Ultra-high vacuum low-temperature scanning tunneling microscope - molecular beam epitaxy combined system

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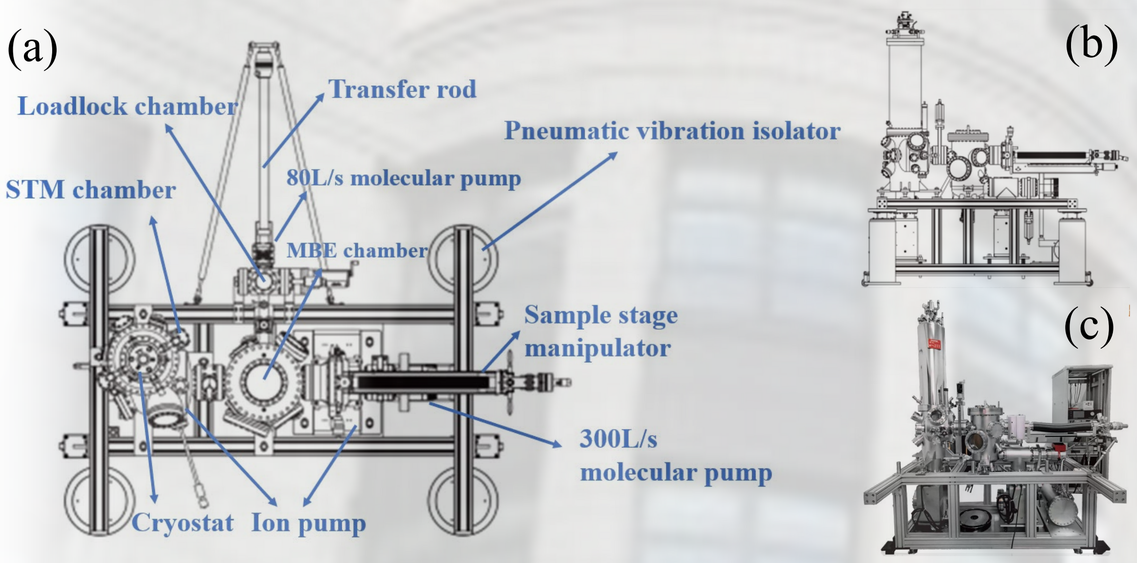
Introduction

Ultra-high vacuum (UHV) low temperature (LT) STM system with MBE from CASAcme is constructed. The STM scanner head takes a modular design with unibody titanium frame. A double-layer cold room is mounted at the bottom of the cryostat. The vacuum level in the STM chamber is better than 10^{-10} Torr, and sample temperature is lower than 5K after cooling down by liquid helium (LHe). The performance of the STM and is demonstrated by characterization of a 2D highly oriented pyrolytic graphite (HOPG) surface.

Overview of LT-STM-MBE system



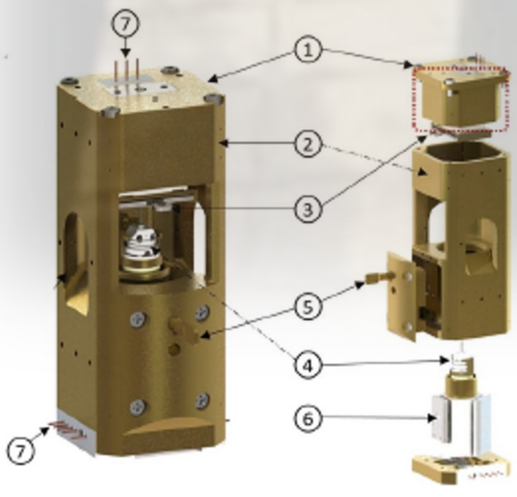
(a) Top view (b) side view of a 3D model of the system (c) photograph of the system

Cold room

①LHe cryostat
②LHe shield frame
③LN_2 shield frame

Double-layer cold room, composed of a LHe shield and a LN_2 shield is mounted at the bottom of the cryostat. Both shield are made of aluminum alloy 6061 with high UHV compatibility and thermal conductivity.

