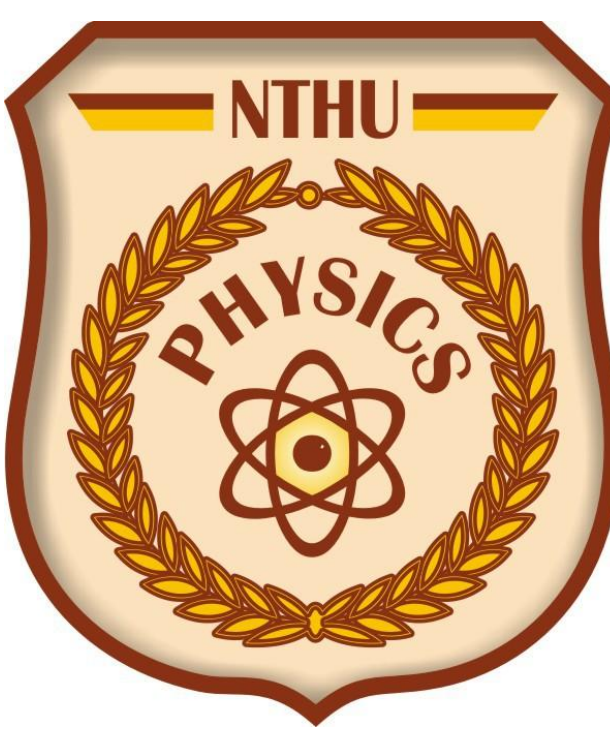




Epitaxial growth of MnTe/Bi₂Te₃ heterostructures on Si(111)



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Introduction

The Bi₂Te₃ and MnTe thin films were grown using a molecular beam epitaxy (MBE) system equipped with K-cell effusion sources for Bi, Te, and Mn evaporation.

During growth, high-purity elemental fluxes were thermally evaporated under ultra-high vacuum (UHV), allowing atomic-level control of the film thickness and composition. The substrate temperature was maintained at ~250–300 °C for Bi₂Te₃ and reduced for MnTe to prevent Te re-evaporation. The deposition rates used in this study were Te: **1.8 Å/min**, Bi: **0.6 Å/min**, and Mn: **1.2 Å/min**.

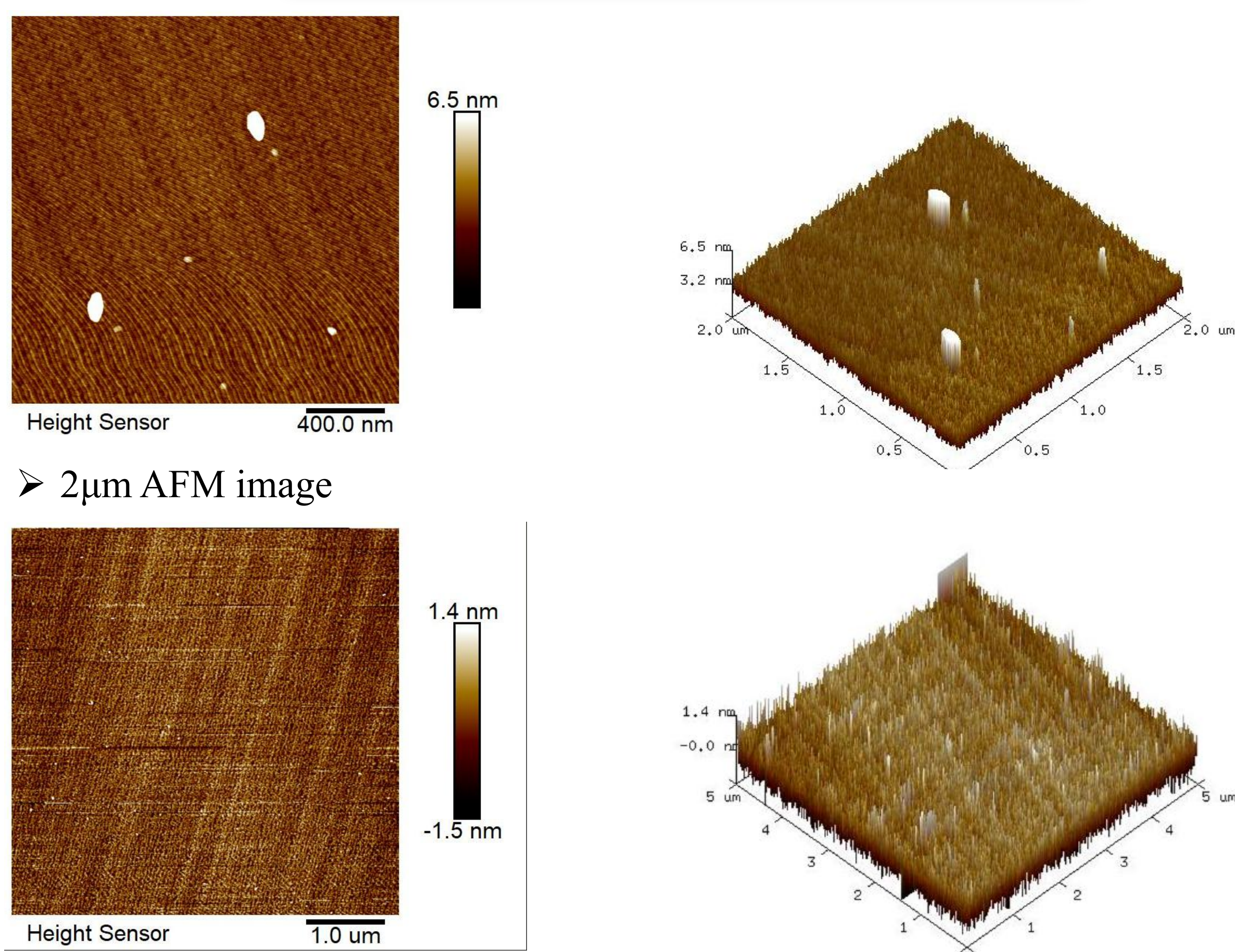
To monitor the growth in real time, we used reflection high-energy electron diffraction (RHEED).

