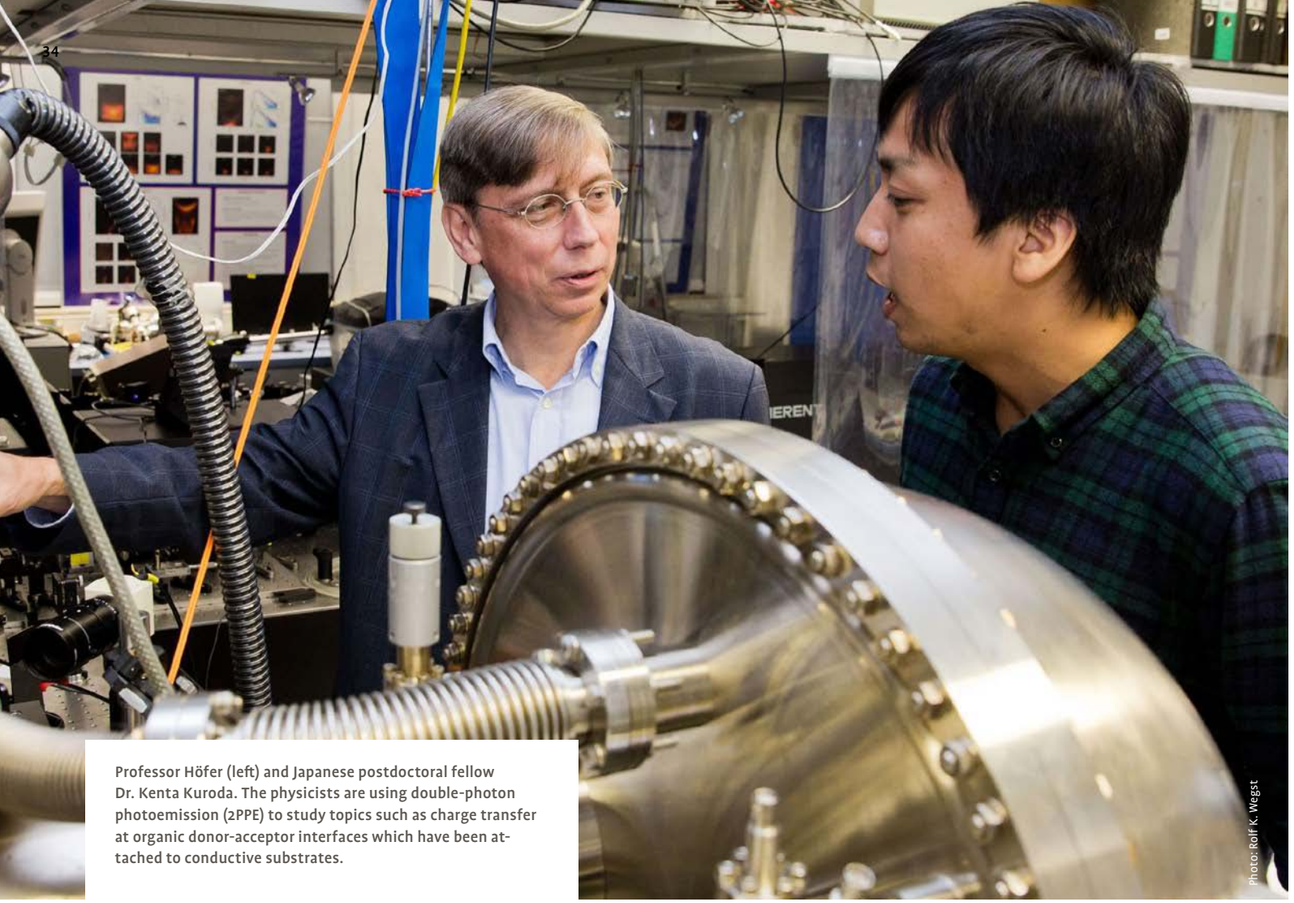


Professor Höfer (left) and Japanese postdoctoral fellow Dr. Kenta Kuroda. The physicists are using double-photon photoemission (2PPE) to study topics such as charge transfer at organic donor-acceptor interfaces which have been attached to conductive substrates.

Photo: Rolf K. Wegst

CONTROLLING STRUCTURES AND DYNAMICS BETWEEN MATERIALS

Interface control

Today, many electronic devices rely on the transport of charges across the interface between different materials. But how exactly does this work and how can it be controlled? Marburg physicists and chemists are addressing this issue within the framework of a collaborative research center. In the long term, their insights may translate into the fabrication of new materials with novel functions.

