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Synthesis of MoS_2 nanowires by chemical vapor deposition with turbulent flow and their characterization

Transition metal dichalcogenides (TMDs) have attracted tremendous attention due to their unique structures and semiconducting properties. Because MoS_2 as a family of TMDs has high stability and great electrical properties, it has been reported that MoS_2 can be used for many applications, such as field effect transistors (FET) [1] and hydrogen evolution reaction (HER) [2] catalyst. Especially, in catalytic reaction, it is considered that MoS_2 nanowires (NW) show better efficiency than layer due to its higher surface area. Although several synthetic methods for MoS_2 NWs [3][4] have been reported, they have some problems, such as long reaction time and use of toxic gas like H_2S. In this work, we explored the easy and safety MoS_2 NWs synthesis method by chemical vapor deposition (CVD). We discovered the fact that monoclinic MoO_2 favor NW shape construction more than plane crystal under turbulent flow. The SEM image of MoO_2 NWs is shown in Fig.1. Turbulent flow makes collision frequency higher than laminar flow, which means that more molecules could achieve nucleation energy. In short, crystal growth is promoted by turbulent flow. Furthermore, when the reactant feed rate is enough high, the reaction proceeds under thermodynamic control. In this condition, monoclinic $P2_1/c$ MoO_2 prefer to grow along (20-1) direction, which is stable in terms of atom density of each surfaces. Fig.2 indicates this growth direction of MoO_2 NWs. These fact means that we can control aspect ratio by tuning conditions of raw material supply. Subsequently, zigzag MoS_2 NWs were synthesized by sulfurize MoO_2 NWs not with H_2S but with sulfur. It is shown in Fig.3. In this method, zigzag MoS_2 NWs are preferentially synthesized because sulfurization process proceeds so that the lattice mismatch is suppressed between $P2_1/c$ (20-1) grown MoO_2 and MoS_2. Here, we established simple synthesis way of zigzag MoS_2 NWs through MoO_2 NWs by turbulent flow. This method allows us to get highly crystalline MoS_2 NWs easily and it will contribute to open the way to apply MoS_2 NWs to high performance devices.

References

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[3] Nath, M *et al.*, Advanced Materials, 13, (2001) 283.
[4] Therese, H. A. *et al.*, Solid state sciences, 8 (2006) 1133.

