Four-Probe Scanning Tunneling Microscope

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We have been developing a four-probe scanning tunneling microscope (4probe-STM), in order to support the yet-being-accelerated development of the circuit minimization. Nowadays, the size of semiconductor devices became as small as 10 nanometers. The development of a 4probe-STM system that has an atomic-scale spatial resolution and the ability of multi-probe tunneling spectroscopy will clarify the nanoscale-specific problems in such devices. In our system, the four-probe STM stage with in-vacuum vibration isolation system is installed in an ultra-high-vacuum chamber with a liquid helium cryostat. The cryostat has an inverse arrangement, where the STM stage is above the cryostat. The heat conduction from the stage to the cooling medium that stays at the bottom of the cryostat is done by a thick copper rod at the center of the helium tank. An ultra-high-vacuum scanning electron microscope (SEM) is placed above the STM stage, with which the relative arrangement of the 4 probes to the sample can be observed with a spatial resolution of ~10 nm. Each of the four probes has three coarse motion axes with stick-slip-type inertial drive, whose movable range is 5~10 mm. These axes also give fine motion ability when used without a slip motion. In addition to these three axes, each probe has another small actuator on the sample holder, which gives fast fine motion of STM tip for ~2 um range that is used for the feedback control of tip-sample distance. Thanks to this fast actuator with small mass being drove, the system has a relatively high resonant frequency for tip-sample distance control at ~1.1 kHz. Newly developed STM electronics can control the four STM probes simultaneously, independently and cooperatively from one personal computer. The electronics is based on a digital feedback control. It also has a built-in sinusoidal modulation generator and lock-in detection module that is implemented by software for a digital signal processor. At the colloquium, the ability of our 4probe-STM to observe atomic structure of samples, to make scanning tunneling spectroscopy measurement and to make cooperative control of multiple probes are demonstrated. Recent improvements for tip-control algorithms and current problems of the system are discussed, as well