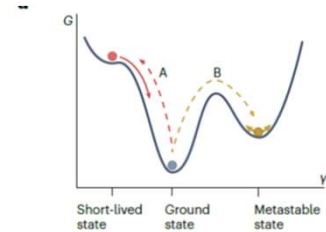


The access to the metastable states away from the thermodynamic equilibrium

- **Metastable state/phase:** a physical phase/state at a local minimum energy (Not ground state)

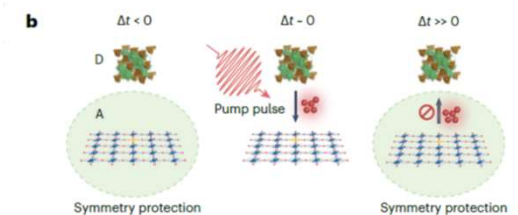
- **Single crystals:**

- ✓ mostly under thermodynamic equilibrium conditions
- ✓ Metastable states can be partly achieved by applying external stimuli (pressure cells, optical pulses...etc)
- ✓ Limited access to metastable states at ambient conditions (high-pressure synthesis, temp/pressure quench technique)



- **Epitaxial thin films:**

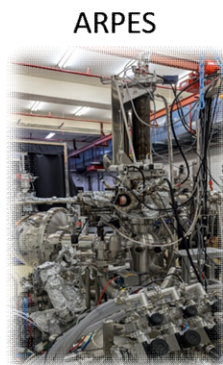
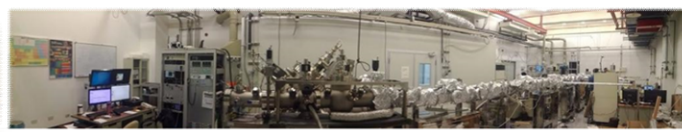
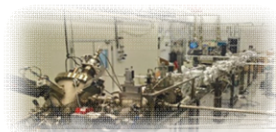
- ✓ Direct access to metastable states via substrate strain engineering (strained stable superconductivity at ambient conditions in RuO₂)
- ✓ Direct access to interfacial physics (interfacial superconductivity of LaAlO₃/SrTiO₃, LaAlO₃/KTaO₃, FeTe/Bi₂Se₃...etc)
- ✓ Direct access to a quasi-two-dimensional regime by thickness control or superlattices structure.
- ✓ Easy follow-up device patterning and fabrication for further investigations on various physical effects.
- ✓ Novel quantum materials in epitaxial-thin-film form provide a wonderful platform for developing novel quantum technology.



Nature Mater. 24 (2025)

Most of condensed matter experiments start with single crystals or thin films!

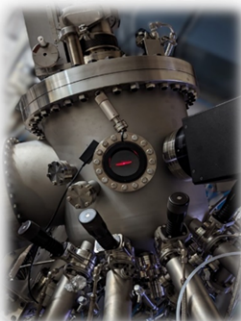
Multi-chamber UHV epitAxial thin film @ room B113-B114
Growth And CHaracterization system (MAGACH) at IoPAS



