Chemical Vapor Transport growth and characterization of WTe_2

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Tungsten ditelluride WTe2: unique member of 2D TMDCs

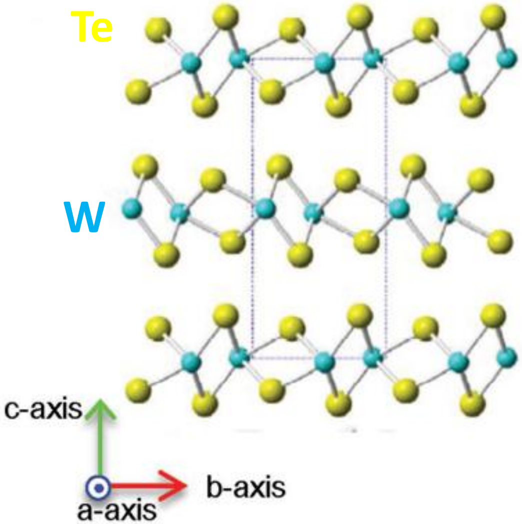
WTe_2 - a type-II Weyl semimetal material with extremely large magnetoresistance

Unique among TMDs as it crystallizes in a distorted 1T′ phase (also known as Td phase). WTe_2 has orthorhombic crystal structure in contrast to the commonly observed 2H and IT structures.

In Td phase, the W-atoms are octahedrally coordinated by Te-atoms and the successive layers in between are rotated by 180° .

The unique electronic nature leads to:

- strong anisotropic electrodynamics,
- extremely large, non-saturated magnetoresistance,
- “negative” magnetoresistivity,
- room temperature ferroelectric semimetal, superconductivity and plasmon polariton activity



small 2016, *12,* No. 42, 5802–5808

Numerous perspectives for topological, spintronic and opto-electronic applications.

Growth of WTe_2 single crystals: Challenges

Due to low chemical reaction activity of Te with W, WTe_2 is very challenging chemically, especially for various synthesis techniques as Chemical Vapor Deposition (CVD) and Molecular Beam Epitaxy (MBE).

The majority of contemporary WTe_2 studies aiming in 2D limit relied on mechanically-exfoliated samples from single crystals.

Necessity for an improvement of the synthesis and growth techniques for preparation of high quality crystals closer to the structural perfection.

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Fei Hou, Dawei Zhang, Pankaj Sharma,* Simrjit Singh, Tom Wu, and Jan Seidel*

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Nanosheets

Environmental Instability and Degradation of Single- and Few-Layer WTe_2 Nanosheets in Ambient Conditions

*Fan Ye, Jaesung Lee, Jin Hu, Zhiqiang Mao, Jiang Wei, and Philip X.-L. Feng**

Growth of WTe_2 single crystals by Chemical Vapor Transport (CVT)

- A mixture containing stoichiometric amounts of W and Te powder was slowly heated from RT to 920°C for 12 h, and held at 920°C for 3 days in a sealed evacuated quartz ampoule.
- WTe_2 single crystals were grown from the synthesized powder by CVT with Br_2 as transport agent for 14-21 days in a sealed evacuated quartz ampoule with source and growth zones kept at 895°C and 715°C, respectively.
- The obtained bulk crystals were pumped under dynamic vacuum at RT for 1 day to remove any residual Br.