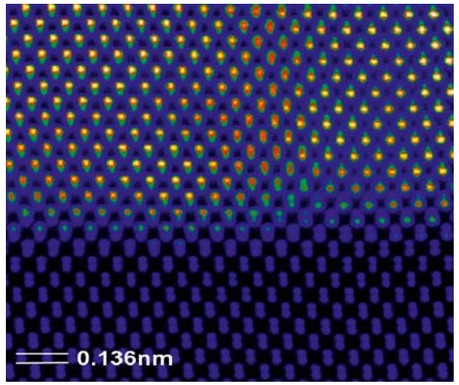
Evermore functions on increasingly smaller surfaces: Today's semiconductor devices, as those integrated in computer chips, are miniaturized to an extent that their optical and electronic properties are determined largely by their internal interfaces or, as physics Nobel laureate Herbert Kroemer puts it, »the interface is the device.«

Basic research, which initiated this development to miniaturization decades ago, has been unable to keep up with the rapid technological progress. This in turn limits new advances, such as hybrid materials that combine the properties of metals or other inorganic materials with those of organic or biomaterials. Biosensors and new types of solar cells are examples of their potential application.

»It is extremely difficult to track down the faint traces of interfaces experimentally, as they are often hidden under several layers of other materials,« says Prof. Dr. Ulrich Höfer, professor of surface physics at Philipps-Universität. He is the spokesman for the Collaborative Research Center on the »Structure and Dynamics of Internal Interfaces«, which was established by the German Research Foundation (DFG) in 2013 to close this knowledge gap. The study of internal interfaces is considered one of the most pressing research issues in solid-state physics. »Such a complex issue necessitates a long-term commitment in order to achieve lasting results,« says Höfer. More than 60 scientists in the fields of semiconductor physics, surface physics and surface chemistry, chemical synthesis, structural analysis and laser spectroscopy are involved in the center, which is set up to operate over a 12-year period. Altogether, members of 15 research groups in the Marburg chemistry and physics departments are joined by a guest project based at the renowned Donostia International Physics Center in San Sebastián, Spain.

Höfer believes that the Center for the study of internal interfaces comes at just the right time. »Considerable progress has been made in recent years in electron microscopy and laser spectroscopy. Presently, it is for the first time that we can characterize certain structures on the atomic scale, as we now finally have the necessary microscopy at our disposal. Additionally, optical methods allow us to monitor electronic processes at interfaces deep within solid objects.« Initially, the research is not focusing on operational functional materials, as these usually contain many poorly defined interfaces. »Instead, the focus is on gaining a fundamental understanding of physical processes at the interface,« says Höfer, explaining the Center's current emphasis. To that end, the scientists are developing model systems with individual, specially prepared internal interfaces. These are then structurally characterized at the atomic level so that their optical and electronic properties can be studied systematically. Knowing how chemical bonding, electronic coupling and energy transfer between materials function it will one day become possible to customize interfaces and manufacture materials or components with novel properties and functions.

Interfaces between two inorganic semiconductors can be highly controlled and described very effectively, and form the basis of the worldwide semiconductor industry. However, model development for interfaces between different organic materials and between organic and inorganic semiconductors is still in its infancy. This notwithstanding, the team headed by Marburg professor of molecular solid-state physics Prof. Dr. Gregor Witte has reached a first milestone towards a deeper understanding of organic-to-organic interfaces. In an experiment, small amounts of fullerene C60, a spherical molecule made up entirely of carbon atoms, was layered on top of an organic semiconductor made of pentacene, an elongated molecule. As the structures of these two materials are as different as a regular orange pile and a brick wall, it was necessary to match them up at their interface. This was achieved by fine tuning the pentacene's temperature during the growth of the C60overlayer. Depending on the temperature, the researchers were able to create two-dimensional surfaces, one-dimensional chain compounds or even zero-dimensional assemblages of molecules (clusters).



The interface between gallium phosphide and silicon as seen in a transmission electron microscope. Source: Prof. Dr. Kerstin Volz

Pentacene is an electron donor while C60 acts as an electron acceptor. Such interfaces between donor and acceptor materials are critical to the functioning of organic solar cells. It is at the interface, where the bonded electron-hole pairs generated by sunlight, also known as excitons, are separated and converted into electric current. This allows the study of the fundamental physical process in an organic solar cell at the pentacene/C60 interface. »Pentacene/C60 is a promising model system for using spectroscopic methods to systematically study and theoretically describe the influence of the interface's atomic structure on the dynamics of charge transfer,« explains Höfer. »This is a central topic at our collaborative research center and a great challenge.«

For more information:

»Structure and Dynamics of Internal Interfaces« Collaborative Research Center: *www.uni-marburg.de/sfb1083*