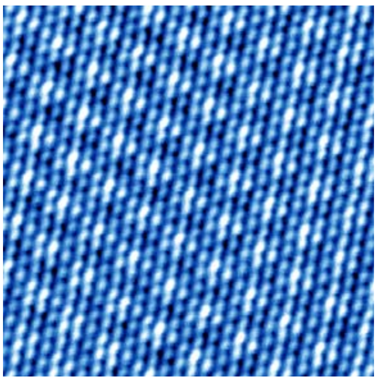
STM/STSの応用と分子観察

Application of STM/STS for molecular observation

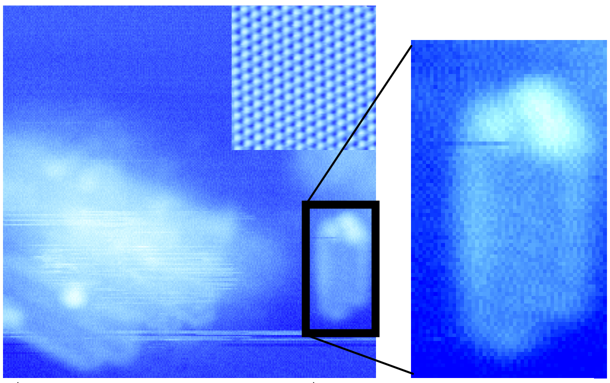
理研　小野 雅紀

Scanning tunneling microscopy (STM) and spectroscopy (STS) has been established as a general technique to probe surface topography, electronic states and so on. Since electrons pass gap between specimen and probe, tunneling current includes much information just below the probe near the specimen surface. When the tip is atomically sharp, we obtain atomically resolved images and spatial maps of t current in real space. To measure differential conductance known as approximately proportional to local density of states (LDOS), we are able to obtain a spatial distribution of both occupied and unoccupied states. For instance, spatially modulated structures can be observed with data analysis methods such as electrostatic potential [1], quasiparticle interference [2] and so on. Those are some of important methods of investigating sub-nanoscopic electronic states. Manassen *et al*. detected a modulation of spin precession in the tunneling current at the Lamor frequency induced by a constant magnetic field [3]. To use a technique of inelastic tunneling spectroscopy, Heinrich *et al*. observed spin information as energy variation induced by Zeeman effect [4]. The purpose of this study is to seek possibility of application of spin-detection for molecular-scale electronics and highly correlated electron system, and furthermore techniques and methods of STM use for those researches.

To detect individual spin-precession frequency of paramagnetic atoms or radical molecules on surface, home-made STM system, namely electron spin resonance(ESR) STM, was constructed by attaching radio-frequency amplifier(rf-amp). Therefore rf measurement and STM observation can be done simultaneously in multiple environment, low temperature(~4.2K) in ultra-high vacuum(<5nPa) with magnetic filed(<0.1T).



(left figure)
STM image on $NbSe_2$ surface.
T = 4.5 K, 8×8 nm^2 V_s = 20 mV / I_t = 20 pA



(center and right figure)
STM image on TEMPO/HOPG surface.
T = 4.5 K, 4×4 nm^2 V_s = 2.5 V / I_t = 4 pA

An obtained STM image as shown in left figure, it clearly shows atomic arrangement as bright protrusions and brighter modulation caused by charge density wave on NbSe2 surface. TEMPO (2,2,6,6-Tetramethyl-1-piperidinyloxy) molecules on HOPG (highly oriented pyrolytic graphite) were also observed as shown in center and right(zoomed image) figure, but it is no atomic resolution so far. Now we try to investigate individual spin at atoms and molecules using ESR-STM.

In this talk, I will discuss the application of STM/STS study for investigating property of individual molecules.

This work is a collaboration with N. Tsuboi, T. Hanaguri and H. Takagi.

[1] M. Ono *et al*, Phys. Rev. Lett. **96**, 16801 (2006).
[2] T. Hanaguri *et al*., Nature Phys. **3**, 865 (2007).
[3] Y. Manassen *et al*., Phys. Rev. Lett. **62**, 2531 (1989).
[4] A. J. Heinrich *et al*., Science **316**, 466 (2004).