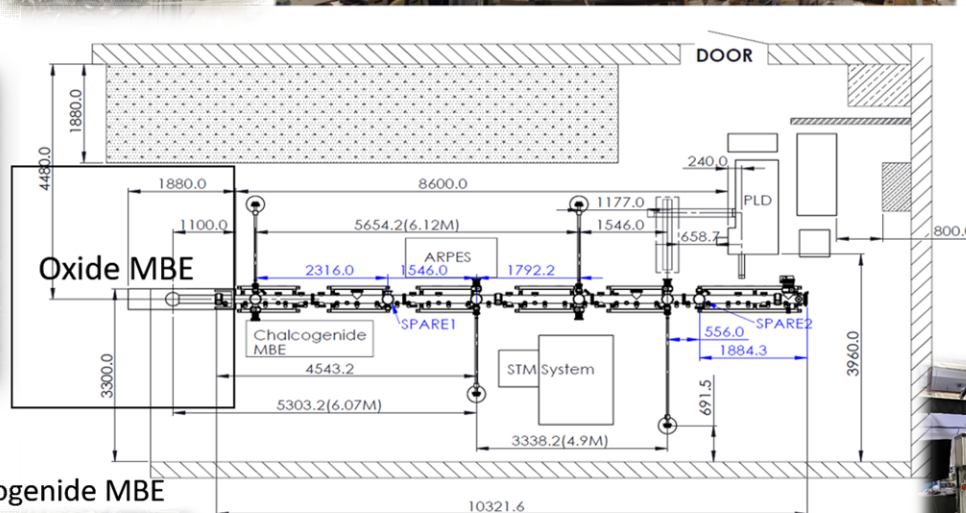
ARPES

of combinations:
 $C_1^5 + C_2^5 + C_3^5 + C_4^5 + C_5^5 = 31$

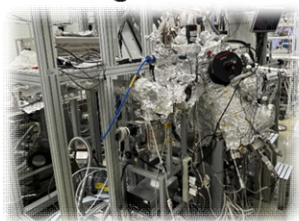
Oxide MBE



Wei-Li Lee
Akhilesh Singh



Chalcogenide MBE

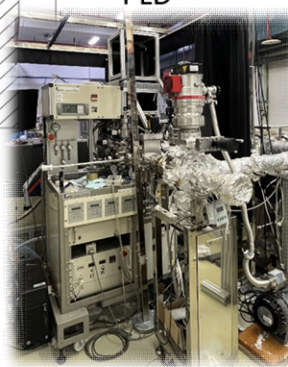


Wei-Li Lee
M.K. Wu
Akhilesh Singh

VT-SPM



Wei-Li Lee
Ing-Shouh Hwang
Wei-Bin Su
Elisha Lu



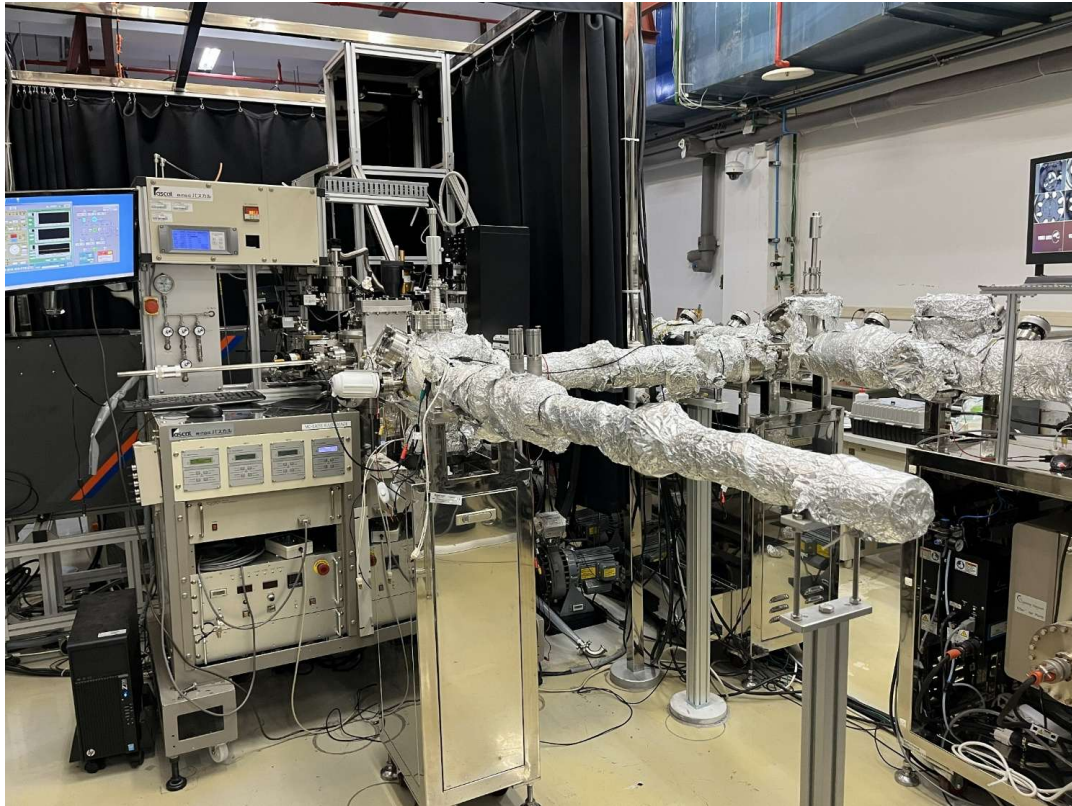
PLD

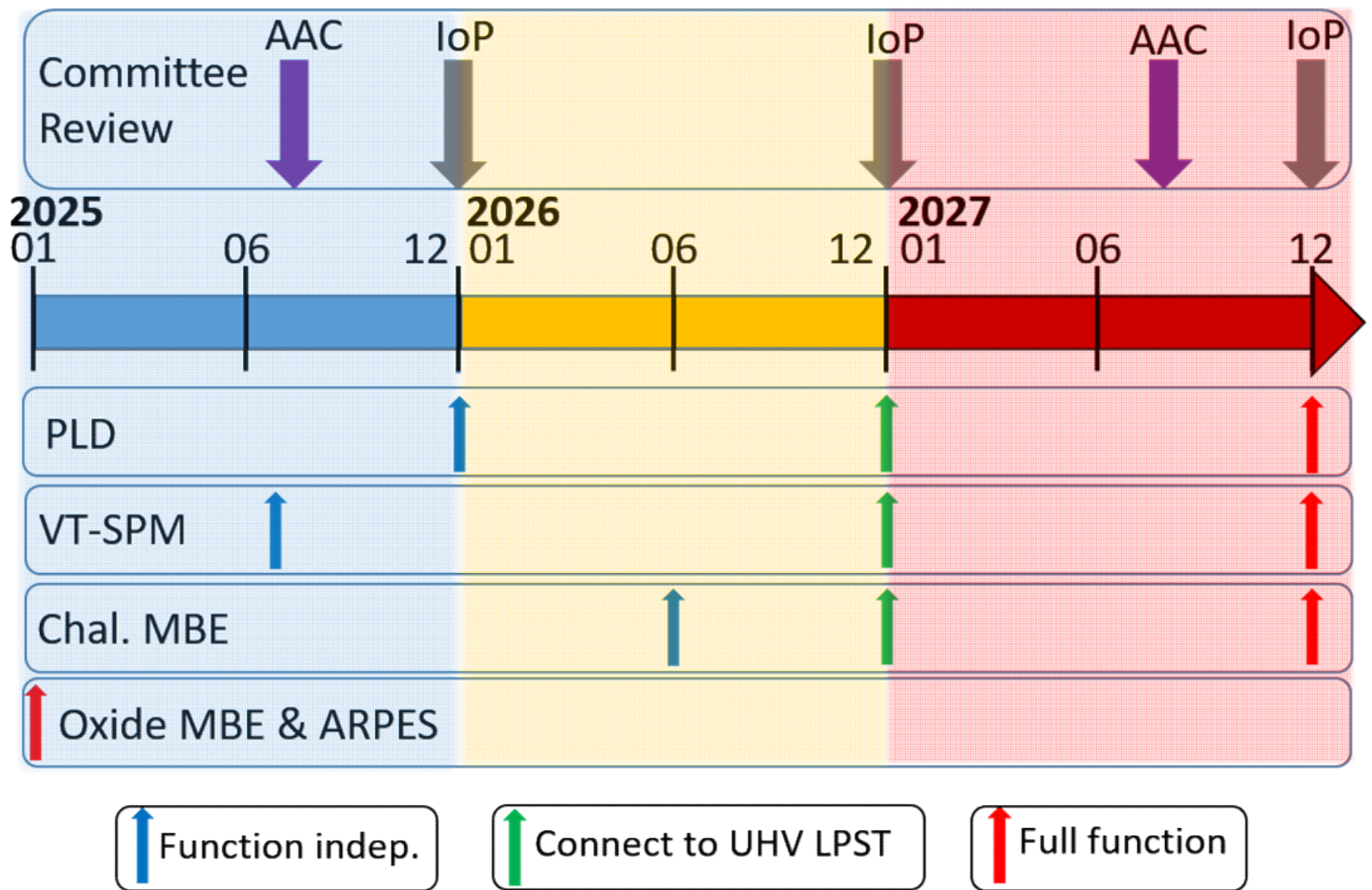
Wei-Li Lee
Eddie Chu
Javed Iqbel

Ferrovac UHV
Shuttle suitcase



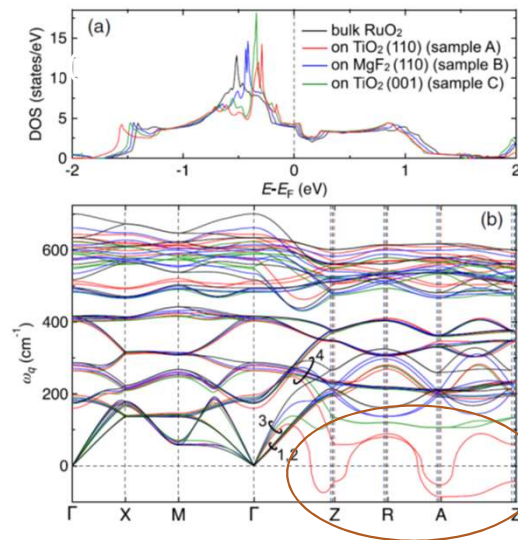
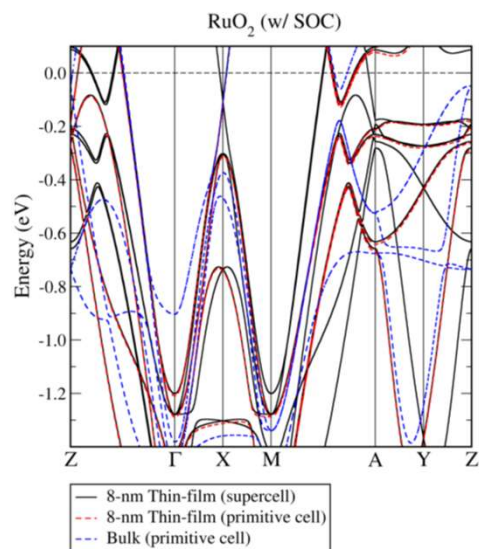
**The PLD is now not only functioning but also
officially connected to the UHV long pipeline @ 2025 Nov.**



