcogenide, chemical vapor deposition, tungsten oxide.

Introduction

Two-dimensional (2D) materials have significantly different electronic and physical properties than bulk materials, due to electron localization and lack of interlayer interaction, see Figure 1. Optical and physical properties of monolayers of transition metal dichalcogenides (TMDs) have new possibilities for nanoelectronic and optoelectronic devices. Two-dimensional (2D) materials are quite interesting for the manufacture of photosensitive devices, such as photodetectors, multifunction memory devices. In addition, the hybridization of WS_2 layers with other two-dimensional (2D) layered materials intensively studied for fabricating vertical and planar heterostructures. Recently, the synthesis of laminates MoS_2 and WS_2 studied in several approaches, such as mechanical exfoliation, liquid exfoliation and sulfurization of transition metals and oxides of these metals. The CVD method can be more promising for growing a high-quality WS_2 thin sheet [1, 2].

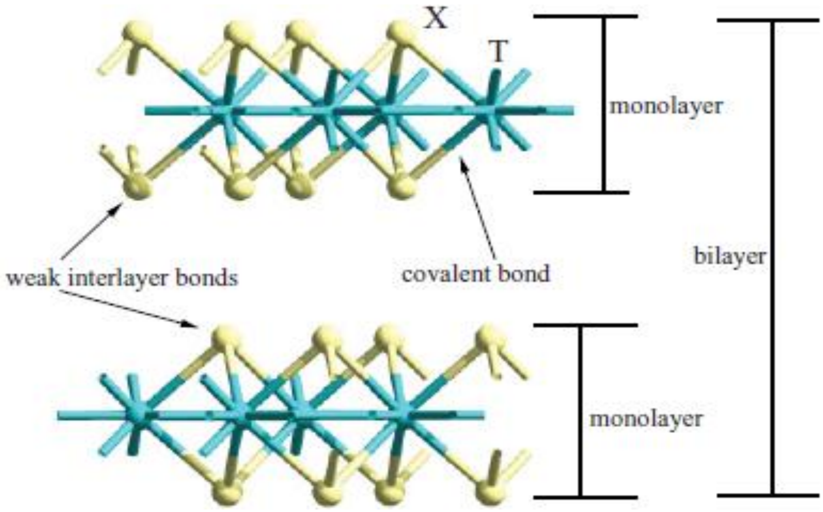

Fig.1. 2D transition metal dichalcogenides.

New 2D optoelectronic devices created by integrating various 2D materials into heterostructures with unique characteristics. However, the synthesis of graphene and related 2D materials and heterostructures remains a problem; therefore, the development of new methods is a quite interesting area of research. Chemical vapor deposition (CVD) recognized as the most effective method for the synthesis of graphene and many other 2D materials.

1. Experimental section

CVD complex setup for the synthesis of two-dimensional materials designed and assembled, see Figure 2, mentioned in previous work [3]. The CVD consist from quartz tube with three heating zones, which operated by thermo controllers. There are gas supply systems controlled by MKS. In addition, there is a pump for reach vacuum. A magnet sample holder used to fix or move out sample in quartz reactor. Therefore, synthesis parameters such as temperature, pressure and gas flow can be managed at the CVD system.

Fig. 2. Main view of the CVD setup

A detailed study of the growth of individual grains of WS_2 carried out in this CVD system. A quartz substrate with a small amount of nanosized WO_3 powder used. The temperature of WO_3 powder is 900 ºC and supplying inert gas flow with the chalcogen vapor through the powder surface, sublimated WS_2 droplets formed on the quartz substrate (Figure 3).

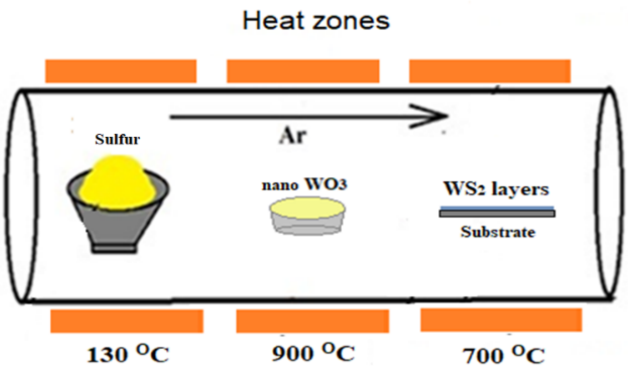

Fig.3. Synthesis of 2-D TMD layers

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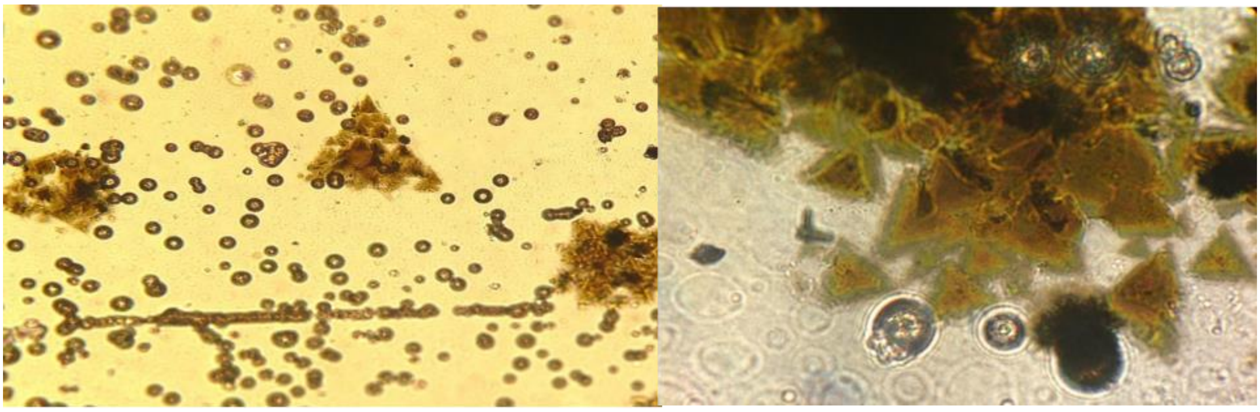
2. Results and discussion

