

## Introduction

### Concept of Altermagnetism

(a) Crystal structure of MnTe showing Mn and Te atoms. (b) Band structure plot showing binding energy (eV) vs momentum along the  $k_x$ - $k_y$ - $k_z$  path.

➤ Altermagnets combine features of ferromagnets and antiferromagnets, exhibiting zero net magnetization yet strong time-reversal-symmetry breaking.

➤ MnTe is an altermagnetic semiconductor with high  $T_N \approx 307$  K.

### Observation of Band Splitting

(a) STM topography image showing surface features. (b) Band structure plot showing anisotropic band splitting. (c) STS spectra showing intensity vs binding energy at various temperatures.

➤ Revealed anisotropic band splitting in MnTe below  $T_N$  by APRES and DFT

### Scanning Tunneling Microscopy

➤ Scanning tunneling microscopy (STM) detects tunneling current between tip and sample surface.

➤ Scanning tunneling spectroscopy (STS) measures local density of states (LDOS) of the sample.

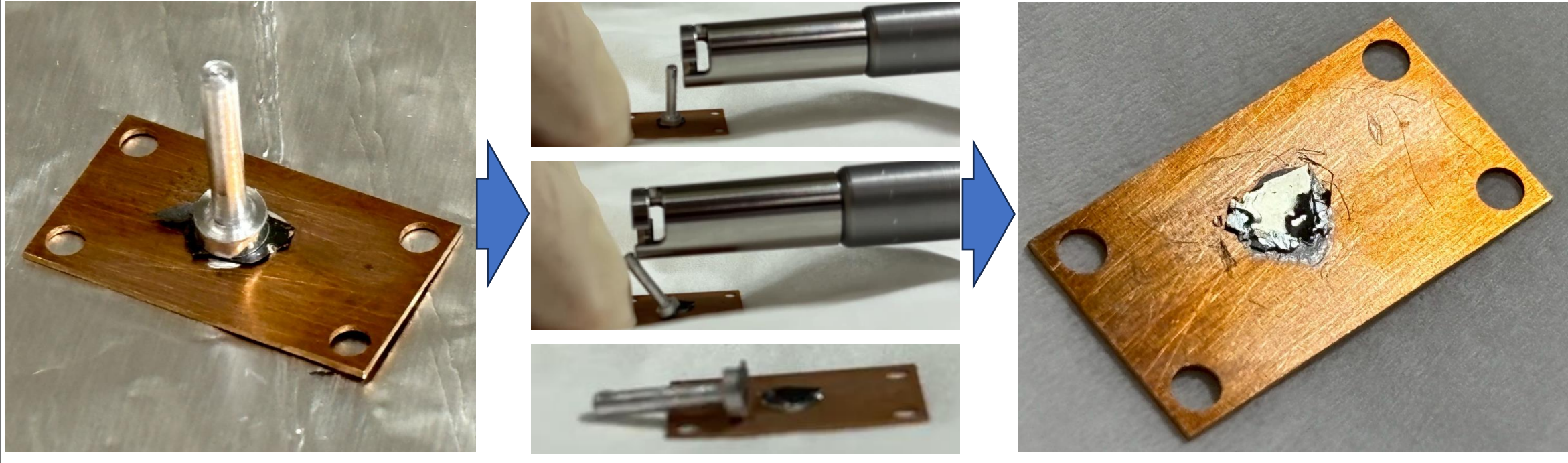
➤ Our STM:

- UNISOKU USM1500
- Operating Temp. 4.2 K or 77 K
- +/- 8T out-of-plane B-field
- Spatial resolution  $\sim 2$  Å

