

Researchers prove existence of new type of electron wave

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New research led by University of New Hampshire physicists has proved the existence of a new type of electron wave on metal surfaces: the acoustic surface plasmon, which will have implications for developments in nano-optics, high-temperature superconductors, and the fundamental understanding of chemical reactions on surfaces.

The research, led by Bogdan Diaconescu and Karsten Pohl of UNH, is published in the July 5 issue of the journal *Nature*.

“The existence of this wave means that the electrons on the surfaces of copper, iron, beryllium and other metals behave like water on a lake’s surface,” says Diaconescu, a postdoctoral research associate in the Condensed Matter Group of the physics department at UNH. “When a stone is thrown into a lake, waves spread radially in all directions. A similar wave can be created by the electrons on a metal surface when they are disturbed, for instance, by light.”

Acoustic surface plasmons have long been predicted on merely theoretical grounds, their existence has been extraordinarily difficult to prove experimentally. “Just one year ago, another group of scientists concluded that these waves do not exist,” says Karsten Pohl, associate professor of physics at UNH. “These researchers have probably not been able to find the acoustic plasmon because the experiments require extreme precision and great patience. One attempt after the other did not show anything if, for example, the surface was not prepared well enough or the detectors were not adjusted precisely enough.”

The new experiment that found the acoustic surface plasmon used an extremely precise electron gun, which shoots slow electrons on a specially prepared surface of a beryllium crystal. When the electrons are reflected back from the electron lake on the surface of the metal, some of them lose an amount of energy that corresponds to the excitation of an acoustic plasmon wave. This energy loss could be measured with a detector that was placed in an ultra-high vacuum chamber, together with the beryllium sample. The energy loss is small but corresponds exactly to the theoretical prediction.

Research on metal surfaces is important for the development of new industrial catalysts and for the cleaning the exhaust of factories and cars. As the new plasmons are very likely to play a role in chemical reactions on metal surfaces, theoretical and experimental research will have to take them into account as a new phenomenon in the future. In addition, there are several promising perspectives in nano-microscopy and optical signal processing when the new plasmons are excited directly with light diffracted off very small nano-features.

The researchers estimate that, depending on their energy, the waves spread down to a few nanometers, and die out after a few femtoseconds (one millionth of a billionth of a second) after they have been created, thus witnessing very fast chemical processes on atomic scale.

Another potential application is using the waves to carry optical signals along nanometer-wide channels for up to few micrometers and as such allowing the integration of optical signal propagation and processing devices on nanometer-length scales. And one of the most interesting but still very speculative applications of the plasmons relates to high temperature superconductivity. It is known today that the superconductivity happens in two-dimensional sheets in the material, which give rise to the special electron pairs which can move without resistance through the conductor.

How this happens precisely is unclear but acoustic plasmons could be part of the explanation. If this is the case, it is a great advantage that it is now possible to study the plasmons on surfaces, where they are much easier to probe than inside the material.

Citation: Bogdan Diaconescu, Karsten Pohl, Luca Vattuone, Letizia Savio, Philip Hofmann, Vyacheslav M. Silkin, Jose M. Pitarke, Eugene V. Chulkov, Pedro M. Echenique, Daniel Farías y Mario Rocca. Low-energy acoustic plasmons at metal surfaces. *Nature*, doi:10.1038/nature05975.

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