Titanium STM scanner head



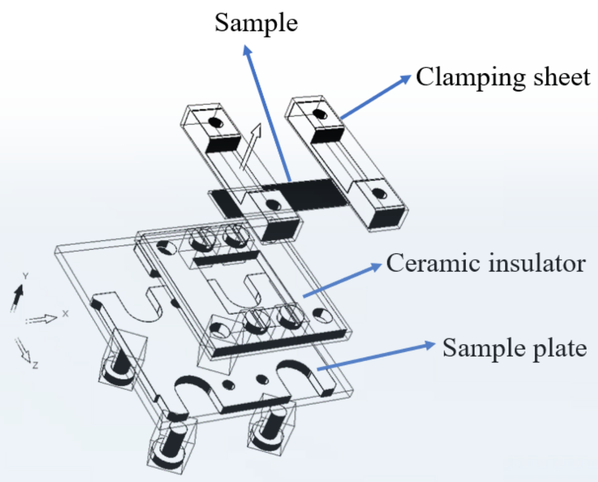
①Sample motion stage
②Unibody frame
③Sample
④Tip holder
⑤Stress-adjusting screw
⑥Pan's stepper screw
⑦Electrical feedthrough

The scanner is levitated by three springs to isolate vibration. The tip-approach module has the classic structure of Pan's design. The vertical travel distance of the tip is 8mm.

Reference:

1. Wu, Z. B. *et al. Review of Scientific Instruments* **89**, 113705 (2018)
2. S. Pan, *International Patent Publication Number WO 93/19494 (International Bureau, World Intellectual Property Organization, 30 September 1993).*
3. He, G. *et al. Review of Scientific Instruments* **91**, 013904 (2020)

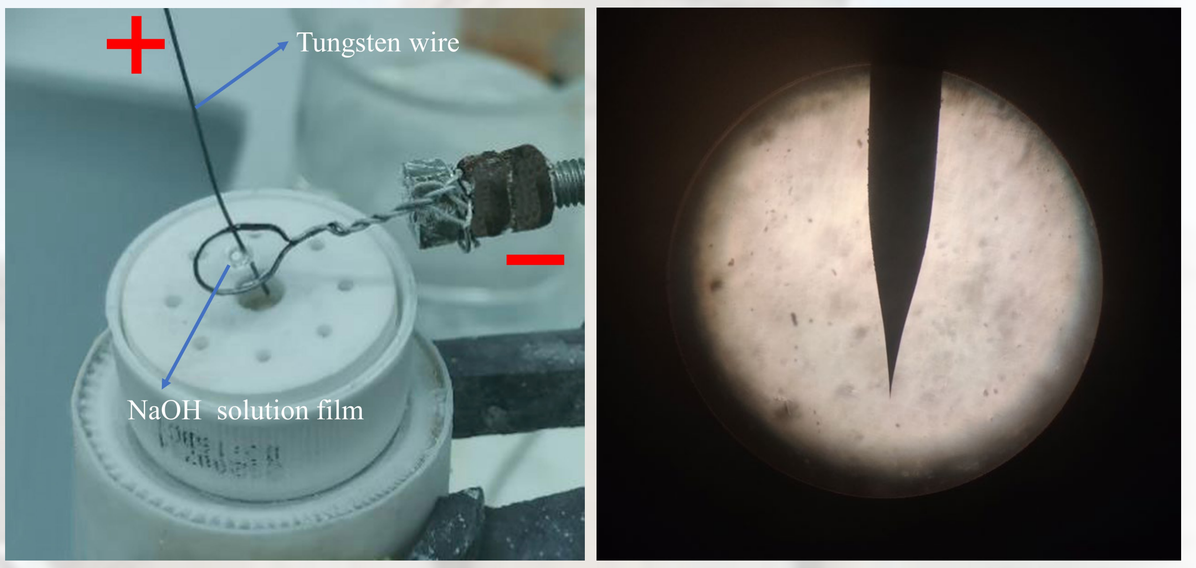
Molybdenum DC sample holder



Sample is mounted between the clamping sheet and ceramic insulator for direct current heating. We chose molybdenum (Mo) as the sample holder material for better UHV compatibility and less contamination for Si-related sample.

