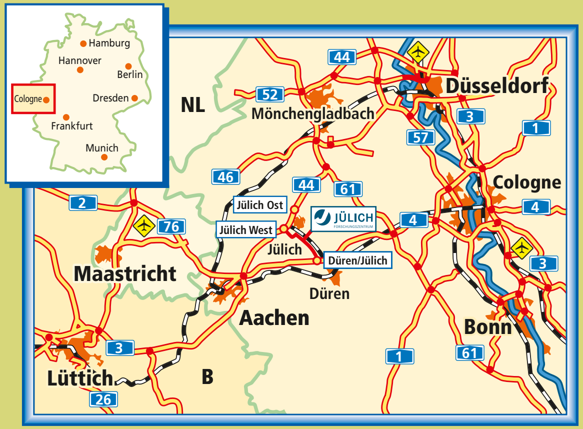
The IFF Spring School in Jülich, the Peter Grünberg Institute, and JARA-FIT

The annual IFF Spring Schools were first brought into being in 1970 by the Institut für Festkörperforschung (IFF). Since then, these schools have made it possible for students and young scientists to gain a two-week insight into a current topic related to condensed matter physics.

As a result of a restructuring of our research organization in 2011, four new institutes emerged from the former IFF and the former IBN (Institute for Bio- and Nanosystems): Research in electronic systems and phenomena, as well as their applications in nano-electronics and information technology, is located in the Peter Grünberg Institut (PGI), named after our colleague who received the Nobel Prize for physics in 2007. The Jülich Centre for Neutron Science (JCNS) is dedicated to the operation of neutron scattering instruments and national and international neutron sources. Soft matter and biophysics research is integrated into the Institute of Complex Systems (ICS). The Institute for Advanced Simulation (IAS) focuses on developing and applying high-performance computing for quantum phenomena, solid-state research, and complex systems. The Spring School is organized in succession by these four institutes.

The PGI consists of eleven departments: Quantum Theory of Materials, Theoretical Nanoelectronics, Functional Nanostructures at Surfaces, Scattering Methods, Microstructure Research, Electronic Properties, Electronic Materials, Bioelectronics, Semiconductor Nanoelectronics, and the JARA Institutes for Green Information Technology and for Quantum Information. We operate the Helmholtz Nanoelectronics Facility (HNF) and, together with the Central Facility for Electron Microscopy at the RWTH Aachen University, the Ernst Ruska-Centre (ER-C) for Microscopy and Spectroscopy with Electrons. In addition, our departments participate in the operation of synchrotron and and neutron beam lines as well as the Jülich supercomputers. We are part of the Jülich Aachen Research Alliance within the section Fundamentals of Future Information Technology (JARA-FIT) in which we collaborate with the physicists, chemists, electrical engineers, material scientists, and biologists of the RWTH Aachen University. In a concerted way, we conduct exploratory research in nanoelectronics and quantum phenomena with an emphasis on potential long-term applications in information technology and beyond.

How to find us:



