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Phase-controlled synthesis of $MoTe_2$ on Graphene/Ir(111)

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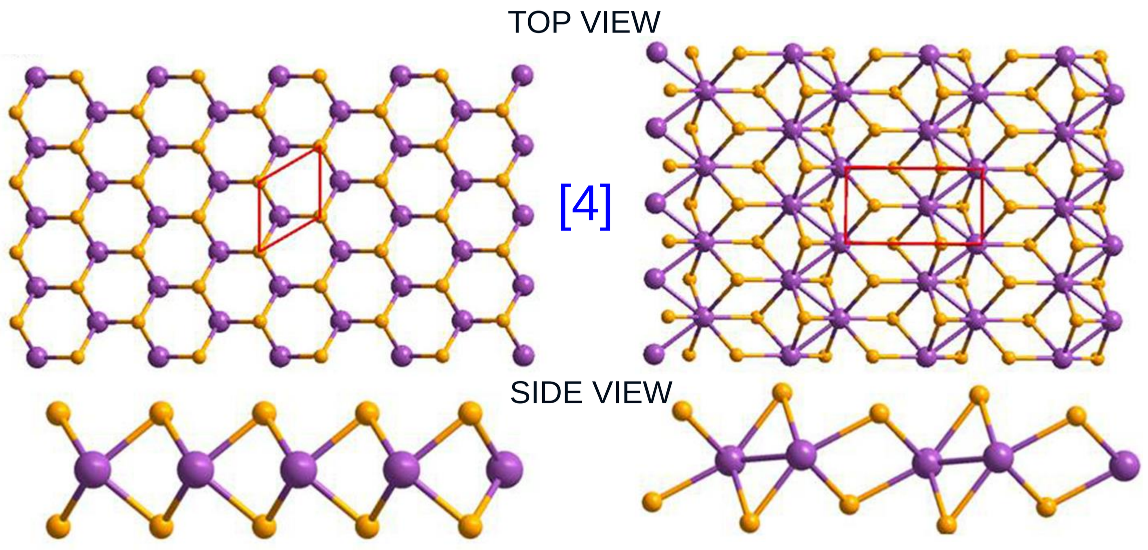
ABSTRACT

In the last decade, transition metal dichalcogenides (TMDs) have demonstrated a great potential in a wide range of areas ranging from opto-electronics, catalysis, energy storage or quantum electronics [1]. They are layered compounds with a MX_2 stoichiometry, where M is a transition metal element and X is a chalcogen element. Interestingly, their electronic properties depend on their thickness and phase, such as the semiconducting hexagonal phase of $MoTe_2$ showing an indirect bandgap in bulk (2H phase) or a direct bandgap at the monolayer (1H) [2] or its semimetallic distorted octahedral phase (1T′) predicted to exhibit quantum spin Hall (QSH) effect in the monolayer regime [3]. Here, we report the growth of 2D islands of $MoTe_2$ by molecular beam epitaxy (MBE) on graphene grown on the (111) face of an Iridium single crystal. We can control the formation of 1H- and 1T'-phases varying the growth parameters, such as the sample temperature or Mo/Te ratio. Their structural characteristics are studied by means of scanning tunneling microscopy (STM).