## Experiment Result

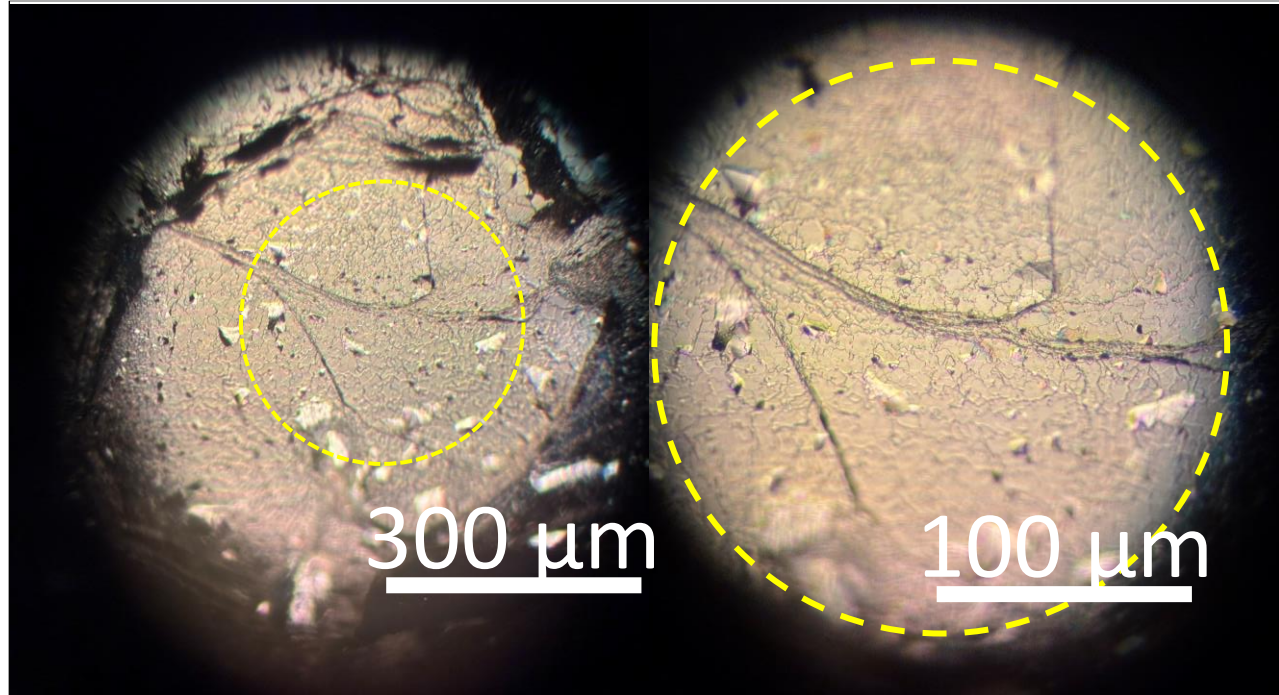
### Bulk MnTe

#### Cleaving Process



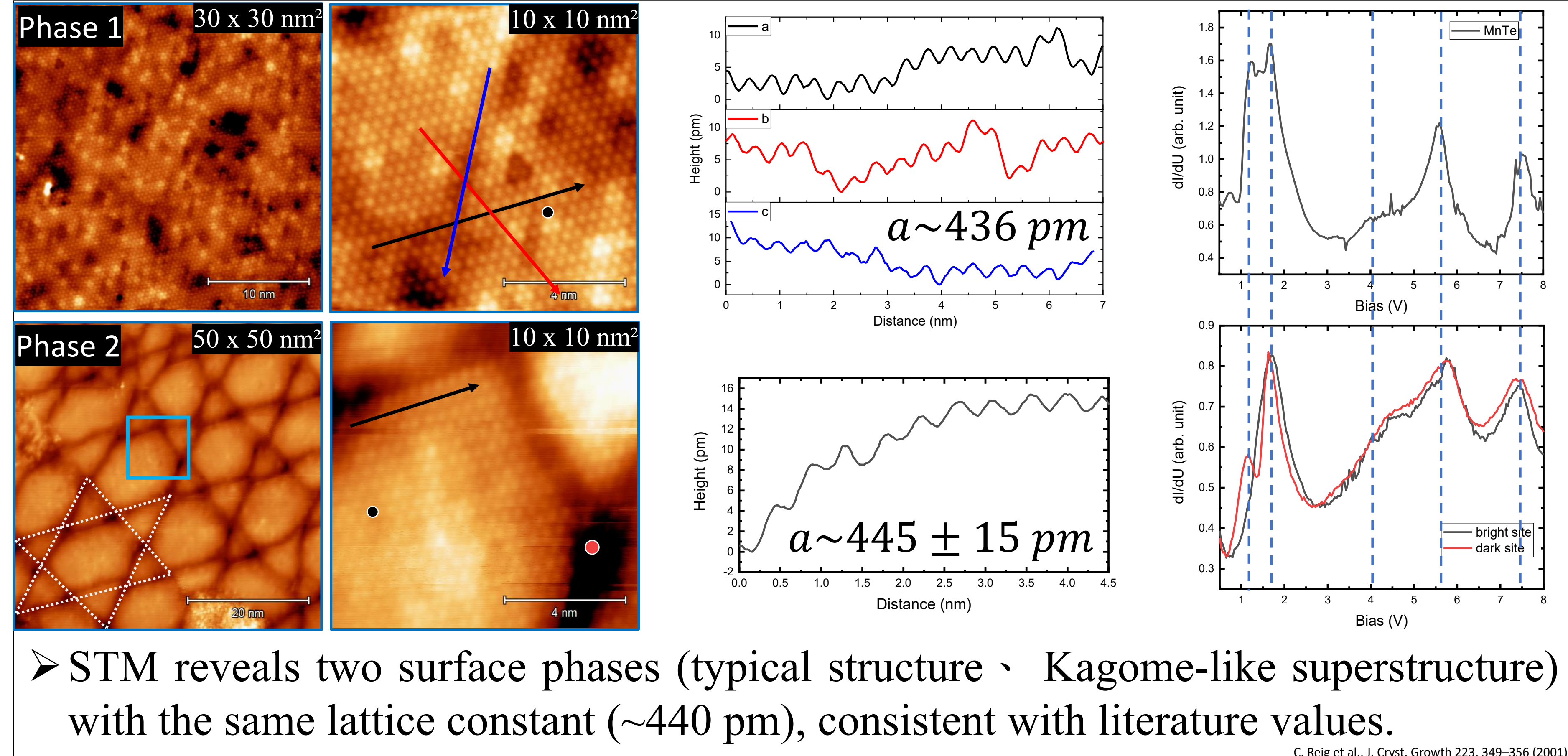
➤ MnTe bulk was mounted on BeCu, cooled down to 77 K, and cleaved in UHV.

#### Optical Microscopy after Cleaving



➤ layer-wise surface was observed by OM after cleavage.