In RHEED, a high-energy electron beam (typically 10 keV) is directed onto the surface at a very slightly angle. Because the electrons interact mainly with the topmost atomic layers, the resulting diffraction pattern is extremely sensitive to surface crystallinity and growth mode.

Streaky patterns indicate smooth two-dimensional epitaxial growth, while spotty or ring-like patterns correspond to roughening or three-dimensional nucleation. In addition, RHEED intensity oscillations were used to estimate the growth rate and the formation of individual quintuple layers during Bi₂Te₃ deposition.

This combination of MBE and RHEED provides precise control over the heterostructure growth on Si(111).

AFM result of Bi₂Te₃



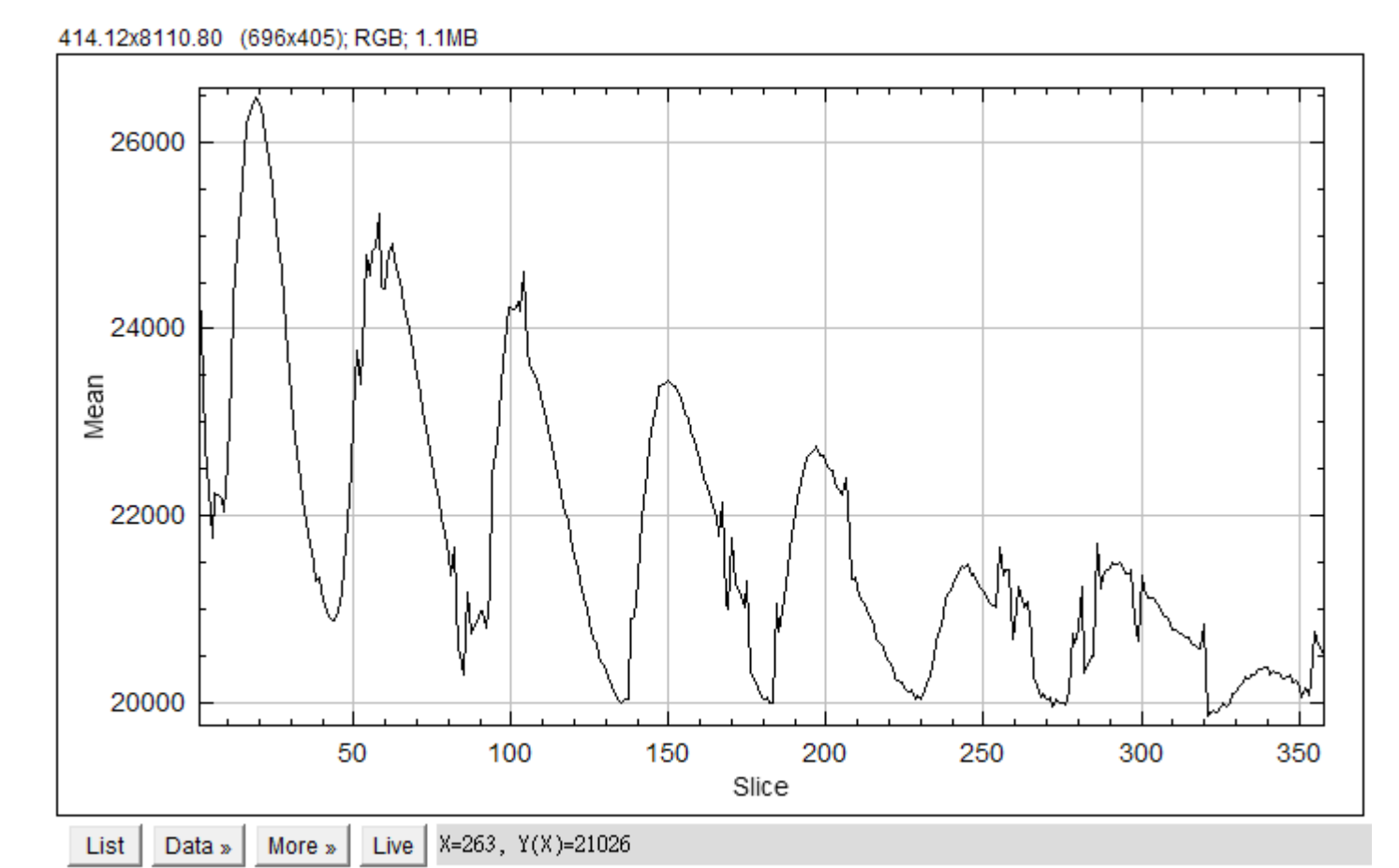
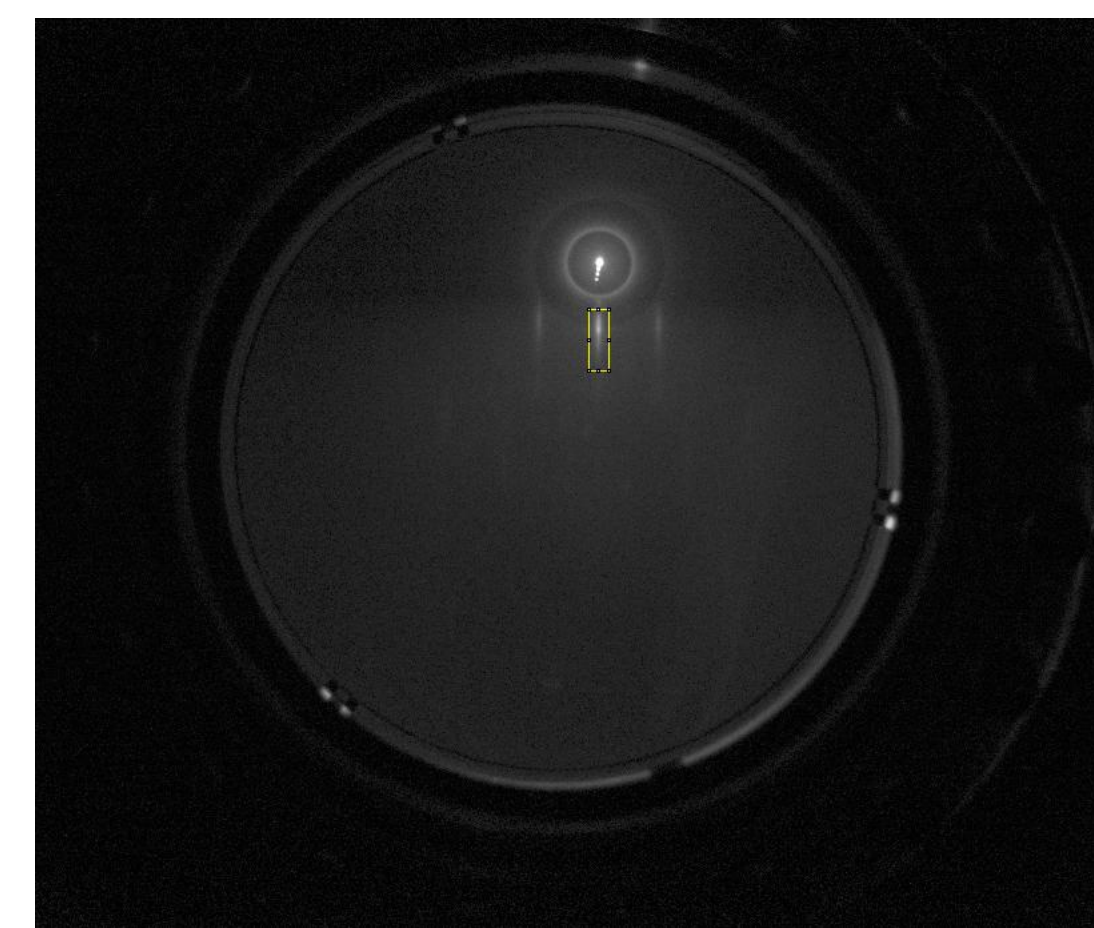
➤ 2 μm AFM image

➤ 5 μm AFM image

The AFM characterization of the Bi₂Te₃ film demonstrates a flat and homogeneous surface over multiple length scales. Both small-scale (2 μm) and large-scale (10 μm) scans confirm that the film exhibits minimal surface irregularities, suggesting uniform layer growth and good crystallinity.