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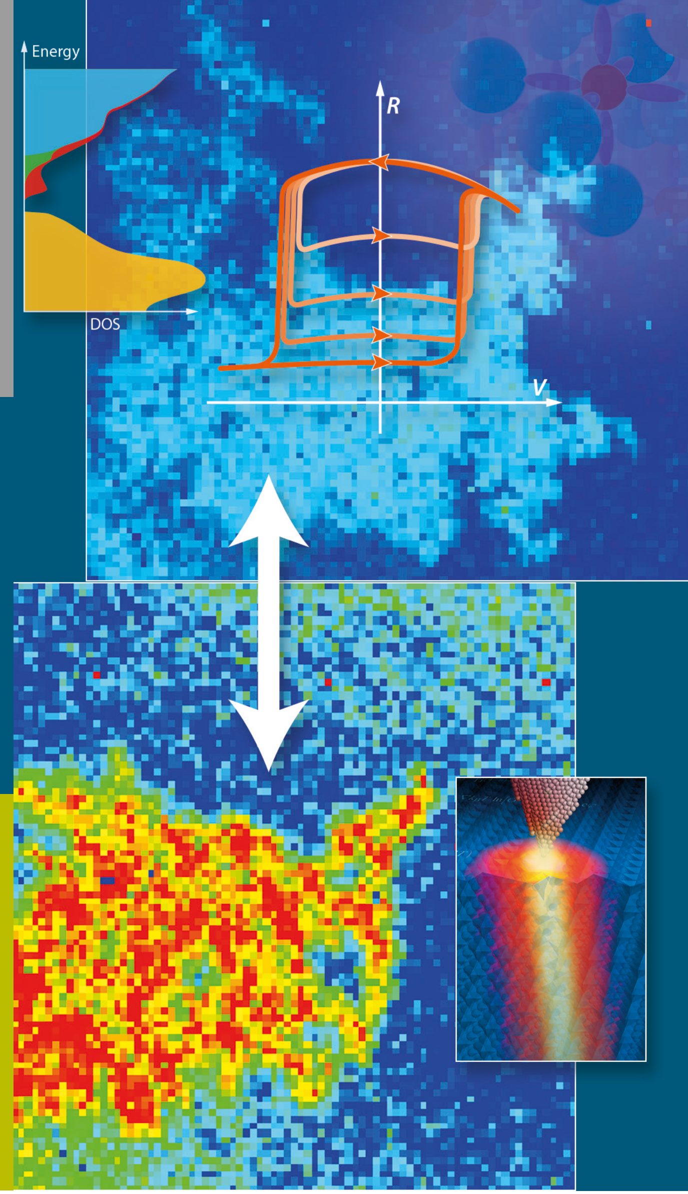

Memristive Phenomena – From Fundamental Physics to Neuromorphic Computing

47th IFF Spring School 2016
22 February – 4 March 2016
in Jülich, Germany

JÜLICH
FORSCHUNGSZENTRUM

Overview

Memristive phenomena combine the functionalities of electronic resistance and data memory in solid-state elements, which are able to change their resistance as a result of electrical stimulation in a non-volatile fashion. In nanoelectronics, this functionality can be used for information storage and unconventional logic, as well as neuromorphic computing concepts that are aimed at mimicking the operation of the human brain.

A multitude of fascinating memristive phenomena has emerged over the past two decades. These phenomena typically occur in oxides and higher chalcogenides and are one of the hottest topics in current solid-state research, comprising unusual phase transitions, spintronic and multiferroic tunneling effects, as well as nanoscale redox processes by local ion motion. They involve electron correlation, quantum point contact effects and exotic conformation changes at the atomic level.

Programme

The Spring School provides a comprehensive introduction to and an overview of current research topics covering the physics of memristive phenomena, with an emphasis on understanding the underlying basic principles.

The school comprises approximately 50 hours of lectures, including discussions, as well as offering the opportunity to visit the participating Institutes in Forschungszentrum Jülich. All lectures will be given in English. Registered participants will receive a book of lecture notes that contains all of the material presented during the school. The lectures are grouped together in five sections, which are outlined below.

Fundamentals

Material properties provide the basis for understanding the physics of the processes that occur during memristive phenomena. These lectures focus on atomic and electronic structure, with an emphasis on metal oxides and higher chalcogenides that are used in memristive cells, lattice disorder in these materials, phase transition processes and ionic transport mechanisms. This section concludes with the physics of redox processes, electron transfer at interfaces, electronic transport properties including correlation effects, Mott insulator-metal transitions, and electron tunneling.

Technology

In order to achieve functional and energy-efficient electronic circuits, memristive cells must be integrated with CMOS digital circuits using process technology and designed to match specific applications, such as information storage in memory or information processing in logic circuits. Cell design and state-of-the-art integration technology are introduced in this section of the Spring School. The lectures focus on chemical and physical vapor deposition techniques (molecular beam epitaxy, pulsed laser deposition and sputtering), in combination with optical, electron-beam or nano-imprint lithography, ion etching and atomic precision polishing. As an alternative to these top-down techniques, promising bottom-up approaches that involve molecular self-assembly processes are described briefly.