#### STM Topography and STS Measurements



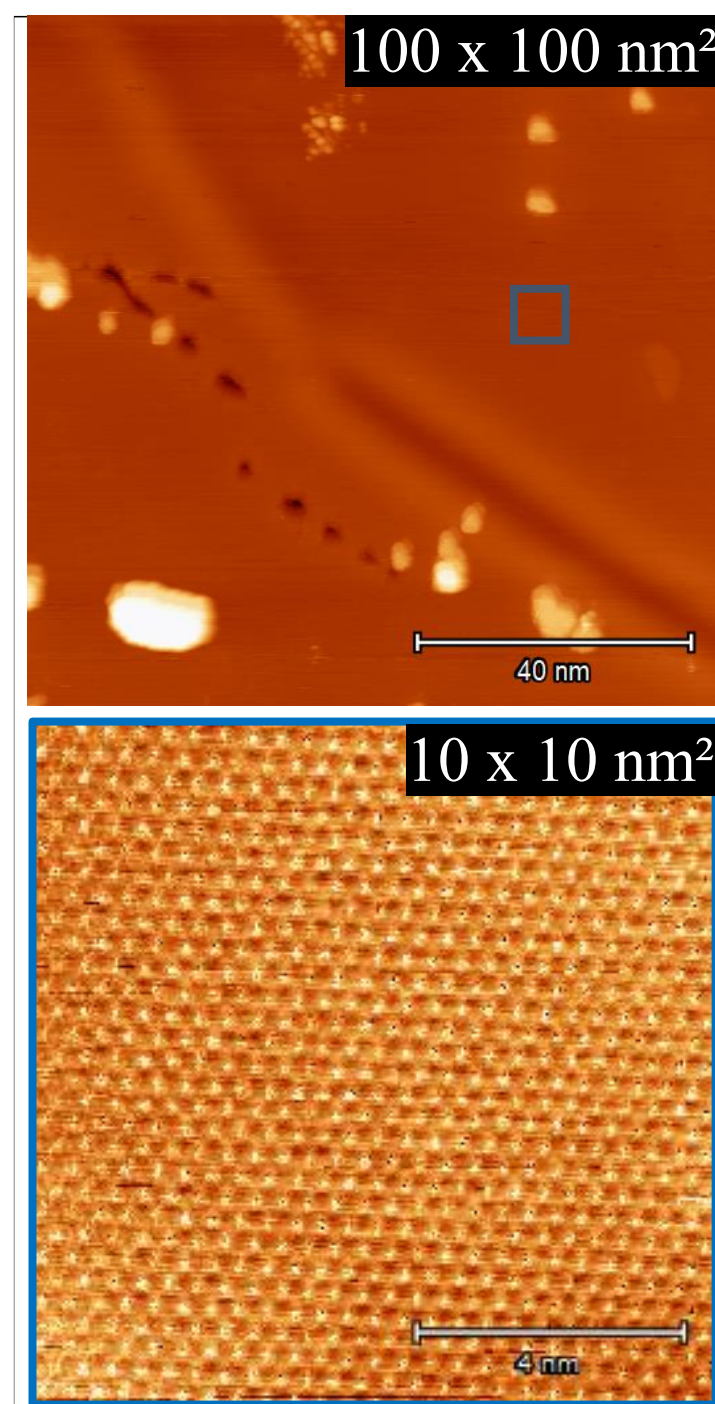
### Thin Film MnTe

#### Clean $\text{Bi}_2\text{Te}_3$

#### STM Topography

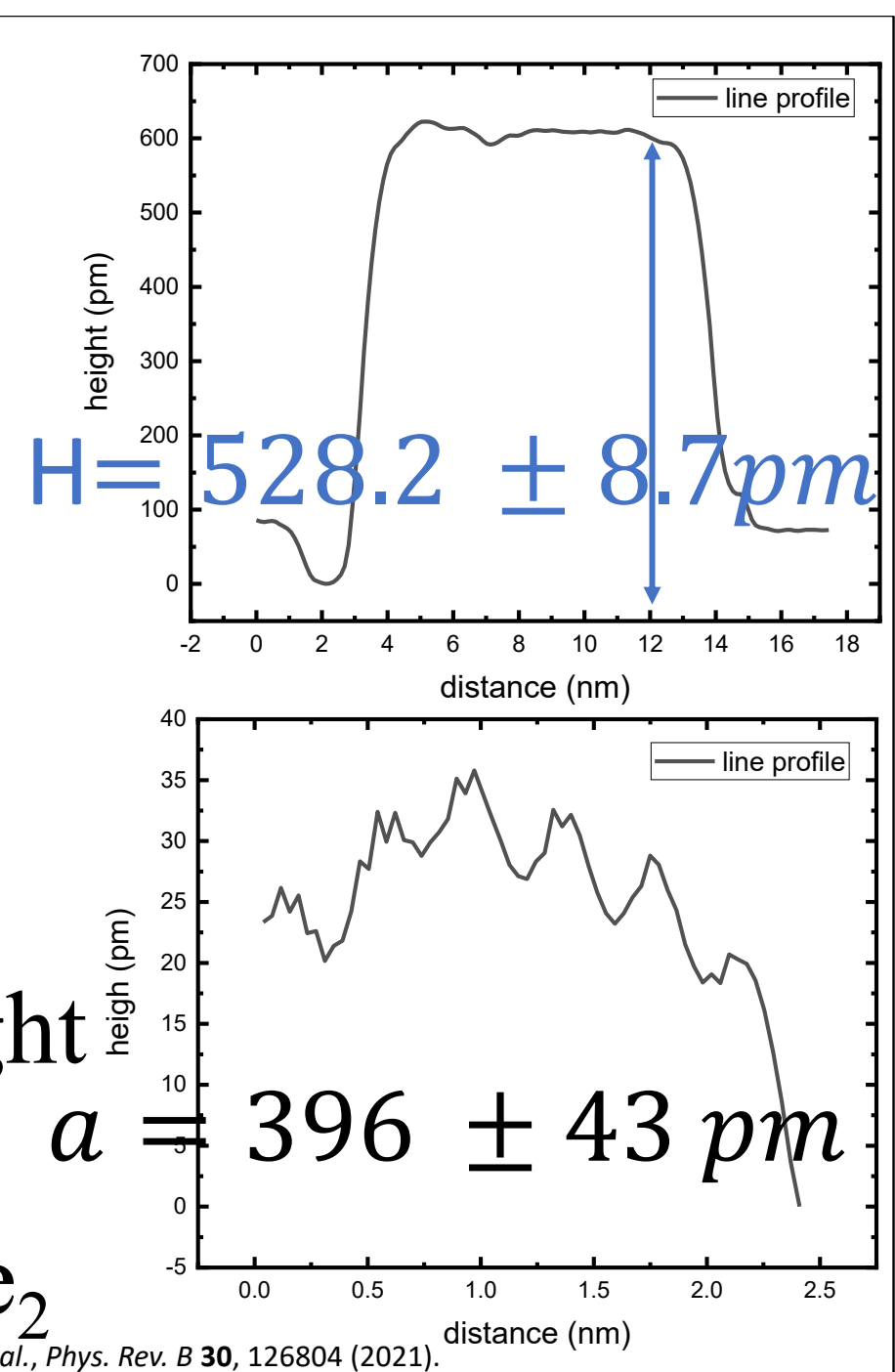
#### Mn Deposition Only

- Cleave BT substrate @RT in UHV