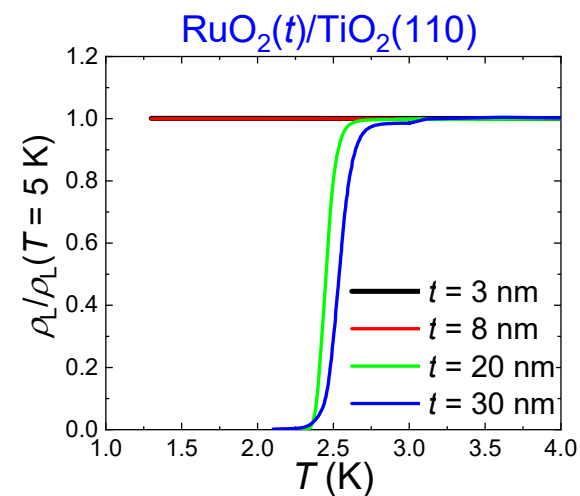


Oxide MBE + ARPES

2025/11/06



Strained-stabilized Superconductivity

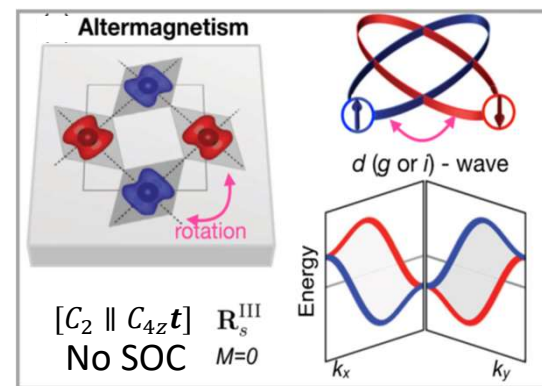
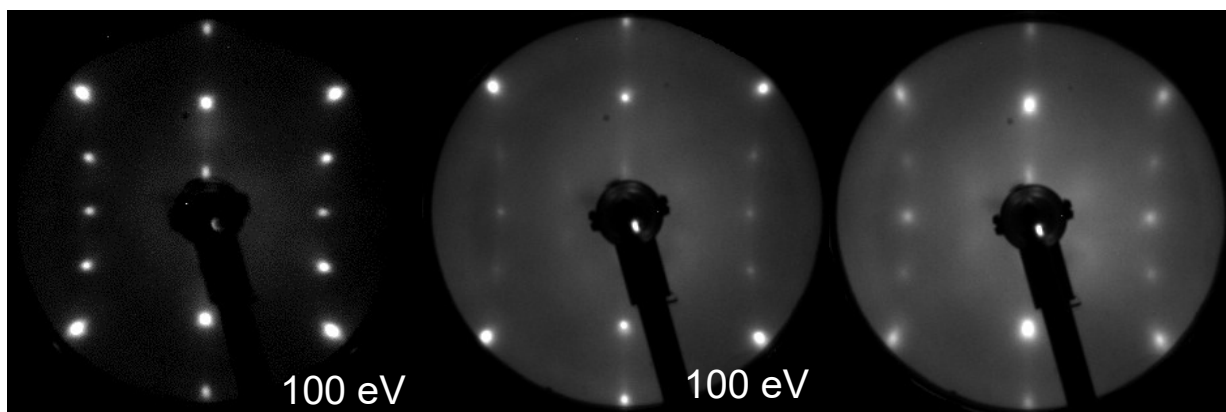


LEED Patterns of 20 nm RuO₂ with Different Doping

20 nm RuO₂ undoped

10% Cr

15% Cr



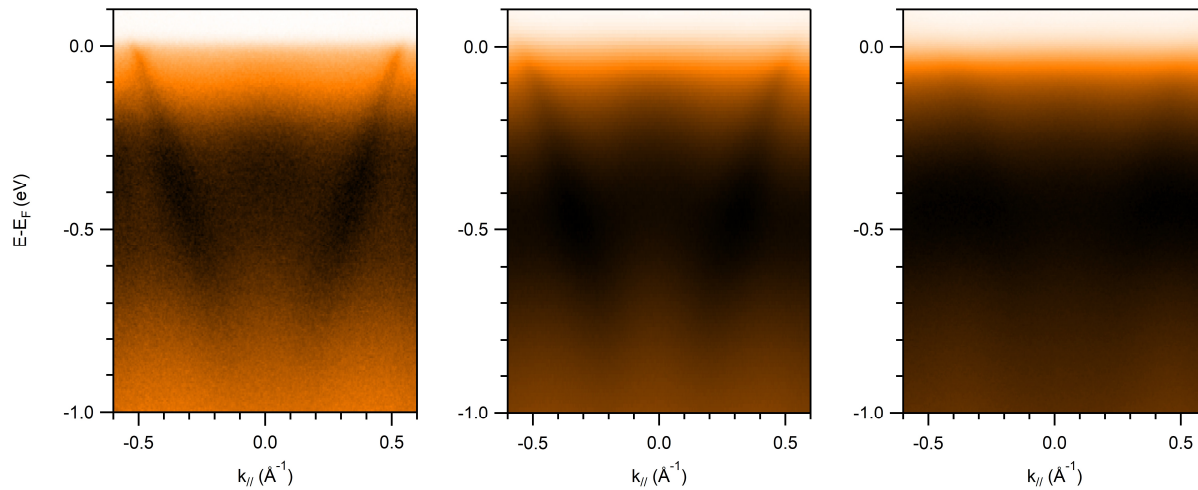
Magnetism ? Altermagnetism ?