INTRODUCTION

STRUCTURE

$MoTe_2$ is a TMD composed by a layer of Mo atoms between two layers of Te atoms

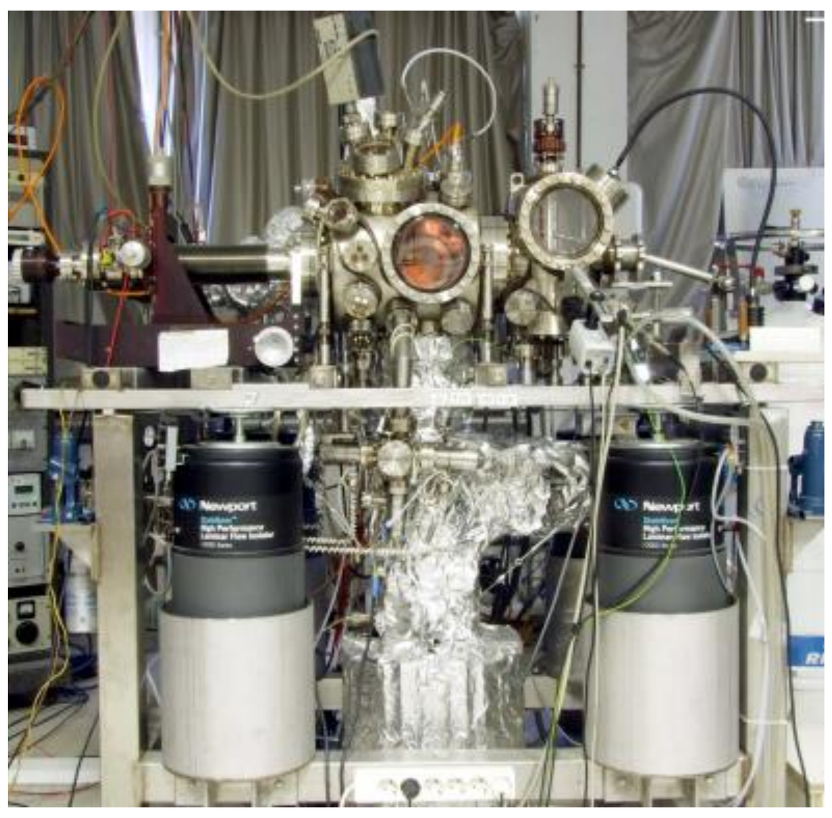


The **1H-phase** is a semiconductor with direct bandgap.

The **1T'-phase** is a semimetal with a very small or negligible bandgap.

SET-UP

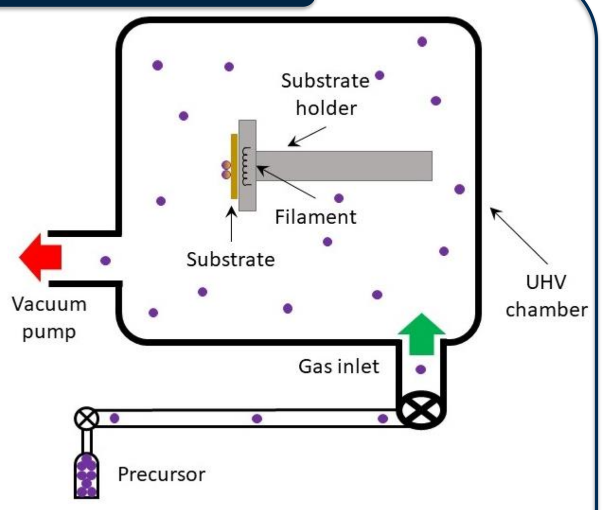
UHV system   Variable Temperature STM



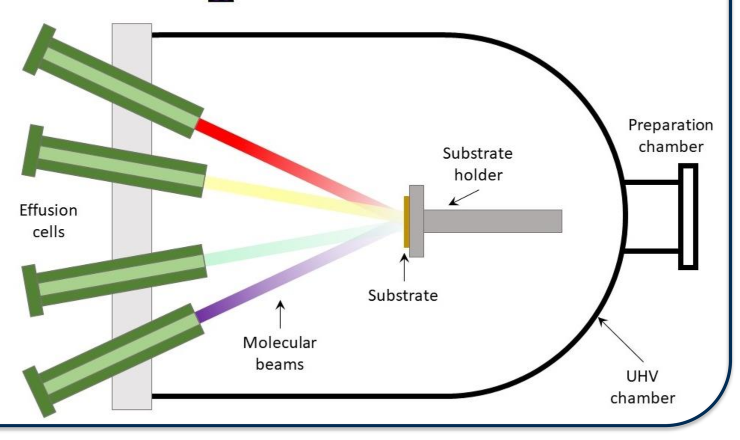
GROWTH

(1) Cleaning the sample:
3 Cycles:
Ar^+ sputtering:
$E = 1\,keV, \Delta t = 5'$,
$P_{Ar} = 3.6 \times 10^{-6}$ Torr
Annealing: ~ 1600 K