- Deposit Mn @RT by E-beam evaporator
- Transfer into STM



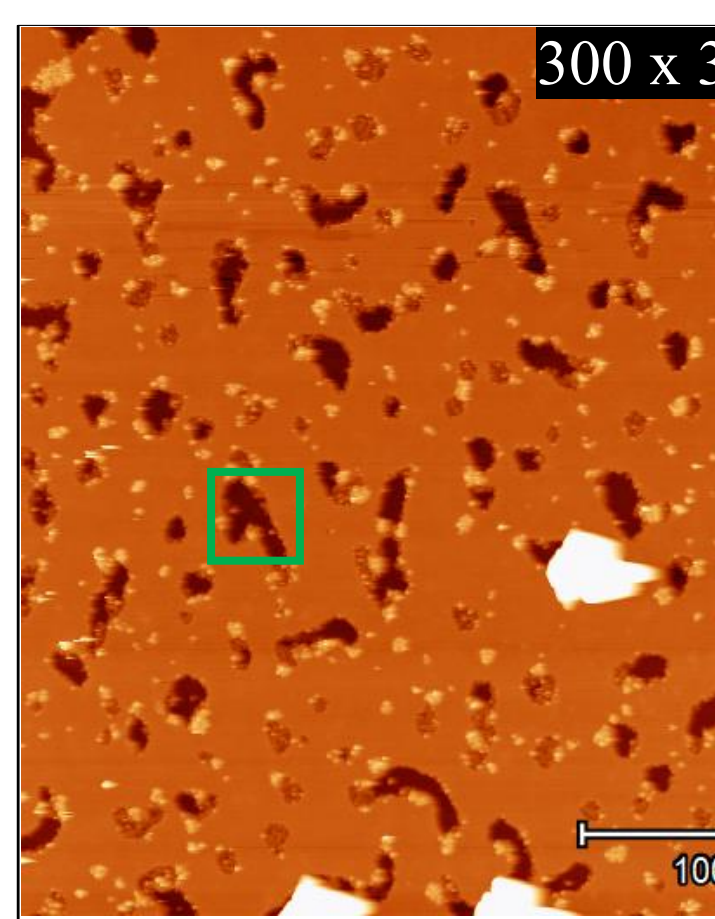
➤ After depositing Mn on cleaved BT substrate, small islands with apparent height 528 pm were observed, and a (1x1) hexagonal structure was obtained.