Analysis and characterization

Functional characterization of memristive cells can be performed by using electric sweep and pulse tests over a wide dynamical range, from sub-nanoseconds to kiloseconds. In order to understand the microscopic mechanism of memristive phenomena, a plethora of advanced microscopic, scattering, and spectroscopic techniques are required. Due to the fact that memristive cells are typically nanoscale objects and atomic and electronic configuration changes that lead to resistance changes are tiny, the elucidation of the operating principles of memristive cells is highly challenging and sometimes beyond the techniques that are currently available. These lectures cover X-ray diffraction methods, aberration-corrected high-resolution transmission electron microscopy and spectroscopy, off-axis electron holography and tomography, photoemission electron spectroscopy and microscopy, and cutting-edge scanning probe techniques.

Memristive phenomena for non-volatile electronic functions

The fascinating internal physical mechanisms of memristive phenomena in oxides and higher chalcogenides can be grouped into nanoscale phase transitions, nanoionic redox processes and the modulation of the tunnel transmission through barriers because of changes in the barrier or the terminals. Magnetic terminals lead to the chance to exploit magnetoresistive and spintronic effects, such as spin-transfer torque. These lectures will cover nanoionic redox processes, i.e., processes in which local ion motion in metal oxides is highly non-linear as a result of thermal and/or field enhancement, leading to a valence change of the metal ions and a corresponding modulation of the electron transport. Phase change memories rely on volatile electronic threshold switching followed by a thermally-induced phase transition between an amorphous and a crystalline state, in which disorder controls electron transport. In the case of functional tunneling oxides, electron transmission can be modulated by electrostatic, ferroelectric, multiferroic or nanoionic effects in the tunneling barrier.

Applications and Future Directions

The last section of the Spring School comprises lectures that cover present and future application areas, such as memories for information storage, unconventional logic and neuromorphic computing concepts that are aimed at emulating the function of the human brain. Aspects of memristive circuits such as the required selector devices in array architectures, as well as reliability issues and ultimate physical limits of further miniaturization, will be explained.

General Information

Venue

The IFF Spring School will take place in the Auditorium of the Forschungszentrum Jülich from 22nd February – 4th March 2016.

Participation

Participants are expected to have a basic knowledge of solid-state physics, chemistry, and material science.

Registration

If you wish to attend **without** booking accommodation, the registration fee is 50 Euro. The accommodation fee is 360 Euro (registration fee included – see following section). All participants are asked to register at **www.iff-springschool.de** before 18th December 2015.

Travel Information

A shuttle service will take participants to Forschungszentrum Jülich in the morning and back to their accommodation after the lectures are concluded. The daily transfer is free for all registered participants.

Accommodation, Lunch and Dinner

Low-cost accommodation will be arranged at a youth hostel in Aachen. The accommodation fee of 360 Euro includes the registration fee, 12 overnights stays from 21.02. – 04.03.2016 in a four-bed room, breakfast and dinner. Lunch will be provided at Forschungszentrum Jülich from Monday to Friday at your own cost.

Arrival: Sunday, 21st February 2016
Start of lectures: Monday, 22nd February 2016
Departure: Friday afternoon, 4th March 2016

Students who have not yet finished their Master's degree can apply for financial support from Forschungszentrum Jülich to cover part of the accommodation costs. To qualify for this support, valid proof of student status as well as a letter of reference must be supplied. Accommodation for participants from nearby universities can only be provided if there are still places available after the registration deadline.

Payment and Cancellation Policy

On completing the registration for IFF Spring School you will receive an email confirmation. Participants will receive an invoice with all relevant information regarding the transfer of the fee in due course. Cancellations must be received before or on 24th January 2016, otherwise a cancellation fee of 50 Euro is required.

Hotels in Aachen and Jülich

If you would prefer to stay in a hotel in Aachen or Jülich at your own expense, please contact **springschool@fz-juelich.de** for an accommodation list.