Development and performance evaluation of preamplifier circuit for multi-probe STM

T. Koyama[1], N. Kaneda[1], O. Takeuchi[1], and H. Shigekawa[1]

[1]Institute of Applied Physics, Univ. of Tsukuba,
Tsukuba, Ibaraki 305-8573, Japan.

http://dora.bk.tsukuba.ac.jp/

In multi-probe STM, the bias voltages applied on the probes are varied in order to flow some current from a probe to another, or to measure the sample surface potential using the probes. Especially when we make such measurements without contacting the sample but over a tunnel gap, the stray capacitance of the shielded cables that connect the probes to the preamplifiers, in addition to the large tunnel resistance, affects the measurements in an adverse way. When the tip bias voltage is swept in a current measurement, large displacement current (nA scale) flows into the stray capacitance, which is detected on the preamplifier, resulting in unignorable error. In a sample potential measurement, the stray capacitance (~100 pF) and tunnel resistance (~1 GΩ) form a low pass filter, with which the measurement bandwidth becomes very narrow, ~1 Hz (Fig.1 broken line).

We developed a preamplifier that compensates the stray capacitance for multi-probe STM. It is capable of precisely measuring the sample potential and the tip current over a tunnel gap. With the compensation, the bandwidth of the potential measurement was expanded to ~300 Hz with a tunnel resistance ~1 GΩ (Fig. 1 solid line). When it overcompensates, however, the noise level increased and finally the circuit oscillated. (Fig. 1 dashed line)

In order to make an accurate current measurement, the compensation must be extremely precise (~100 ppm). Thus, we implemented another compensation circuit for fine-tuning. With using different approach, the fine compensation does not affect noise and stability performance. With it, the displacement current was reduced from ~1 nA down to ~0.1 pA in an I-V measurement when the tip-bias voltage was swept from -50 mV to 50 mV in 4 seconds as shown in Fig. 2.

Consequently, we successfully expanded the bandwidth of a potential measurement and improved the accuracy of a tunnel current measurement over a tunnel gap by compensating the stray capacitance. Since the fine adjustment of the compensation is the key technique in such measurements, we will discuss adequate adjustment procedure of compensation circuit and also its impact to the noise and stability performance.

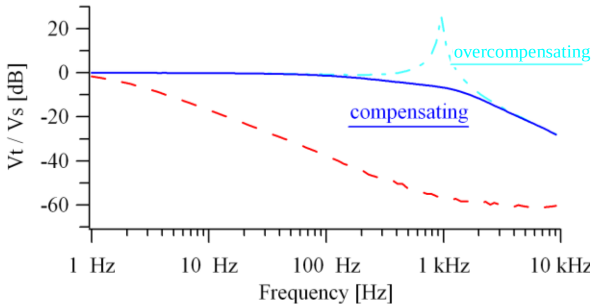

Fig. 1 . Bandwidth in potential measurement

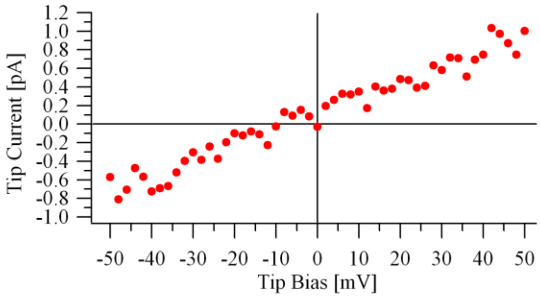

Fig. 2 . I-V characteristic of Au(111)