Measurement along the $\overline{\Gamma M}$ direction ($h\nu=21.2$ eV)

20 nm RuO₂ undoped

10% Cr

15% Cr

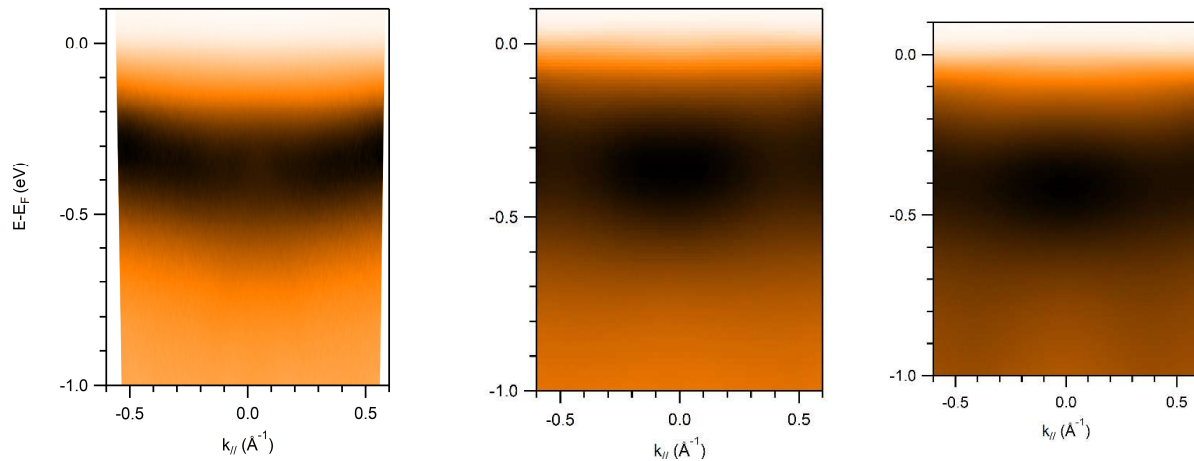


$\overline{\Gamma A}$ direction

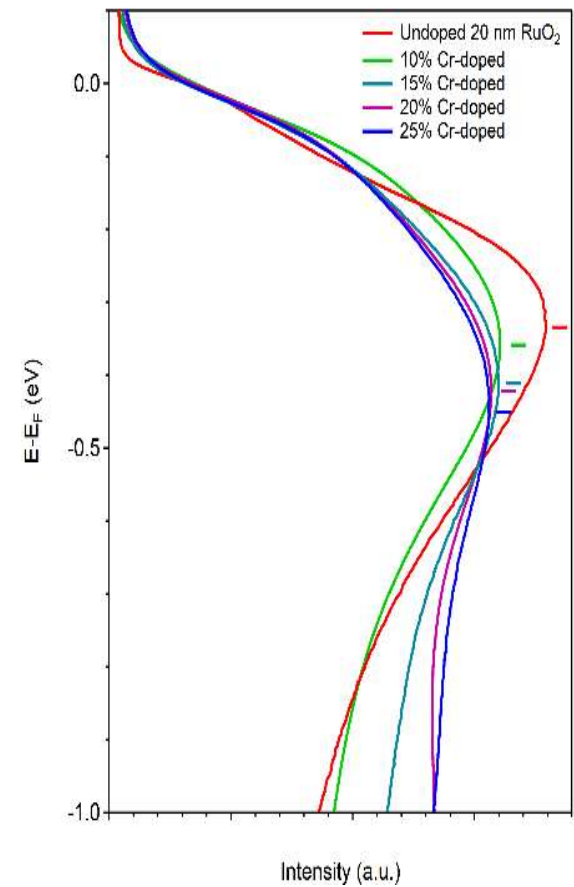
20 nm RuO₂ undoped

10% Cr

15% Cr



Flatband moves away from FS with Cr doping



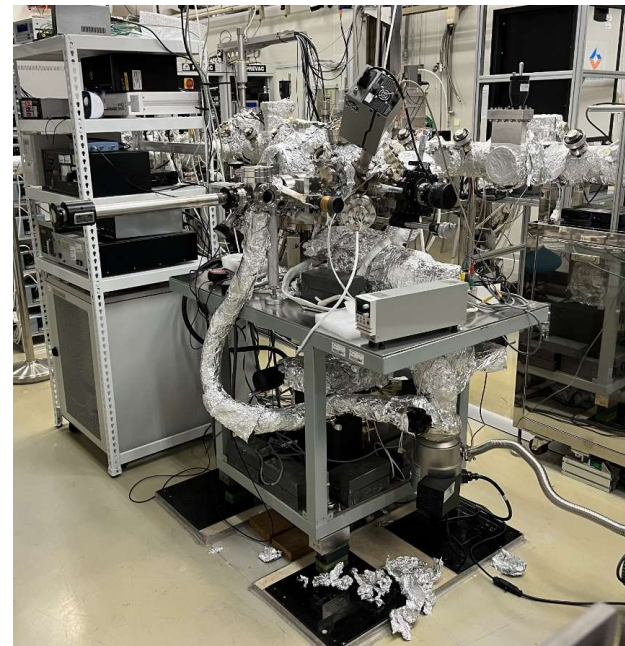
Test images using VT-SPM

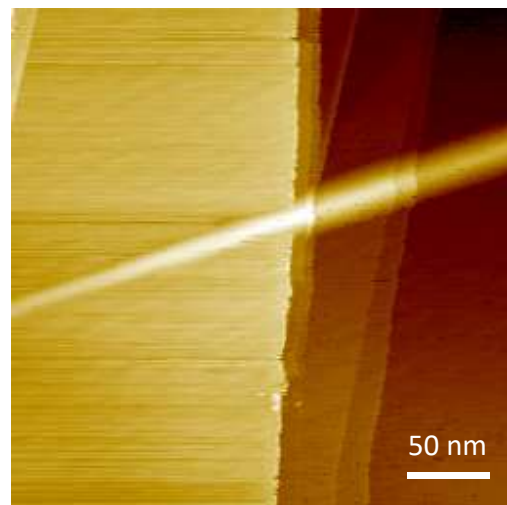
2025/11/06

**VT-SPM after removal of the
active vibration isolation stage**

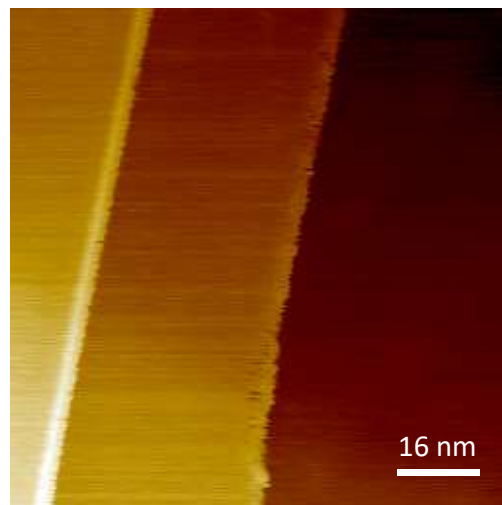