(2) Growing graphene:
CVD:
33L at 1443K

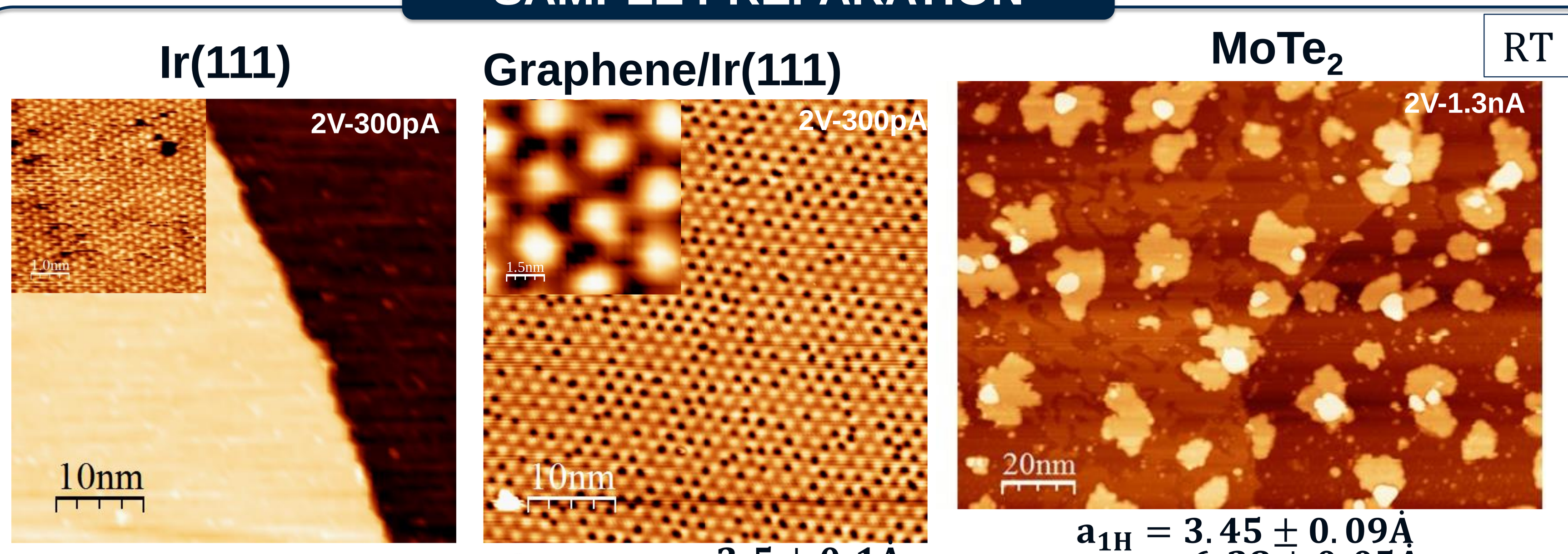


(3) Co-evaporating Mo-Te:
MBE:
$\Delta t = 30'$
$Flux_{Mo} = 20 - 150$ nA
$T_{Te} = 603 - 613$ K
$T_{Sample} = 370 - 540$K