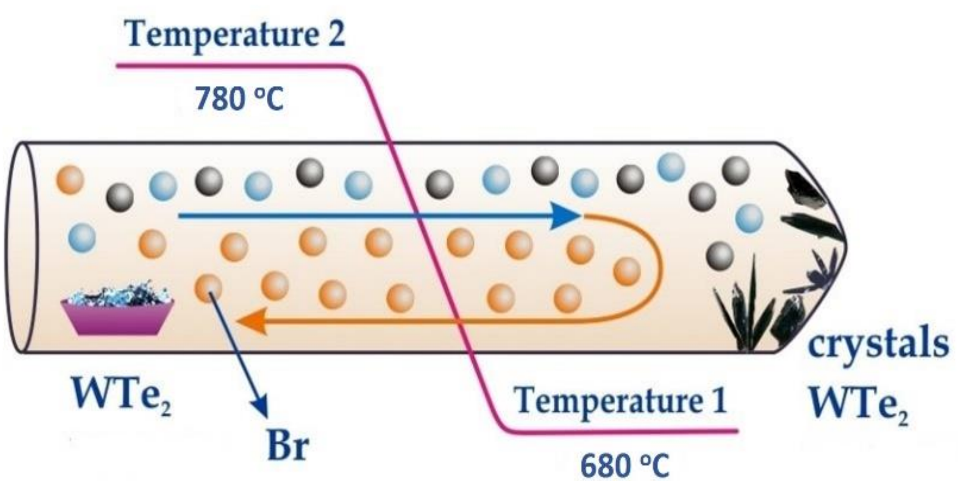


Fig. Schematics of WTe_2 single crystals growth process by CVT method

Fig. Photograph of WTe_2 single crystals

XRD and Raman analysis

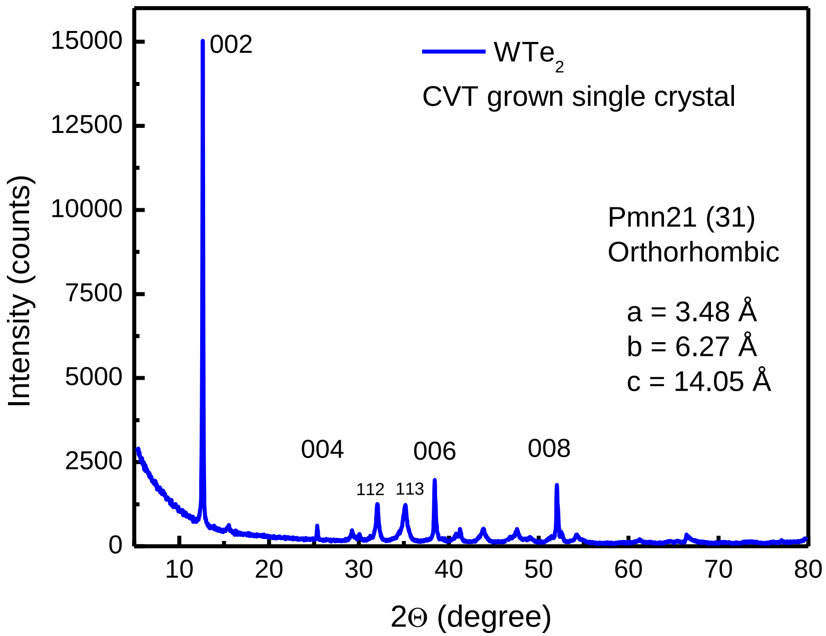


Fig. XRD analysis of WTe_2 single crystals

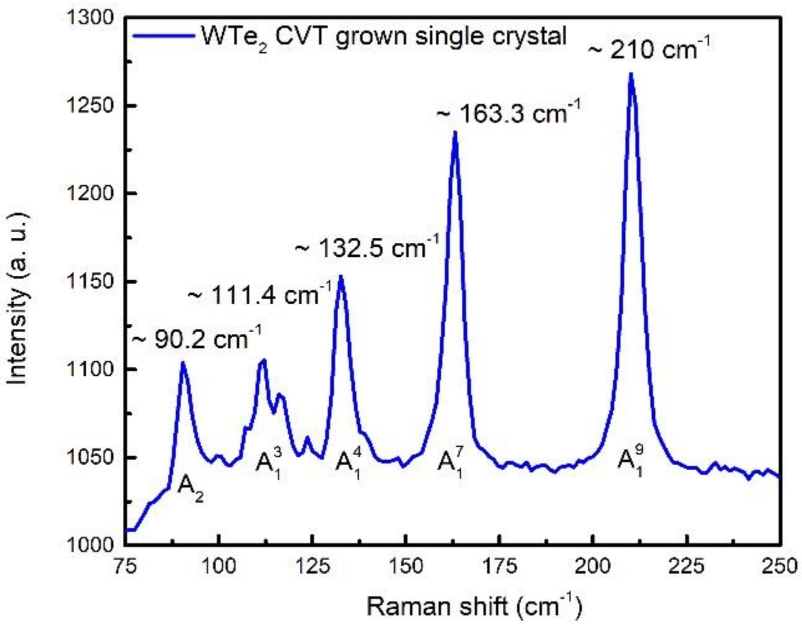
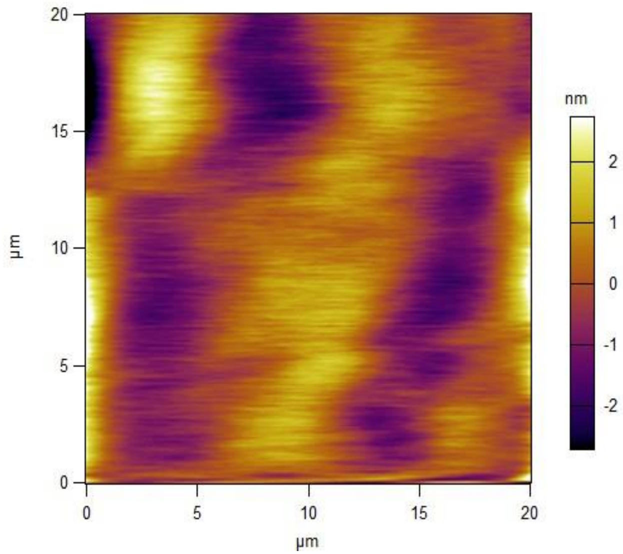


Fig. Raman spectra and characteristic vibration modes for WTe_2 single crystal

- X-ray powder diffraction (XRD) patterns confirms that WTe_2 crystallizes in space group $P_{mn}21$ in orthorhombic Td structure.
- Raman shows typical vibrational modes for WTe_2 detected at: A_1^9 ~ 210 cm^{-1}, A_1^7 ~ 163 cm^{-1}, A_1^4 ~ 132 cm^{-1}, A_1^3 ~ 111 cm^{-1} and A_2 ~ 90 cm^{-1} confirming the desired chemical composition.

AFM analysis



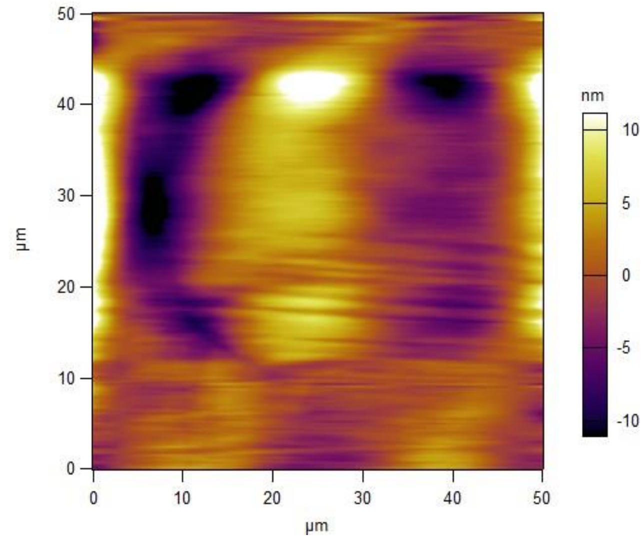


Fig. AFM analysis of two separate sectors from WTe_2 single crystal surface topology.

- AFM data revealed that the surface topology is close to the structural perfection even on a nanoscale level (RMS roughness relief varies within 1 nm to 4 nm).

- This is a fine verification of the quality of the crystal which will be suitable for further alterations as mechanical exfoliation for instance.

Conclusion

Detailed description of the preparation stages, technical considerations and growth procedure of WTe_2 by means of Chemical Vapor Transport method are presented.

Performed XRD and Raman spectroscopy analysis verified excellent crystallinity of WTe_2

The surface topology via AFM analysis with construction of topography 2D map revealing a few nanometers variation of the morphology features.

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