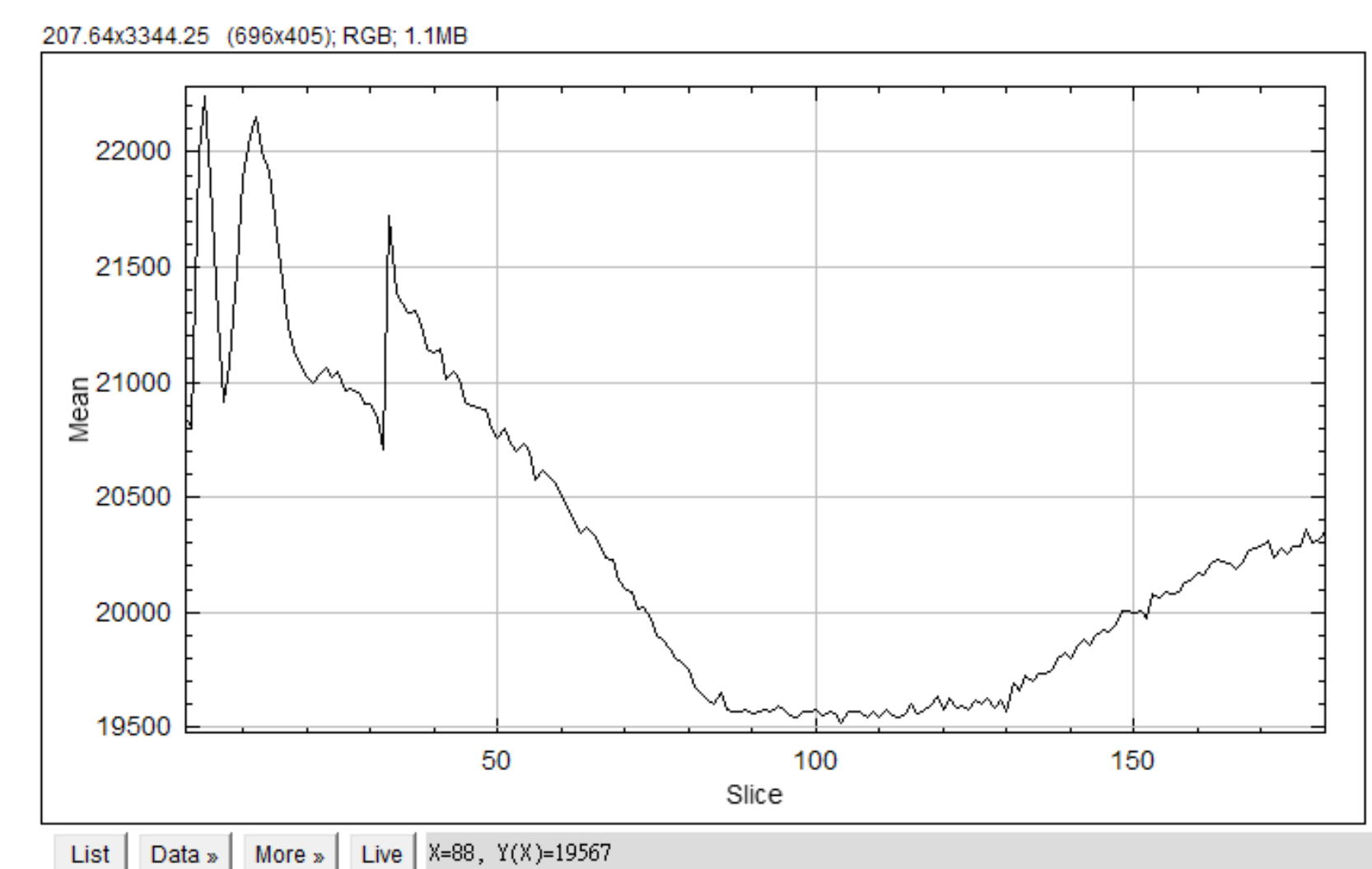