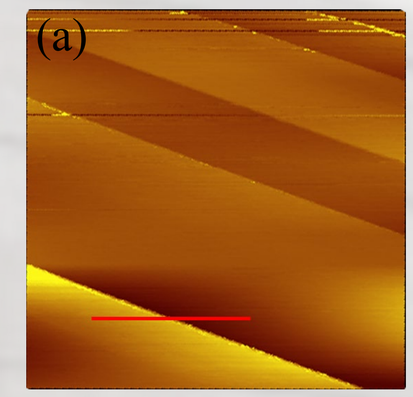
* We thank Wentao Yang for useful inspiration and patient guidance on the design of DC sample holder.

Homemade tungsten tip

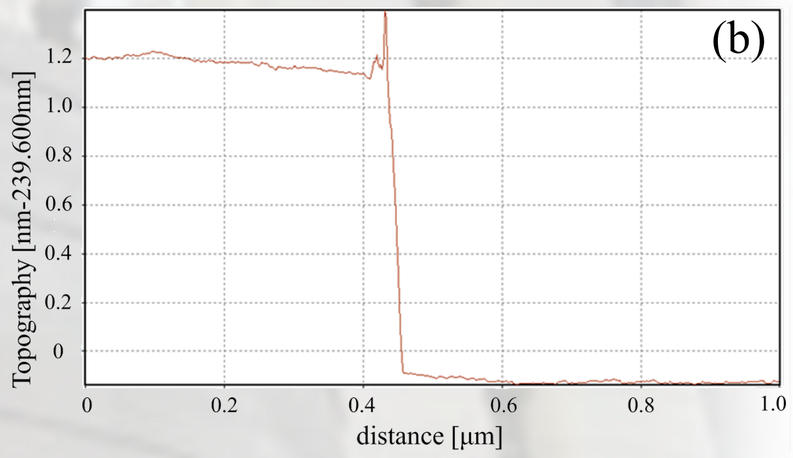


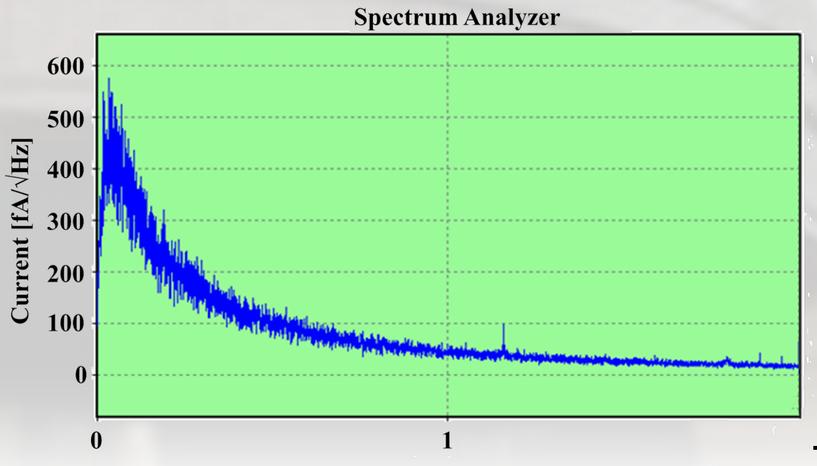
Tungsten tips are fabricated by electrochemically etching. 2 mol/L NaOH solution is chosen as electrolyte.

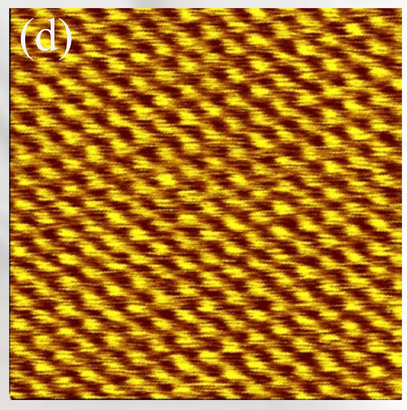
HOPG surface characterization (RT)



0.5nA 1.01V $1\times1\mu m^2$







-2.6nA -80mV $3\times3nm^2$

(a) Large scale STM image of HOPG surface. (b) Topography measured along redline in (a). (c) Frequency spectrum of the tunneling current at a fixed height with I_t=500pA, V_b=1V. (d) Atomic resolution STM image of HOPG.

Conclusion

- UHV-LT-STM-MBE system was constructed and the performance of the system under room temperature (RT) has been demonstrated by the characterization of HOPG surface.
- Stability and validity of this system at low temperature (77K & 5K) is still under testing.