Probing nanosale superconductivity in organic molecular chains

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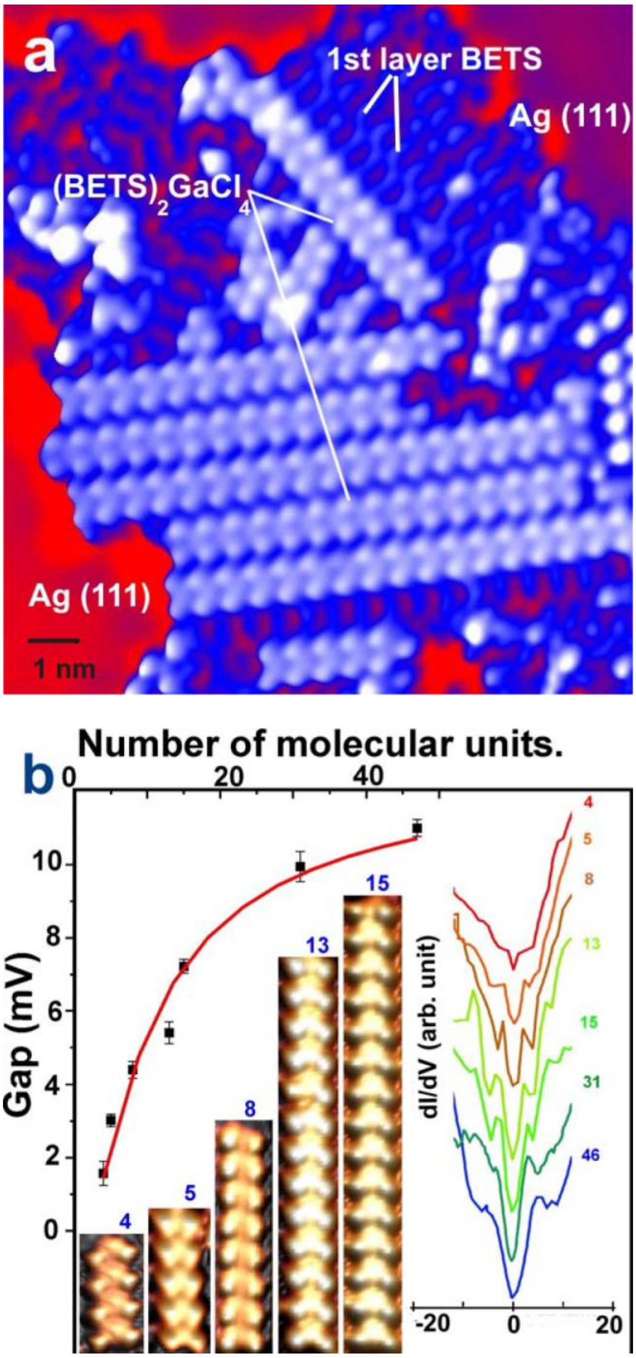
The BSC theory has provided a general framework for understanding the microscopic origin of superconductivity in simple metals. With the emergence of new materials, especially high Tc and organic superconductors, clear deviations from the standard theory are reported. Several theories have been proposed to provide microscopic paring mechanisms and thereby elucidating the macroscopic properties for these unconventional superconductors.

In order to unravel details on the mechanism and test theories one needs to investigate the local nanoscale properties on clean systems. For this purpose we have synthesized high quality single crystals of (BETS)2GaCl4, where BETS is (ethylenedithio)tetraselenafulvalene, as source materials for engineering sub-monolayers and chain like structure on Ag(111) surface. In bulk (BETS)2GaCl4 has a superconducting transition temperature Tc of ~8 K and a two-dimensional layered structure that is reminiscent of the high-Tc cuprate superconductor.

We present low temperature scanning tunneling microscopy and spectroscopy to study directly the nanoscale electronic properties of (BETS)2GaCl4. We show that superconductivity still robust down to a single layer islands and chain like structures. A single chain of (BETS)2GaCl4 molecules displays a superconducting gap that increases exponentially with the length of the chain. Moreover, we show that a superconducting gap can still be detected for just four of (BETS)2GaCl4 molecules. Real-space spectroscopic images directly visualize the chains of BETS molecules as the origin of the superconductivity. These findings not only pave the way to study nanoscale superconductivity on other nanosystems, especially high Tc cuprates, but also to investigate paring mechanism versus structural parameters and molecular manipulations.

References

[1] K. Clark, A. Hassanien, S. Khan, K.-F. Braun, H. Tanaka and S.-W. Hla, "Superconductivity in just four pairs of (BETS)2GaCl4 molecules", Nature Nanotechnology 5, (2010).261.



Size dependent molecular superconductivity. a, An STM image revealing shorter molecular chains at the centre. Light blue are doubled stacked BETS while darker features are the first layer BETS, The superconducting gap as a function of molecular units. The inset shows the molecular chains with 4, 5, 8, 13, and 15 units. The right inset illustrates corresponding dI/dV curves that reveal superconducting gaps of these chains.