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Nano-scale superconducting contacts studied by scanning tunneling microscopy

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In the trend of miniaturization of devices, electrical conductance through atomic-scale contacts is of significant importance for practical application of atom switch and single molecular devices. Because of unknown atomic geometry of the junction, however, the measured conductance often exhibits fluctuation. Here in this study we have studied the conductance properties of atomic superconducting point contact with precise control of contact geometry to investigate atomistic details of conductance channel formation through it.

Using a low-temperature scanning tunneling microscopy (STM), we measured the conductance between the tip and sample surface from the tunneling to contact regimes [1]. By precisely positioning the tip on atomically specific sites of a sample surface such as on-top and hollow sites, site-specific conductance evolutions were obtained. We found using a Pb tip and Pb thin film as a sample the conductance at point contact is larger at hollow site than at on-top site. Furthermore, it is found that the relation of the conductance measured is reversed just before the contact formation; at 20 pm away from the contact the conductance of the hollow site is smaller than the on-top site. These peculiar conductance behaviors can be explained by the attractive chemical force and subsequent conductance channel formation between the tip apex atom and surface atoms.

Since the measurements were performed at low temperature (1.6 K) below the superconducting critical temperature of both tip and sample materials, we obtained the evolution of the Josephson current and subharmonic in-gap structures due to multiple Andreev reflection (MAR) in the conductance spectra. From the analysis of the MAR structures, the complete set of transmission probability {τi} of conduction channels, which is often called personal identification number (PIN) of the junction as it determines all the coherent transport properties, was successfully extracted [2]. We found again site dependent evolution of transmission probabilities and the number of active conduction channels at the contact formation. We will discuss on the mechanism of channel formations based on comparison with the results of theoretical analysis.

References
[1] H. Kim and Y. Hasegawa, Phys Rev Lett 114, 206801 (2015)[2] H. Kim and Y. Hasegawa, arXiv:1506.05528 (2015).

Figure caption: electrical conductance measured from tunneling (Δz = -20 pm) to contact (Δz = -60 pm) regimes. The measured conductance G is normalized by the quantum conductance G0 given by 2e2/h (~77.5 μS). For each conductance trace, 10 traces taken at the corresponding sites marked in the atomically-resolved STM image (inset) are averaged.