**VT-SPM on 2025 Nov.
@ 2×10^{-10} torr**

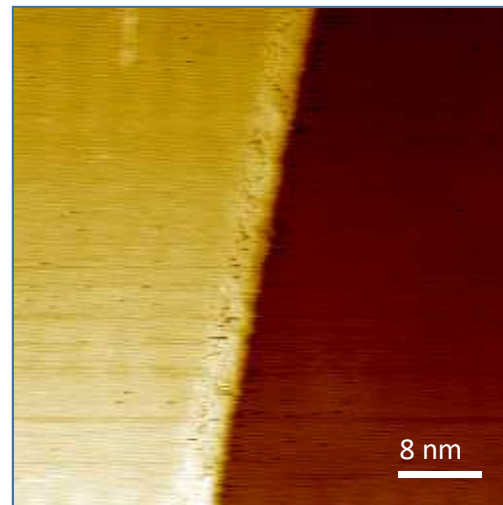




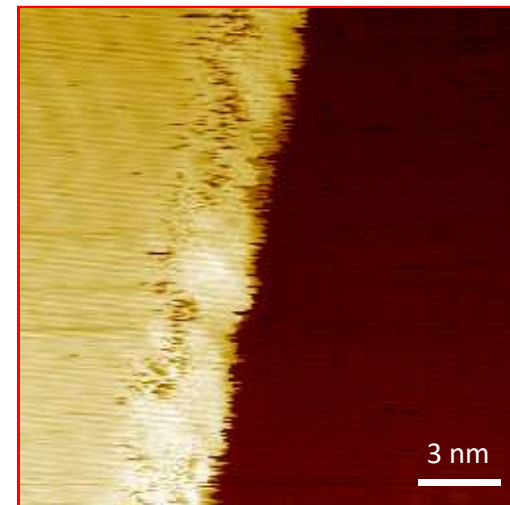
20251023_60-4_300n_1V_400pA



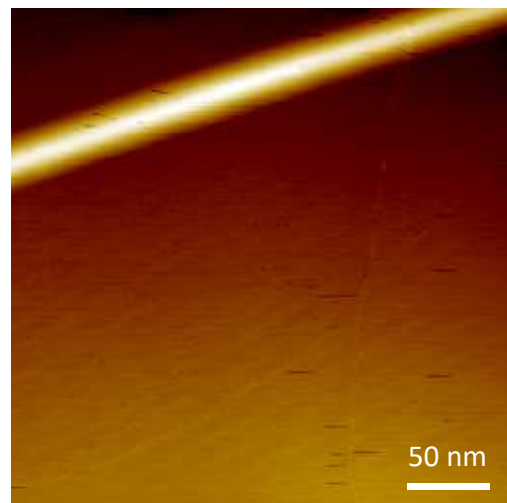
20251023_76-1_100n_1V_400pA



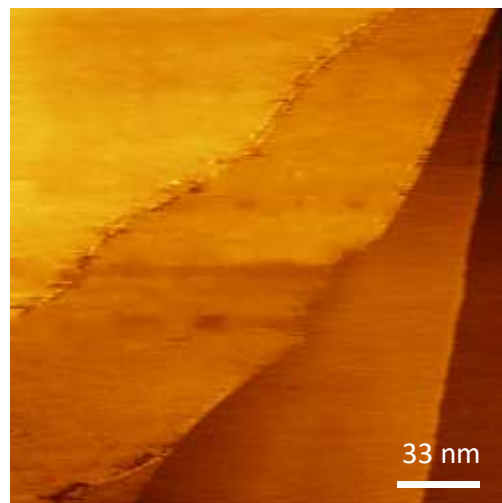
20251023_71-2_50n_1V_400pA



20251023_70-4_20n_1V_400pA



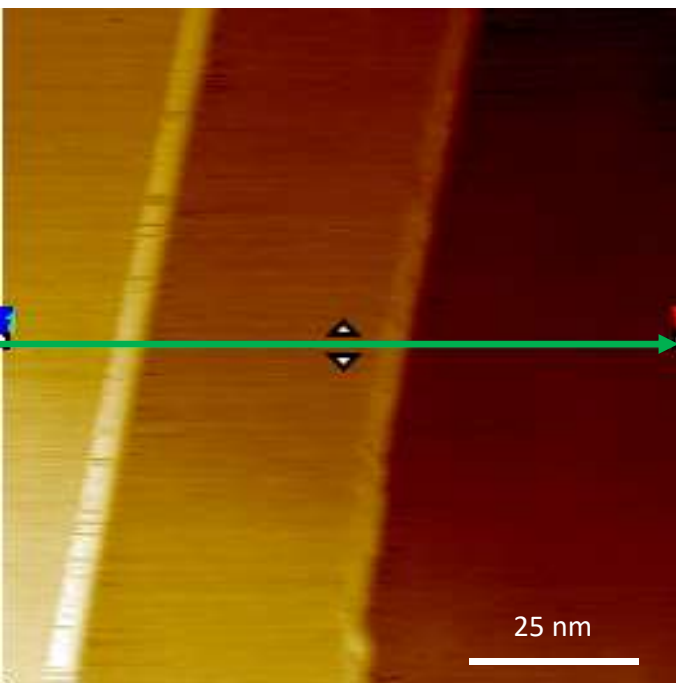
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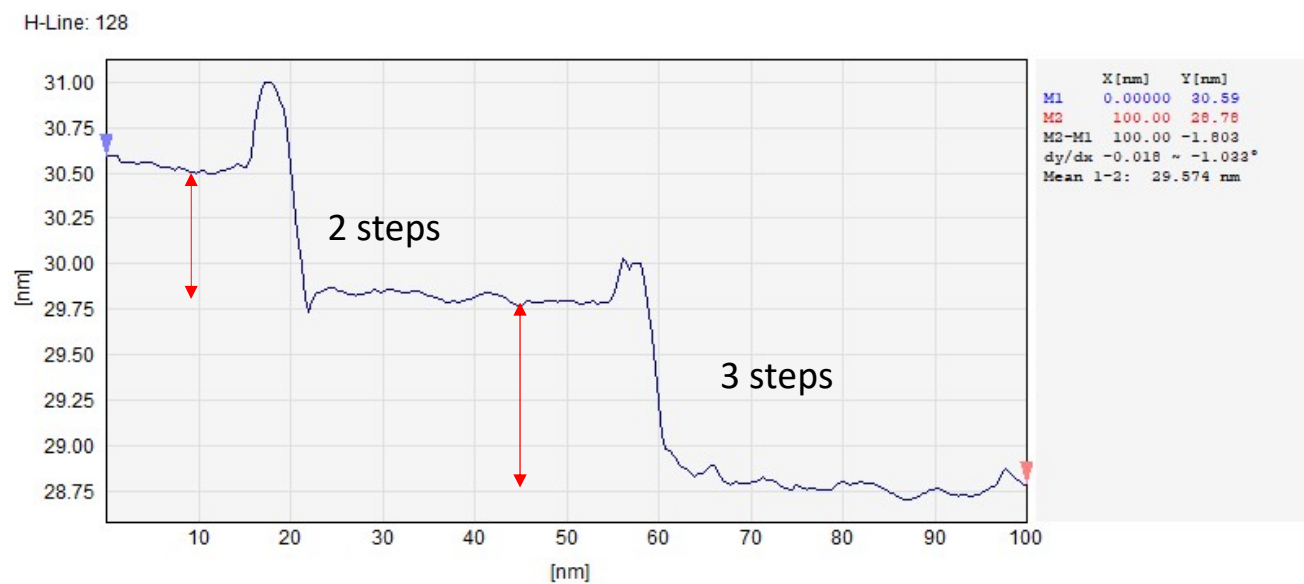
20251023_49-1_200n_1V_400pA