RESULTS

SAMPLE PREPARATION



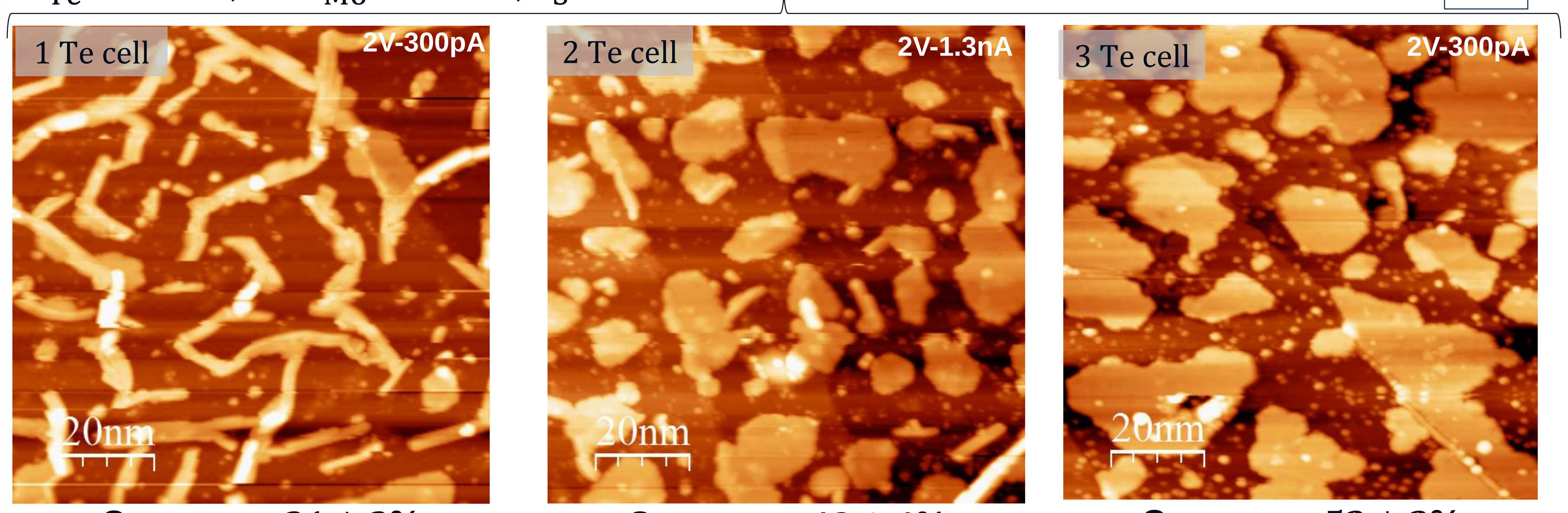
$a_{Ir}^{Clean} = 2.4 \pm 0.1$ Å

$a_{Gr/Ir(111)} = 2.5 \pm 0.1$ Å
$Moiré_{Gr/Ir(111)} = 2.1 \pm 0.1$ nm

$a_{1H} = 3.45 \pm 0.09$ Å
$a_{1T'} = 6.28 \pm 0.05$ Å
$b_{1T'} = 3.32 \pm 0.05$ Å

Te DEPENDENCE

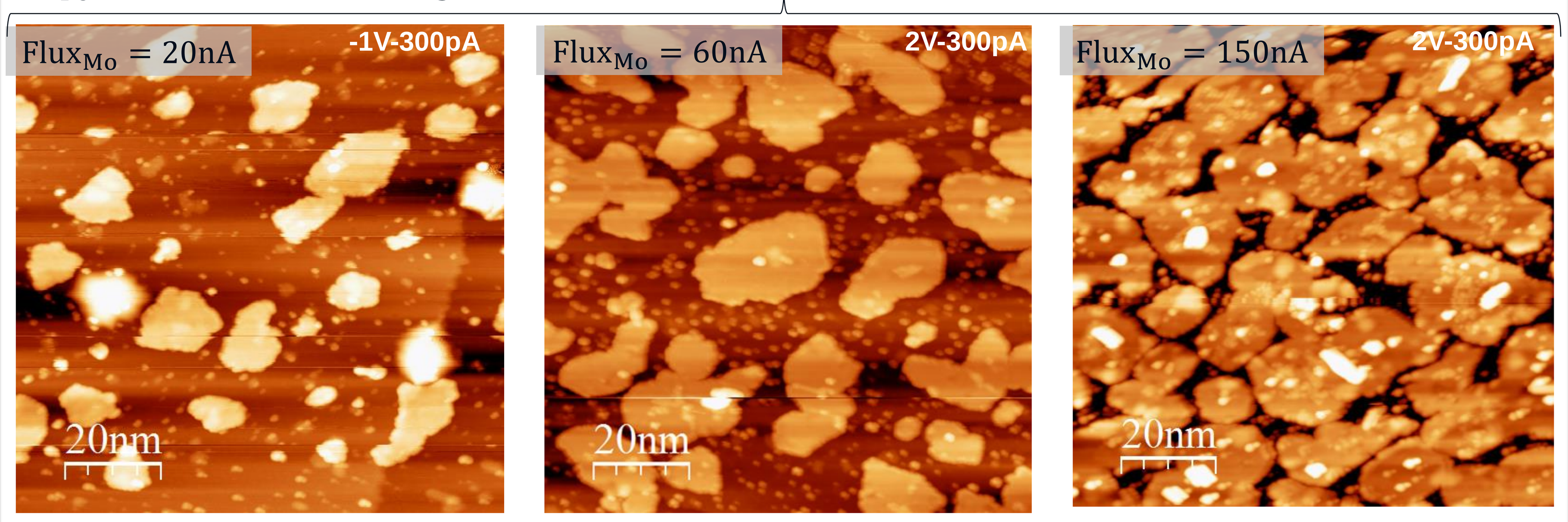
$T_{Te} = 603K, Flux_{Mo} = 60nA, T_S = 493K$ RT



