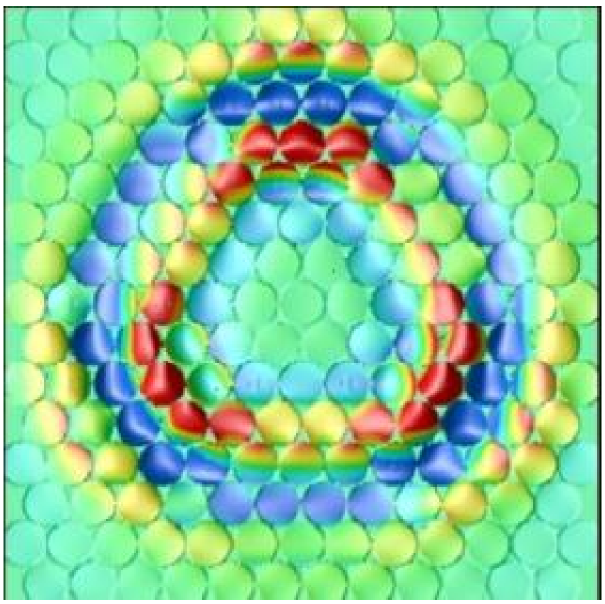
Nano-sonar uses electrons to measure under the surface

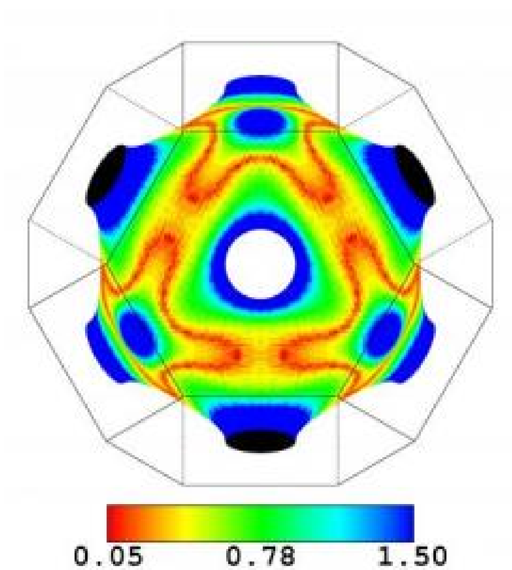
February 27 2009



In a computer simulation, Jülich scientists succeeded in showing what shape these rings take on the crystal lattice of copper. Credit: Forschungszentrum Jülich

Just as sonar sends out sound waves to explore the hidden depths of the ocean, electrons can be used by scanning tunnelling microscopes to investigate the well-hidden properties of the atomic lattice of metals. As researchers from Göttingen, Halle and Jülich now report in the high-impact journal *Science*, they succeeded in making bulk Fermi surfaces visible in this manner. Fermi surfaces determine the most important properties of metals.

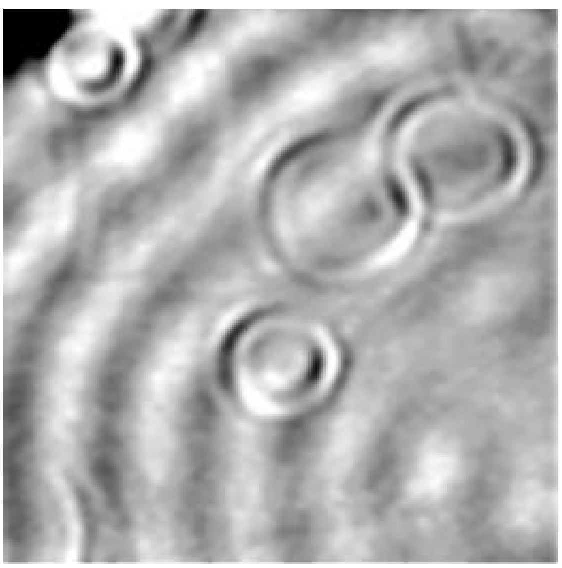
"Fermi surfaces give metals their personality, so to speak," explained Prof. Stefan Blügel, Director at the Jülich Institute of Solid State Research. Important properties, such as conductivity, heat capacity and magnetism, are determined by them. On the Fermi surfaces inside the atomic union, high-energy electrons are in motion. Depending on what form the surfaces have and what mobility is assigned to the electrons, they determine the physical properties of metals.



This is the Fermi surface of copper metal. The colors represent the curvature of the surface, which determines the propagation properties for electron waves. Credit: Martin Luther University Halle

In their latest publication, the researchers report on how they used a scanning tunnelling microscope to direct electrons into a copper sample. As electrons spread out like waves, they pass through the metal and are scattered and reflected at obstacles in the bulk, such as single cobalt atoms. "The overlap between incoming and outgoing waves is so strong," said Dr. Samir Lounis from Forschungszentrum Jülich who turned the theoretical calculations into an experiment, "that they can be measured as spherical patterns on the surface using the scanning tunnelling microscope.

The somewhat deformed rings on the surface allow us to draw direct conclusions on the shape of the Fermi surfaces and the depth of the cobalt atoms, similar to how sonar recognises the ocean floor by means of reflected sound waves. "We hope that more sophisticated methods will make it possible to gain a detailed understanding of deep impurities and interfaces between atomic lattices," explained Lounis. For his simulations of the scanning tunnelling experiment, he used the supercomputer known as JUMP in the Jülich Supercomputing Centre.



A scanning tunneling microscope recognizes spherical patterns on a copper surface (image section approx. nine times nine nanometers). These irregularities in electron distribution are caused by cobalt atoms deep inside the copper. Credit: Forschungszentrum Jülich

In a related article in the "Perspectives" section of "*Science*", the innovative approach is praised. A scanning tunnelling microscope is primarily used to characterise the surface of a sample. Thanks to the theoretical work in Jülich, it can now be used to gain a direct insight into the bulk of solids and to understand interesting effects in the nanoworld.

More information: *Science*, 27 February 2009, Vol 323, Issue 5918, Seeing the Fermi Surface in Real Space by Nanoscale Electron Focusing, Weismann et al.

Source: Helmholtz Association of German Research Centres