Mode: STM
Sample: HOPG

Mode: STM
Sample: HOPG

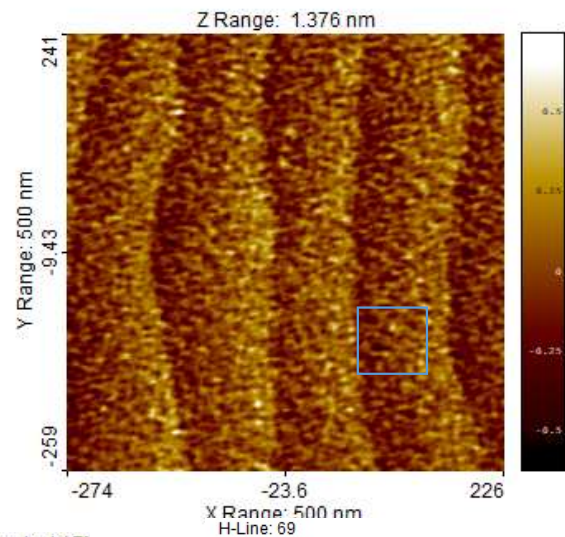


20251023_76-1_100n_1V_400pA

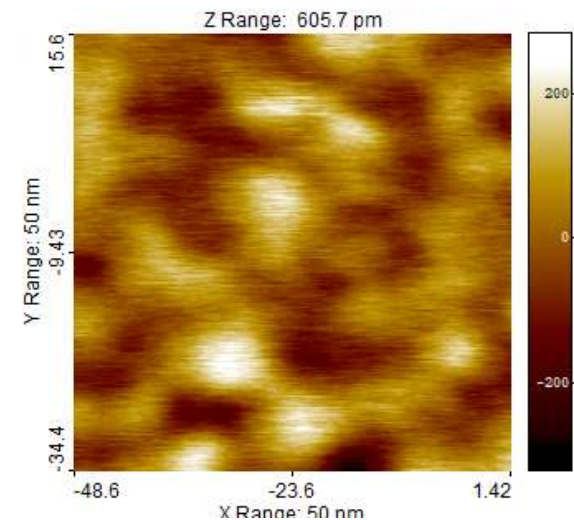


Mode: NC AFM
Sample: SrTiO3

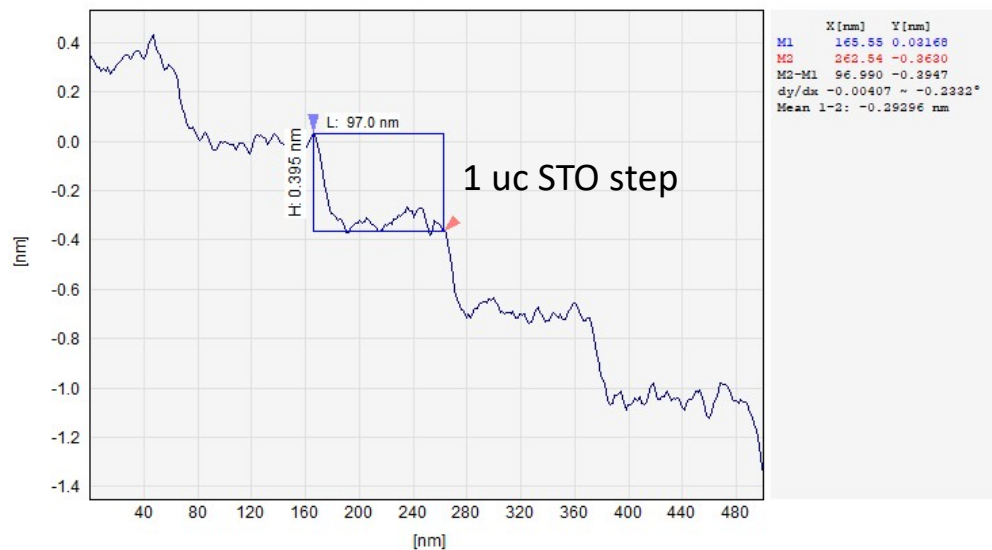
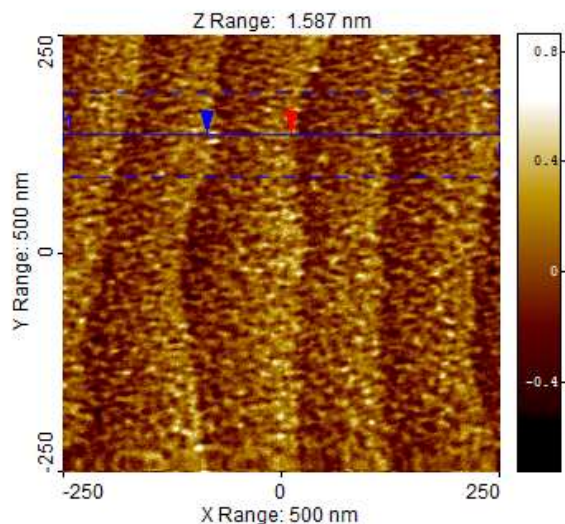
Z TraceUp Fri Oct 03 01:12:56 2025 [8-9] AFM_NonContact AFM_