➤ According to the literature, we supposed the small islands are monolayer  $\text{MnTe}_2$



#### Mn-Te Co-deposition

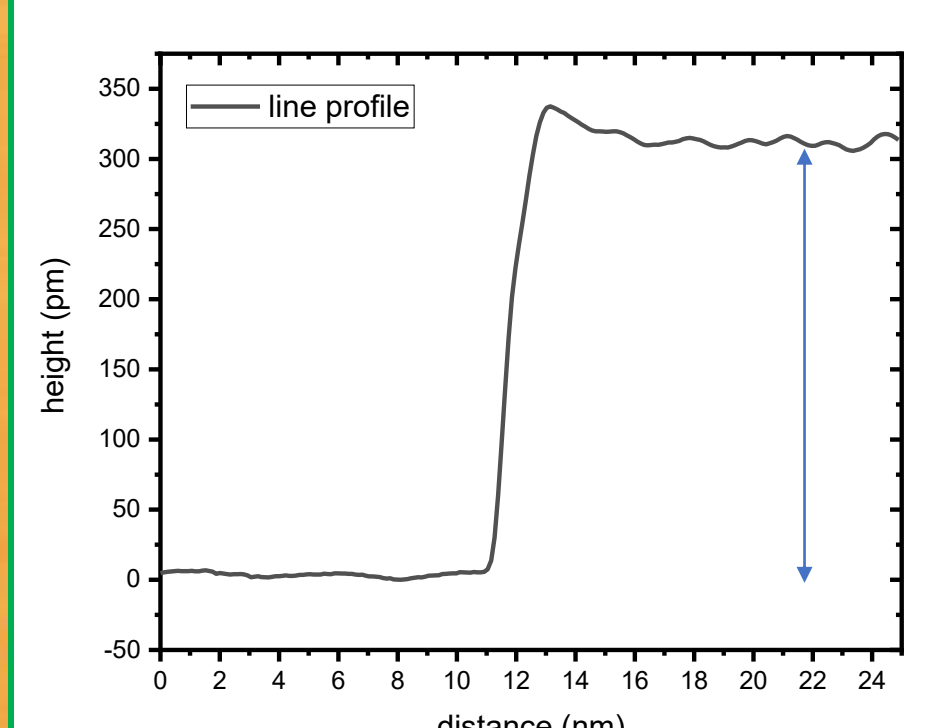
- Cleave BT substrate @RT in UHV
- Co-deposition of Mn and Te
- Transfer into STM



➤ After Co-depositing of Mn and Te on cleaved BT, MnTe islands with apparent height 310 pm were observed

➤ Lattice constant for MnTe islands are  $\sim 438$  pm, consistent with literatures, a (1x1) hexagonal structure was obtained.

$H = 310.6 \pm 6.3$  pm



## Summary

- We successfully cleaved bulk MnTe and revealed two distinct phases using STM, both showing lattice constants around **440 pm**, consistent with literatures.
- For thin films MnTe growth study, Mn deposition on BT produced small islands with hexagonal structure. According to the literature, we assume the islands are monolayer  $\text{MnTe}_2$ . After **co-deposition of Mn and Te**, monolayer **MnTe** islands were observed
- **Future work:** Utilize spin-polarized STM to investigate the **magnetic structure** of MnTe at the atomic scale.