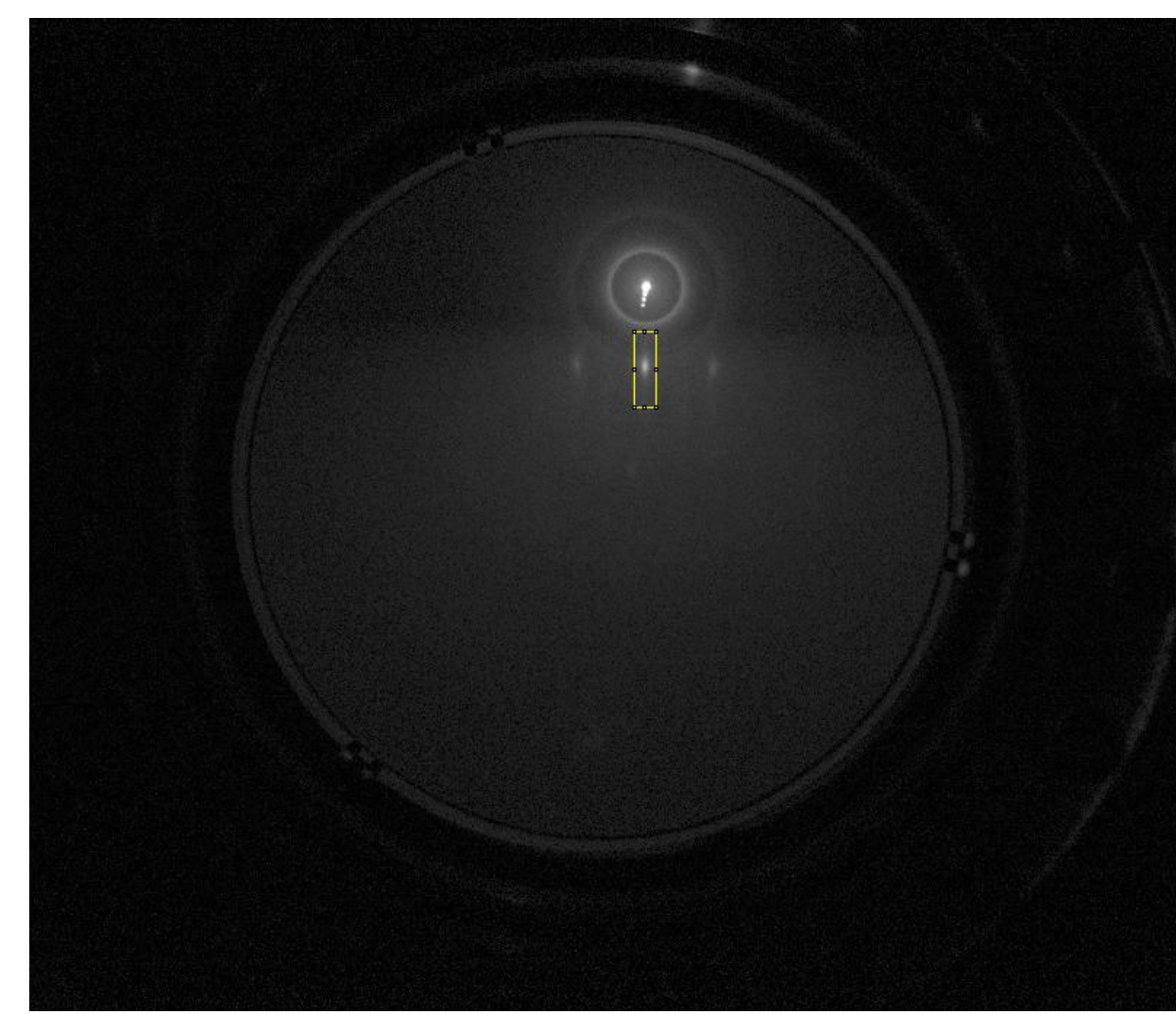
Rheed pattern result

