MEMS-Based Scanning Tunneling Microscopy

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Since its invention in 1982, Scanning Tunneling Microscope (STM) has enabled numerous applications in nanotechnology, such as topographic imaging and nanopatterning, all with atomic precision. The STM, however, is slow and has a limited throughput, mainly due to its bulky piezo-nanopositioner (piezotube). The low Z-axis bandwidth of the STM piezotube results in a slow scan speed, and its single tip limits its throughput.

We address this limitation by replacing the Z-axis of a commercial STM piezotube with a Microelectromechanical-System (MEMS) device. The MEMS device provides higher bandwidth compared to the STM piezotube and thereby improves the speed of the scanner. Further, due to its smaller footprint, the MEMS device can be further extended into an array for parallel operation of a multi-tip STM, providing higher throughput. Here, we redesign and integrate a previously demonstrated one-degree-of-freedom MEMS STM Z-axis nanopositioner[1] (Figure 1) into an Omicron Ultra-High-Vacuum (UHV) STM system.

The MEMS device is designed to have a bandwidth of 13 kHz with 2-µm displacement and to fit the 6 mm by 4.5 mm space available on the tip holder. The MEMS-device assembly is then built by gluing the MEMS device onto the tip holder using UHV-compatible conductive epoxy. The actuation signal to drive the MEMS device uses the third signal leg on the tip holder, which was originally designed for the Omicron qPlus sensor. The platinum tip at the extremity of the MEMS device is sharpened by field-directed sputter sharpening to increase its stability.

By mounting the MEMS-device assembly on the Omicron scanner (Figure 2), a hybrid STM system is achieved in which motions in XY-plane are provided by the piezotube while the Z-axis motion, which requires a faster response but has a smaller range, is delivered by the MEMS device. After coarse approach of the MEMS device to the H-terminated Si(001) sample, the hybrid system is used to take STM images of the sample surface. Figure 3 shows a typical STM image obtained by the hybrid system, proving suitability of the MEMS device for STM applications.

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[1] Alipour, A., et al. "A high bandwidth microelectromechanical system-based nanopositioner for scanning tunneling microscopy." Review of Scientific Instruments 90.7 (2019): 073706.

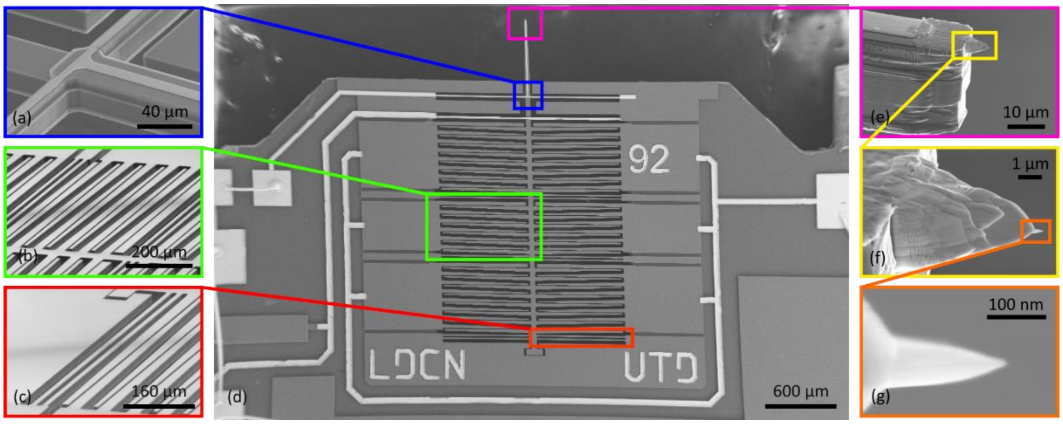

Figure 1: SEM images of the MEMS device: (a) tunneling current routing (b) parallel-plate electrostatic actuators (c) flexures (d) overview of MEMS device (e) shuttle beam end (f) inplane Pt tip (g) tip apex.

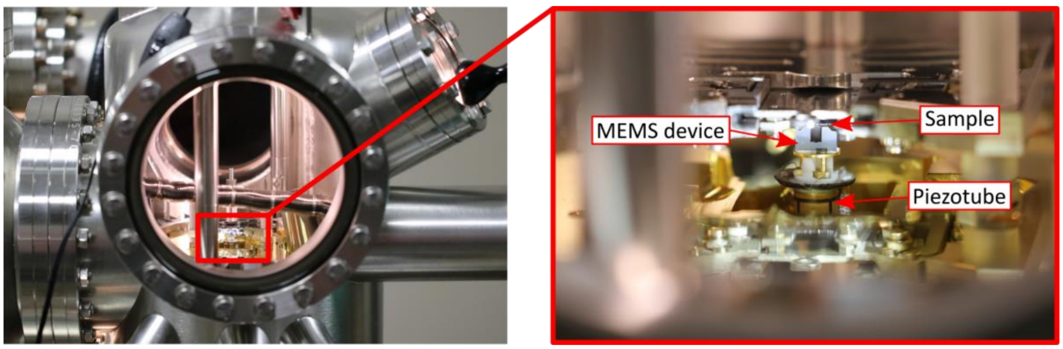

Figure 2: Hybrid STM system with MEMS device delivering Z-axis motion.

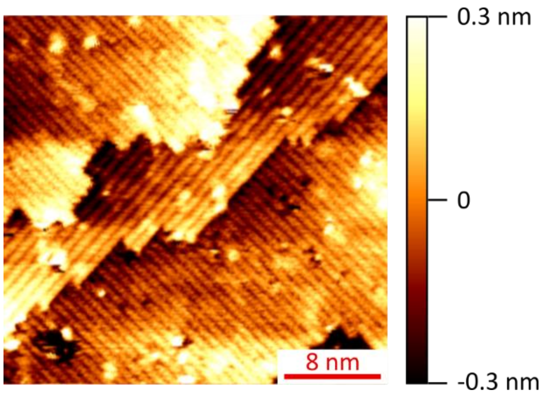

Figure 3: STM image obtained of H-passivated Si(100)-2×1 surface using the hybrid STM system.