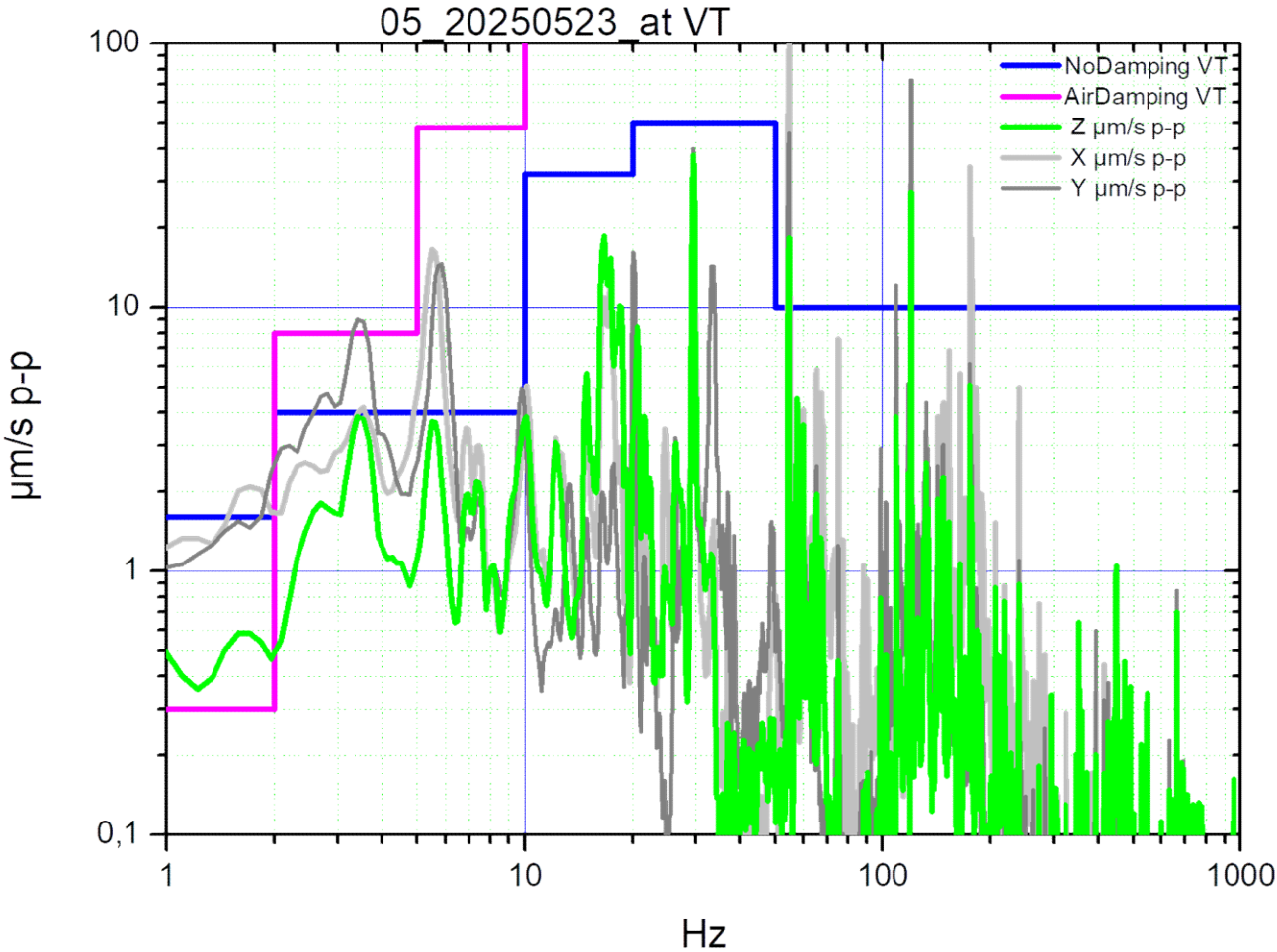
Z TraceUp Wed Oct 01 20:43:48 2025 [5-3] AFM_NonContact AFM_



Z TraceUp Wed Oct 01 14:19:59 2025 [1-1] AFM_NonContact AFM_

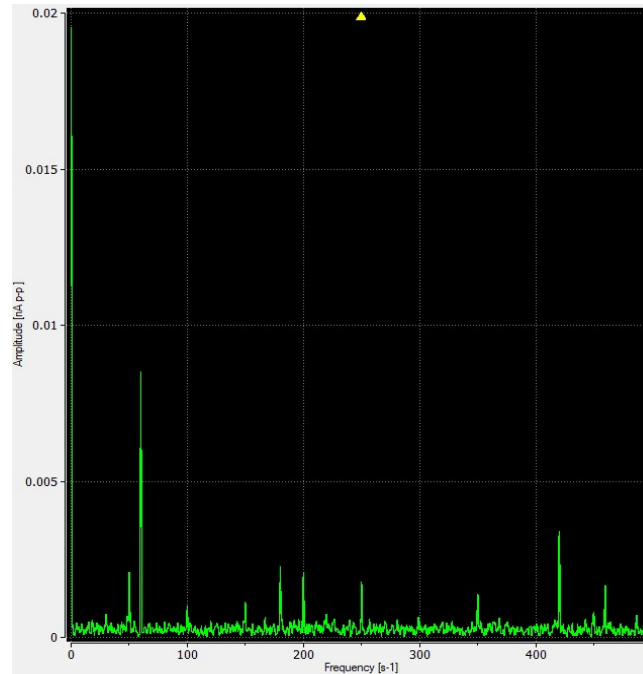
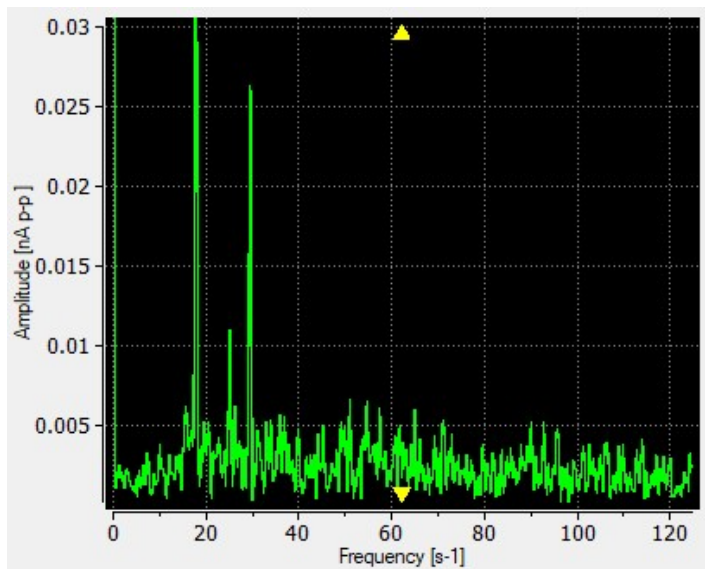


Tests by Martin Rohmer using Omicron VibTool with sensor on top of the VT-SPM chamber