Bi₂Te₃ growth situation



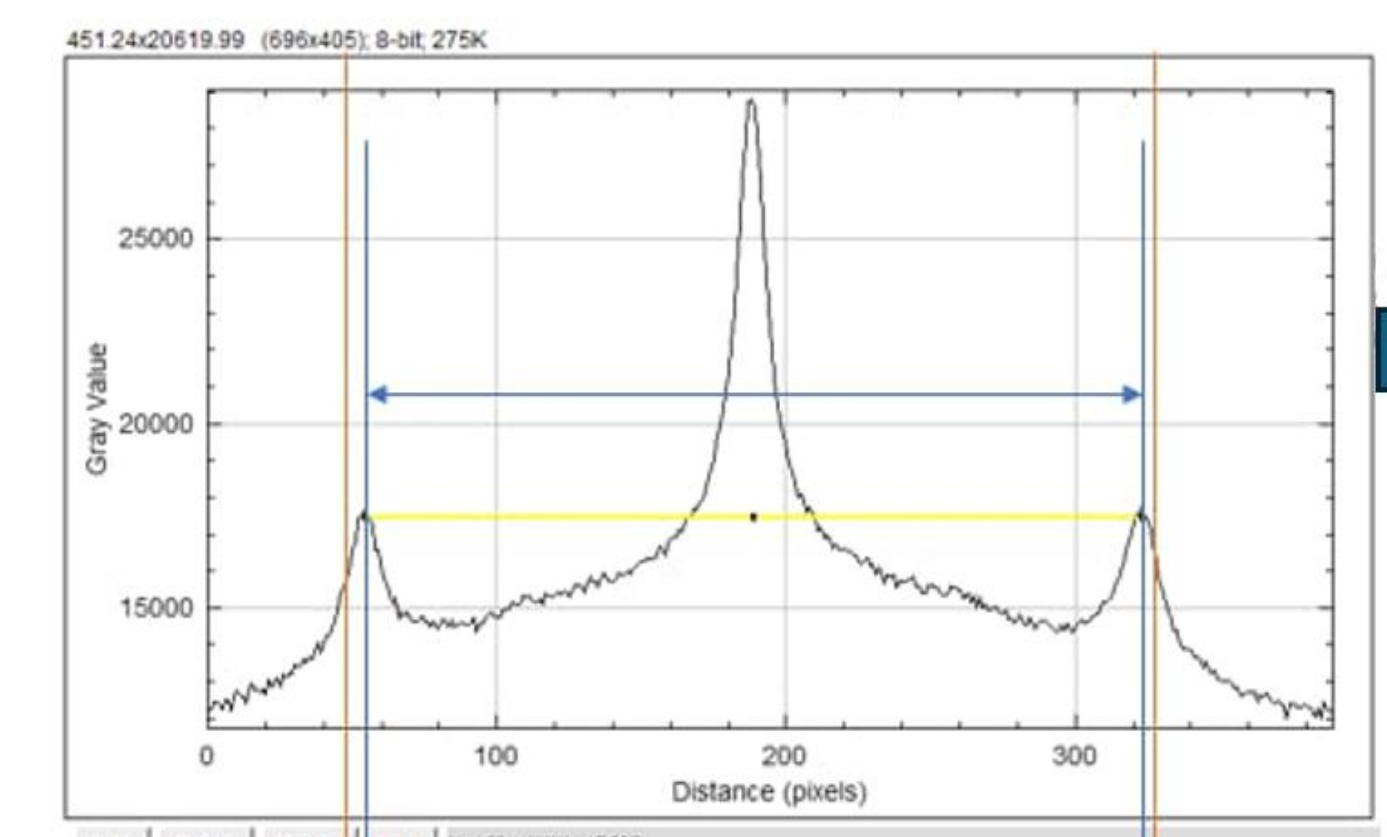
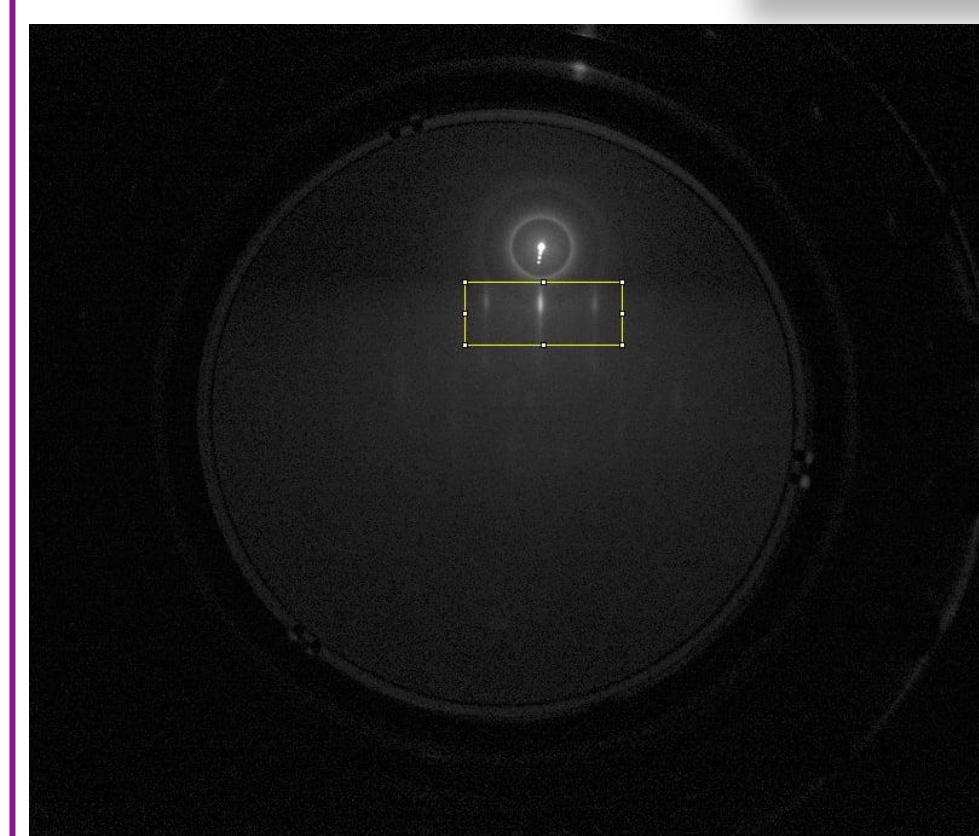
➤ To determine the growth time of each Bi₂Te₃ quintuple layer, we first performed a one-hour calibration growth. The period of the RHEED intensity oscillations obtained from this run was then used to extract the layer-by-layer growth time.

