Gap-dependent scanning tunneling microscopy: from point contact and Josephson junction to orbital selective imaging

By
Prof Yukio Hasegawa
Institute for Solid State physics, The Univ. of Tokyo, Kashiwa, Japan

Date: 26 June 2019, Wednesday
Time: 10.20am – 11.05am
Venue: SPMS-LT5 (SPMS-03-08)
Host: Prof Xiong Qihua / Asst Prof Bent Weber

Abstract

In scanning tunneling microscopy one probes decaying wave functions of electronic states from a sample surface using a sharp needle tip located at very proximate distance from the surface. We usually do not care how the tip is close to the surface as far as the tunneling current flowing between them. There are, however, several cases where the tip-sample gap distance matters, and by carefully analyzing the gap variation one can extract information that cannot be accessible by other methods. Here some of such examples are demonstrated in my presentation.

When the surface has several electronic states whose decaying behavior into the vacuum is different, the relative intensity of each state should depend on the gap distance. On a cobalt-terminated plane of a cleaved CeCoIn5 surface, a square lattice of round-shaped Co atoms is observed in usual tunneling conditions, but at closer distances the atomic shape is transformed into a dumbbell whose orientation alternates x and y directions. The shape transformation of the Co atom is due to the switching of the probed states from s-derived states to d orbitals with the reduction in the gap distance. The alternating arrangement is explained by the ordering of Co d-orbitals induced by enhanced electron correlation at the surface. This is the first real-space observation of the orbital orderings, and was achieved by the selective probing of d-orbitals by setting the gap distance closer than usual STM operations.

At closer distances, the current cannot be described by the simple electron tunneling, and chemical interaction between the tip-apex atom and surface atoms has to be considered. Because of the contribution from the conduction channels formed by the interaction, the contrast of atomically-resolved images taken on Pb(111) surface is enhanced or reversed depending the gap distance. The analysis of the conduction channels of well-controlled Pb atomic point contacts was performed based on the multiple Andreev reflection and Josephson current.

Short Biography

Since his Ph. D. research activities in Department of Applied Physics, The University of Tokyo, under the supervision of Professor Toshio Sakurai, which also include 7-month visiting stay in a group of Prof. Young Kuk at AT&T Bell Lab, USA, Dr. Hasegawa has been working on nanoscale science using scanning probe microscopy. After working as a postdoctoral fellow in a group of Dr. Pheodon Avouris, IBM T.J. Watson Research Center, USA, he worked at Mesoscopic Research Center, Kyoto University, and the Institute for Materials Research, Tohoku University, Japan. In 1999 he moved to the Institute for Solid State Physics, The University of Tokyo, to start up his own research group. Dr. Hasegawa's research subjects include ballistic electron emission microscopy on metal/semiconductor interfaces, observation of electron standing waves and Friedel oscillations, atomic-scale electrostatic potential measurements by Kelvin probe force microscopy, and nano-scale chemical analysis by synchrotron-radiation assisted STM. His recent research activities focus on nanoscale phenomena on two-dimensional superconductivity, spin texture of magnetic thin films and its dynamics, and nanoscale quantum electron transport by potentiometry.

1991: Ph.D. in Applied Physics, The University of Tokyo, Japan
1991: Post-doctoral researcher, IBM T.J. Watson Research Center, USA
1992: Research associate, Mesoscopic Materials Research Center, Kyoto Univ., Japan
1994: Associate professor, Institute for Materials Research, Tohoku University, Japan,
1999: Associate professor, ISSP, The University of Tokyo, Japan
2018: Professor, ISSP, The University of Tokyo, Japan