Scanning Tunneling Microscopy as a Magnetic Probe

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In the last 20 years, there have been a great advance in the measurement techniques of magnetic states using scanning tunneling microscopy (STM). A conventional spin-polarized STM (spin-STM) employs magnetic tips, thus it measures magnetoresistance through a tip-vacuum-sample tunnel junction. An extension of the technique is a telegraph noise measurement, which tells the time trace of magnetic stability in a scale down to a single atom. Techniques not using magnetic tips have also been introduced. Inelastic electron tunneling spectroscopy (IETS) has been utilized to measure a transition between the magnetic states of a nanostructure down to a single atom. The most sophisticated techniques recently developed is the STM combined with electron spin resonance (ESR-STM), by which control of spin states of a single atom is feasible.
In the first part of this talk, I show an interesting result of spin-STM, obtained from bilayer-high Co nanoislands on Cu(111) with Fe-coated W tips. Superparamagnetic response of tip magnetization quantitatively measures the sample-induced field at the tip position. Spin-STM with a varying tip-sample distance revealed a crossover between long- and short-range magnetic couplings.
In the second part, I introduce how an STM is utilized to perform quantum nanoscience researches in the Center for Quantum Nanoscience (QNS). An ESR-STM enables a direct access to the quantum states and magnetic transitions of well-defined magnetic atoms and molecules on surfaces in an atomic scale resolution. This is a remarkable advance in the STM, to be a promising way towards quantum control of individual atoms and molecules.