Figures

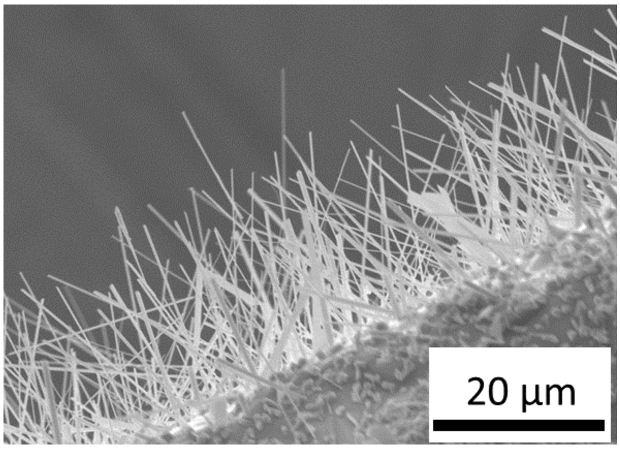

Figure 1: FE-SEM image of MoO_2 nanowires

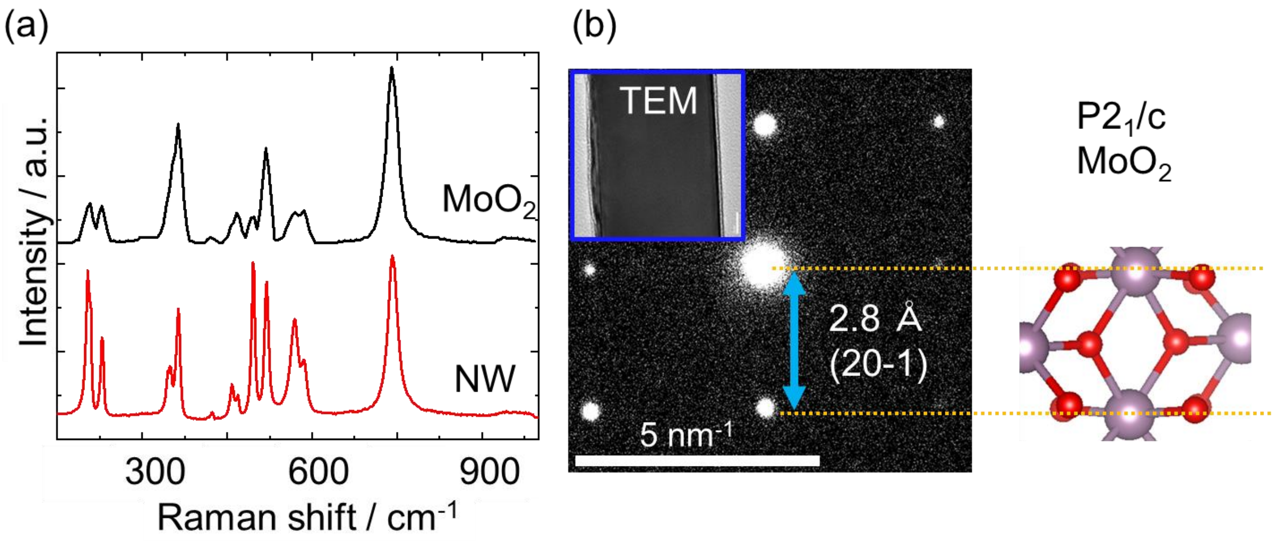

Figure 2: characterization of MoO_2 nanowires
(a)Raman spectra (b)TEM and Selected Area Electron Diffraction (SAED) images

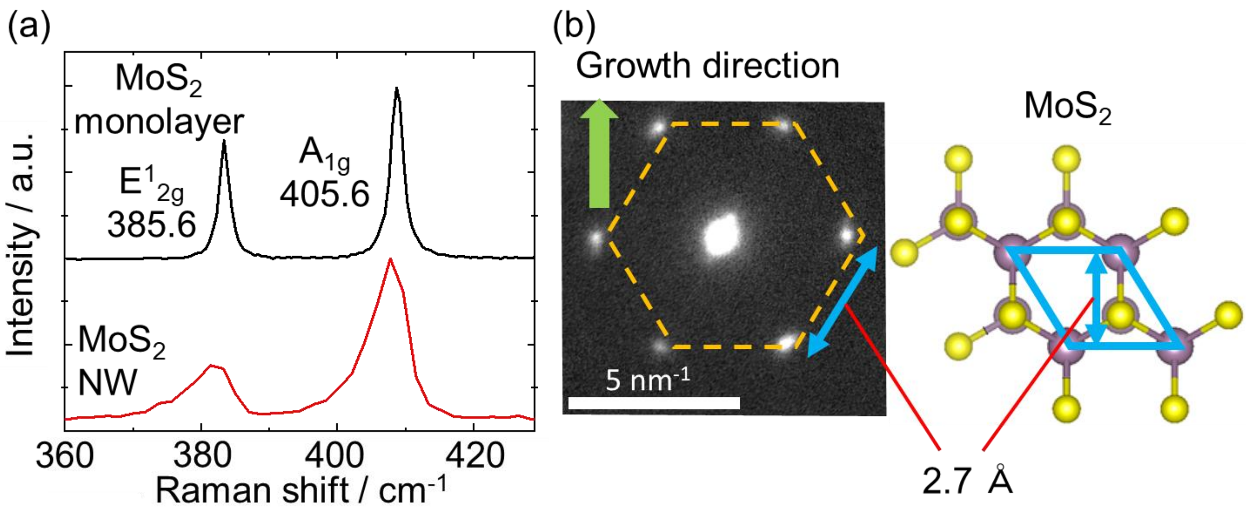

Figure 3: characterization of MoS_2 nanowires (a)Raman spectra (b) SAED image