Coverage=21 ± 2%   Coverage=42 ± 4%   Coverage=52 ± 2%

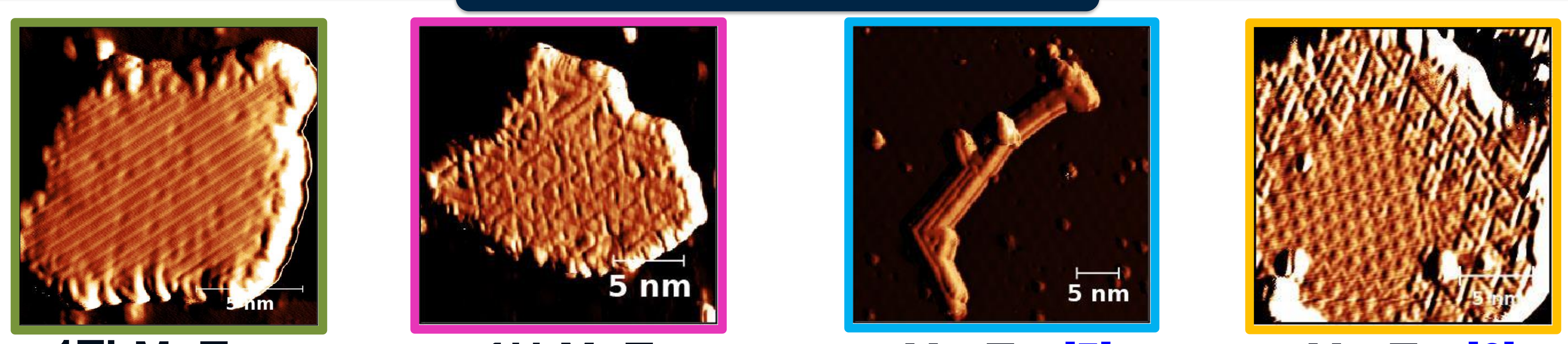
Mo DEPENDENCE

$T_{Te} = 613K, 3$ Te cell, $T_S = 493K$ RT



$Flux_{Mo} = 20nA$: Coverage=20 ± 3%
$Flux_{Mo} = 60nA$: Coverage=46 ± 4%
$Flux_{Mo} = 150nA$: Coverage=84 ± 3%