MnTe growth situation



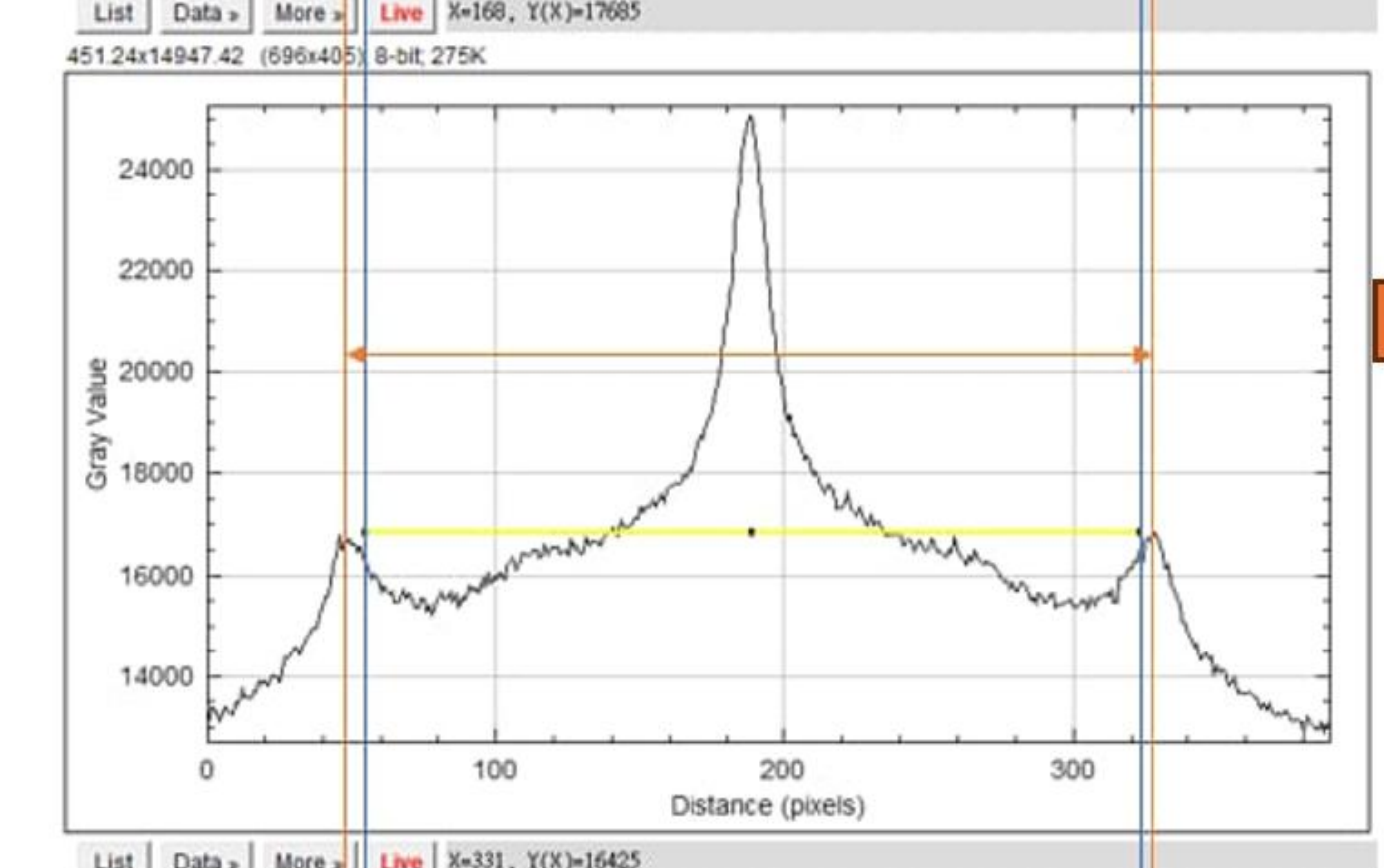
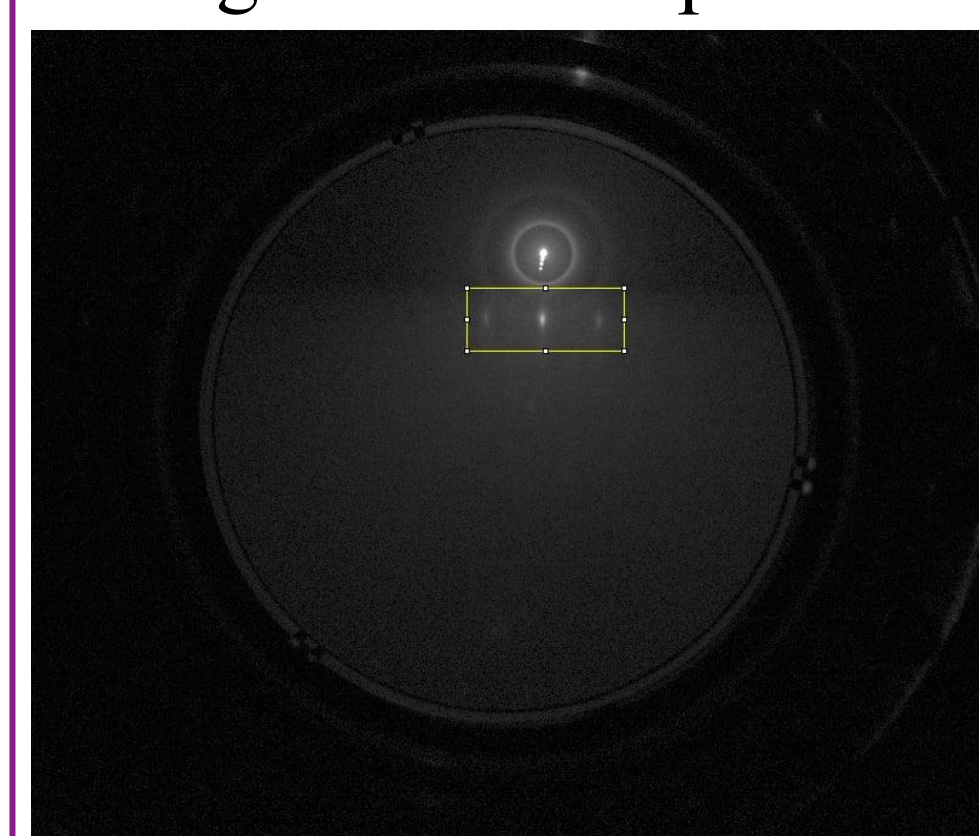
➤ The two initial intensity oscillations are attributed to the growth of the first two MnTe layers on the Bi₂Te₃ surface. These oscillations indicate a transient layer-by-layer growth mode at the early stage of MnTe deposition.

Lattice constant



Pixels distance :270

➤ Fig1. Before deposition - Bi₂Te₃



Pixels distance :280

➤ Fig1. After deposition- MnTe

Using the pixel-distance ratio, we can directly extract the surface lattice constant after deposition.

Since the in-plane lattice spacing is inversely proportional to the RHEED streak separation, we use the known Bi₂Te₃ lattice constant (4.38 Å) as a reference. By applying the pixel ratio (270/280), the calculated lattice constant becomes 4.22 Å, which matches the expected in-plane lattice constant of hexagonal MnTe. This confirms that the surface after deposition is dominated by MnTe rather than Bi₂Te₃.

Summary

AFM measurements indicate that the Bi₂Te₃ buffer layer exhibits clean terraces and a uniform surface morphology, confirming the high quality of the underlying template for subsequent film growth. AFM characterization of the MnTe layer is scheduled for the next stage of analysis and will provide further insight into its surface structure. These results establish a reliable foundation for evaluating the growth behavior and interfacial properties of the MnTe/Bi₂Te₃ heterostructure.