There is a high-resolution optical microscopy analysis in Figure 4 shows the formation of a two-dimensional layer of a separate domain WS_2. In the middle of the crystal, a sublimated WS_2 nucleus distinctly observed, which reacts with tungsten and sulphur oxide pairs to form oriented layers of a two-dimensional material.



a) WS_2/Si b) WS_2/SiO_2

Fig.4. Optical microscope pictures of WS_2 grains: a) onto Si substrate; b) onto SiO_2 substrate

Raman spectroscopy of a grown single crystal of a WS_2 crystal studied using a laser with a wavelength of 514 nm and shows the formation of peaks E2g and A1g modes, which are refer to WS_2 crystals, Fig.5. The intensity of the peaks is almost the same. The choice of the laser length in this wavelength range is due to a more detailed and informative parameter for determining the thickness of the obtained layers compared to other lasers. An analysis of the intensity of the phonon peaks presupposes the formation of a thickness of the region of the contour of the WS_2 crystal in 6 layers**.**

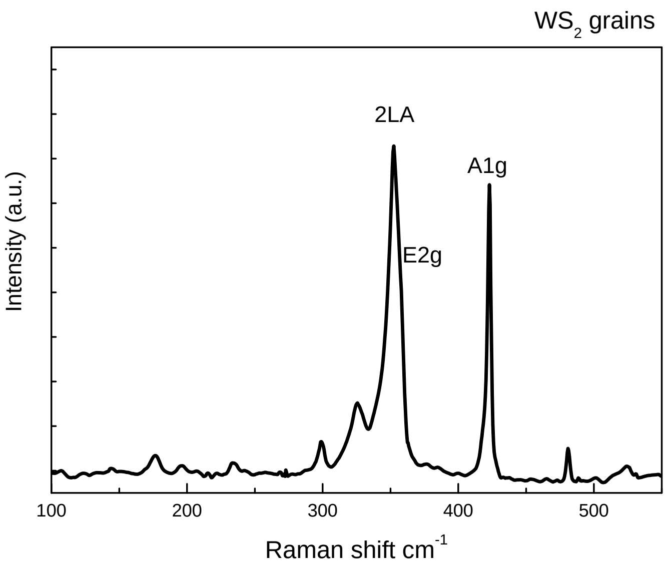


Fig.5. Raman spectroscopy of WS_2 crystal

Figure 6 shows the photoluminescence spectrum of WS_2 grains. The photoluminescence spectrum of a separately synthesized WS_2 crystal showed a band gap value of 1.92 eV in the wave band of 600-660 nm.

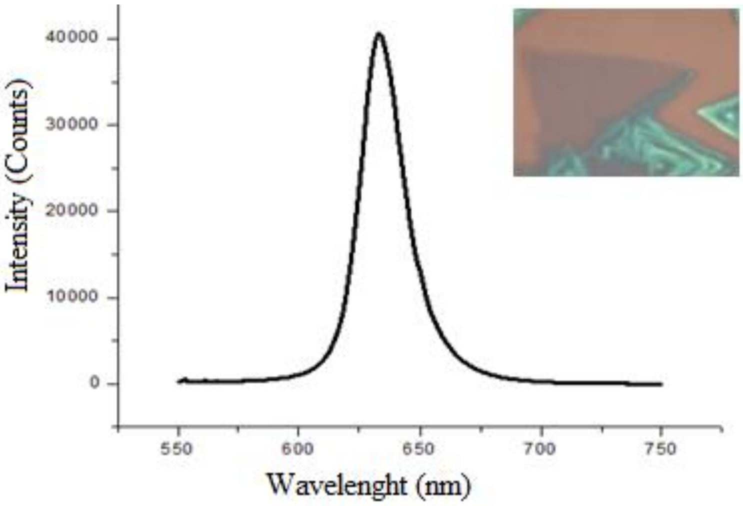


Fig.**6**. Photoluminescence spectrum for produced WS_2 single crystals

The results suggest that the mechanism of grain growth of 2D TMD single-crystal arrays is possible, with direct control of the nucleation process during the initial growth of 2D TMD films, to minimize the formation of crystallization centres in random places and the formation of inclined and specular grain structures.

Conclusion

Obtained WS_2 single crystals characterized by optical microscope, Raman and photoluminescence analysis. Optical microscope analysis demonstrated that triangular WS_2 domains with single-phase crystal structure formed. The thickness of WS_2 is 6 layers, which determined by Raman spectroscopy. Photoluminescence spectroscopy analysis revealed a strong peak between 600-660 nm, typically for a monolayer WS_2 crystal, where the band gap is equal to 1.96 eV. In the further study hybrid multilayer heterostructures based on graphene will developed, where 2D-TMD layers and nanoparticles will deposit on grown graphene layers by using various techniques for further investigation of their electrical and optical characteristics.

Acknowledgements

This research was funded the program AP05132763 «Development and study of graphene based heterostructures for photocatalytic systems and gas sensors applications» by the Ministry of Education and Science of the Republic of Kazakhstan.

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Article accepted for publication 21.11.2018