Noise check – NC AFM mode

Noise check – STM mode

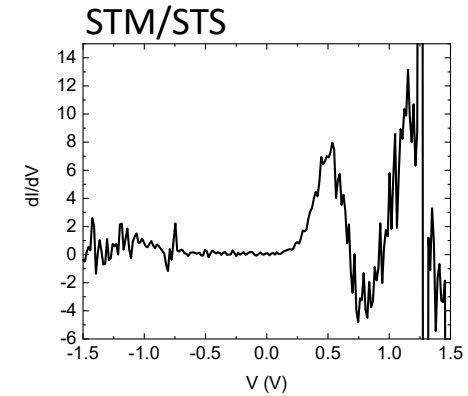
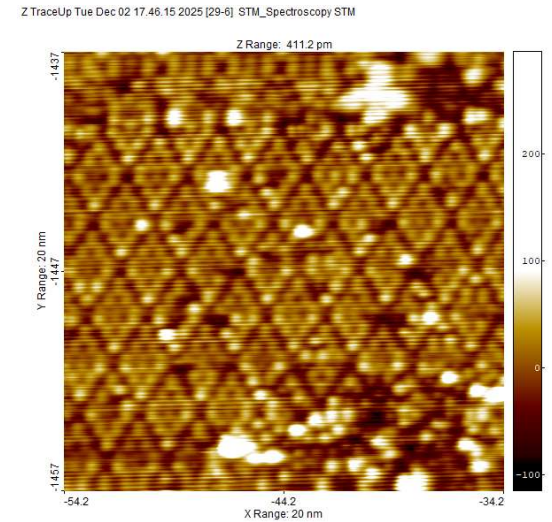
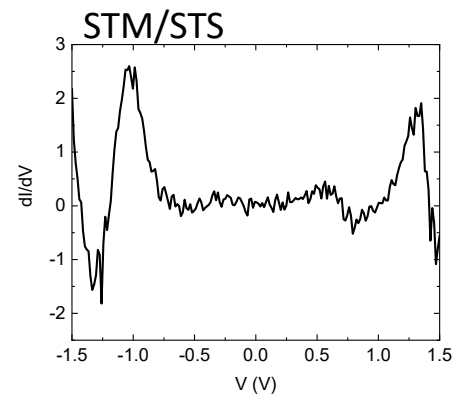
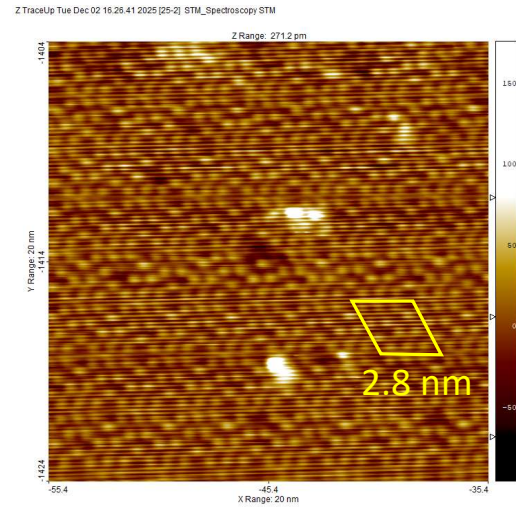
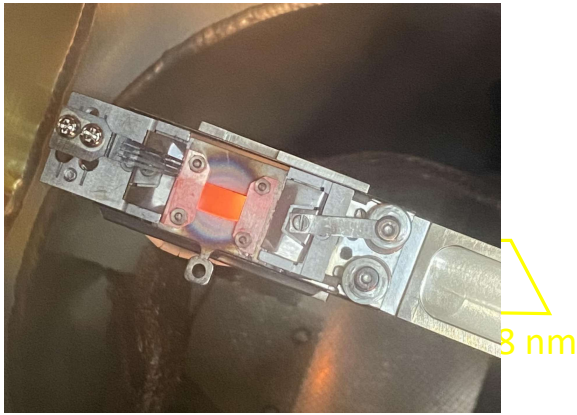


50 and 60 Hz

1. Ground issue?
2. Electrical isolation problem

STM – Si(111) fourth flash

Flash to 14.1A (~1280°C) several cycles



We thank Dr. Fang/Dr. Hwang's group for the help on repairing the heaters and also STM tip preparations!

MAGACH facility updates: 2025 Nov.

ARPES facility

- 100% uptime with SPEC helium lamp (21.2 eV)
- The Omicron VUV 5k plasma helium lamp (21.2 and 40.8 eV) will be back and tested. (ready by Dec. 2025)
- Work for both single crystals and thin films: contact **Dr. Wei-Chuan Chen** for access.

VT-SPM facility

- Both STM and AFM modes in UHV are functioning.
- Noise issues need to be resolved to procure atomically resolved images.
- More tests on different samples are currently underway.
- Contact **Elisha Lu** for access.

PLD facility

- Sample transfer to oxide MBE and ARPES is ready.
- The KrF laser and its optical components are ready.
- Contact **Dr. Akhilesh Singh** for access.

Training courses on PLD and ARPES will be arranged in early 2026 for all QMP/IoP members.

MAGACH facility usage

	QMP PIs	Man powers/operators	Users/collaborators
Oxide MBE	Wei-Li Lee	Akhilesh Singh (supervisor) Javed Iqbal Qasim Ali	Chia-Hung Hsu, SC Weng, CM Cheng Huang, TH Chuang (NSRRC) MW Chu, Danru Qu (CCMS NTU) Martin Vein (Charles Univ.) Milan Orlita (LNCMI-CNRS) Dave Hsieh (Caltech) Liangzi Deng (Houston)
Chalcogenide MBE	Wei-Li Lee M.K. Wu	Akhilesh Singh (supervisor) Other from MK's group	You-Sheng Li (Physics NTU)
ARPES	Wei-Li Lee Shu-Jung Tang (joint)	Wei-Chuan Chen (supervisor) Javed Iqbal	Ryo Nauguchi, Wei-Wou Pai (CCMS NTU) Raman Sankar
VT-SPM	Wei-Li Lee Ing-Shouh Hwang Wei-Bin Su	Elisha Lu (supervisor) Wei-Chuan Chen C.K. Fang Nhu	
PLD	Wei-Li Lee Ying-Hao Chu (joint)	Javed Iqbal (supervisor) Akhilesh Singh Qasim Ali	F.Y. Lo's group (NTNU) Shangfan Lee's group (?)

Welcome more potential users/collaborators using MAGACH facility!

Grand challenge topics using MAGACH facility

- **Strained-stabilized superconductivity under ambient conditions:** (MBE + PLD + ARPES + shuttle suitcase)
 - ✓ Anisotropically strained (110) RuO₂,
 - ✓ La₃Ni₂O₇, (PrLa)₃Ni₂O₇ and other Nickelate families
 - ✓ More to be discovered (SC close to RT ?)
- **Surface atomic and electronic structure:** (MBE + PLD + VT-SPM + APRES + shuttle suitcase)
 - ✓ Correlated oxygen vacancies on the surface of SrTiO_{3-δ}
 - ✓ Surface defect structure and its electronic property in FeSe/FeTe
- **Bilayer thin films for altermagnetism or chiral systems:** (MBE + PLD + shuttle suitcase): ensure a clean interface
 - ✓ Possible altermagnets: La₂CuO₄/TL, RuO₂/TL, MnTe/TL, CrSb/TL (TL: Py, Pt or YIG ...)
 - ✓ Possible Chiral phonons: CaTiO₃, LaNbO₃, CoTiO₃, MnTiO₃...etc
 - ✓ Low-power consumption spin-based electronics
- **Proximity and interfacial physics:** (MBE + PLD + shuttle suitcase)
 - ✓ Bi₂Te₃/Nb: possible topological SC in TI/SC and Majorana edge modes in QAHE/SC
 - ✓ Interface superconductivity in FeTe/Cr-doped Bi₂Se₃
 - ✓ More to be discovered(exotic physical phases)



Accelerating the development of quantum materials and tools to understand quantum phenomena

2025 Nov.



The next phase of the Emergent Phenomena in Quantum Systems Initiative

We are excited to announce the next phase of the Emergent Phenomena in Quantum Systems Initiative. Building on 12 years of groundbreaking research and a \$188 million investment, the foundation will dedicate an additional \$230 million over the next decade to advance the field of quantum materials.

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