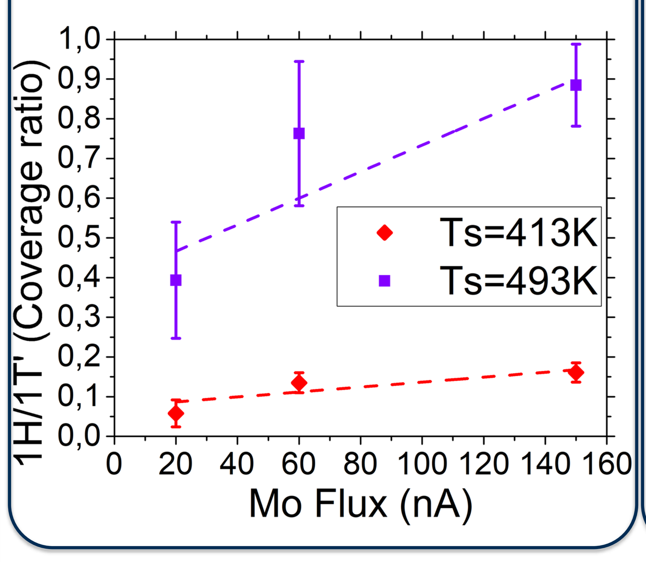
STRUCTURES



1T’-$MoTe_2$ 1H-$MoTe_2$ Mo_6Te_6 [5] Mo_5Te_8 [6]

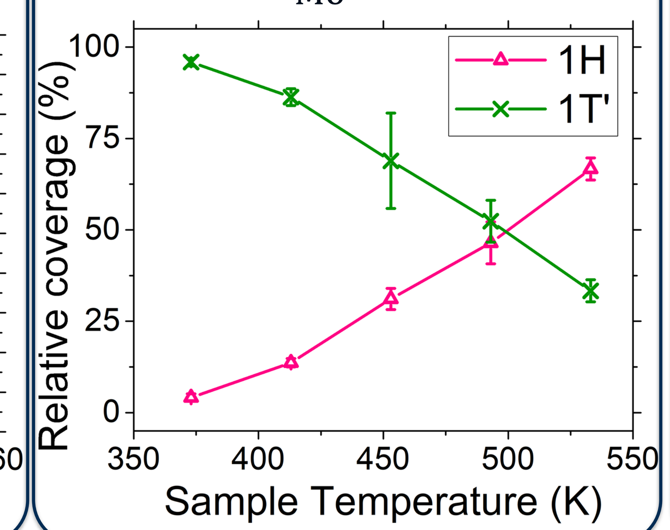
Mo/Te RATIO

3 cell $T_{Te} = 613K$

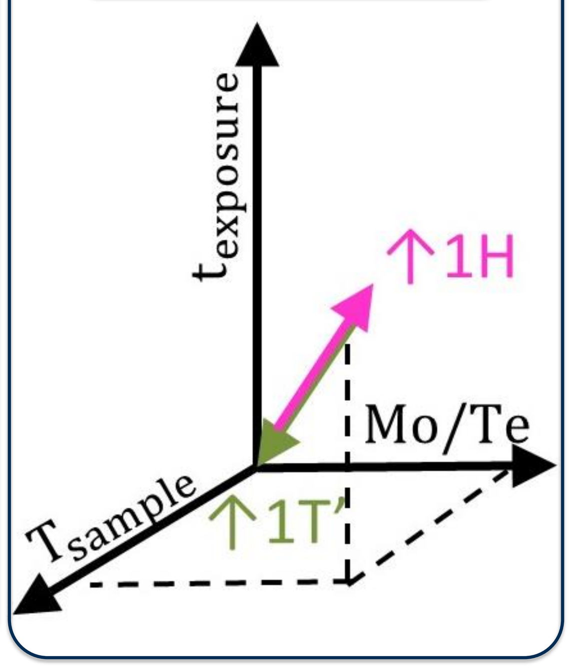


SAMPLE TEMPERATURE

3 cell $T_{Te} = 613K$, $Flux_{Mo} = 150nA$



3D VARIABLE MAP



Summary

- Low Te → New structures (Mo_6Te_6, Mo_5Te_8) and small coverage
- High Mo flux→ Increased coverage
- High Mo/Te ratio → Favored growth of 1H-phase islands
- Low sample temperature during the growth→ Favored growth of 1T’-phase islands
- High exposure time ≡ High sample temperature ≡ High Mo/Te ratio

References

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Webpage

http://nanociencia.imdea.org/nanoscale-imaging-of-2d-materials/group-home

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