TT 35: Focused Session: Charge and Spin Transport through Junctions at the Nanometre Scale

Time: Thursday 9:30–13:00 Location: H 0104

Invited Talk TT 35.1 Thu 9:30 H 0104
The information is the noise: shot noise a tool for investigating atomic and molecular nanowires — •Jan van Ruitenbeek — Kamerlingh Onnes Laboratory, Leiden University, Netherlands

Shot noise is the intrinsic noise in an electron current arising from the discrete character of the electron charge. It carries information on the quantum mechanical electronic structure of nanoscale conductors. In atomic wires shot noise can be exploited for obtaining information on the number of conductance channels and their transmission probability. We have applied shot noise analysis to single-molecule junctions. The outstanding property that distinguishes a molecule from a quantum dot is its floppy character. This leads to the observation of electron scattering on vibration modes of the molecule, known as Inelastic Electron Tunneling Spectroscopy (IETS). While IETS is now being exploited by many groups for the study and characterization of metal-molecule junctions, the influence of inelastic scattering is expected to affect electron transport more deeply. The conductance can be viewed as the first moment in the probability distribution of a charge q being transmitted through the junction during a given period of time. The second moment is the shot noise in the current. For bias voltages above the vibration mode energy corrections to shot noise have recently been predicted by several groups. As a first test of these predictions measurements will be discussed in terms of two-electron effects.

Invited Talk TT 35.2 Thu 10:10 H 0104
Electronic transport and magnetism in one-atom contacts — •Carlos Untiedt — Dep. Fisica Aplicada. Facultad de Ciencias (Fase II). Universidad de Alicante. Alicante. Spain

The smallest object that we could connect to an electronic circuit will be formed by just a single atom. With the use of the Scanning Tunneling Microscope (STM) we can fabricate and modify such bridges. There has been a great advance in the understanding of the electronic properties of these [1]. However it has been very difficult to extract consequences of the magnetism on their transport properties.

Recently we reported the observation of an effective Kondo screening of the magnetic moment of one-atom contacts between pure ferromagnetic metals by the conduction electrons [2]. Using a STM or Electromigrated Break Junctions we fabricated atomic contacts on these ferromagnetic materials and Fano-Kondo resonances where found in the conductance with the characteristic behavior of a Kondo system.

One of the advantages of our set-up configuration is the capability of the STM to study and analyze hundreds of atomic contacts. This has given us the unique opportunity of performing statistics on the Fano parameters of our conductance curves. A statistical analysis allow us to discuss on the dependence of the Kondo system with the different degrees of couplings to the environment. Finally we will show some of our latest results including Pt chains suggesting a magnetic moment being developed.

[1] Agraït,Yeyati, Ruitenbeek, Phys. Rep. 377 (2003)
[2] Nature 458, 1150(2009)

Topical Talk TT 35.3 Thu 10:50 H 0104
Metallic atomic-size contacts: The role of absorbed noble gas atoms and anisotropic magnetoresistance — •Juan Carlos Cuevas — Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid, Spain

In this talk I will review our efforts to resolve two basic puzzles in the context of metallic atomic-size contacts. First, I will discuss how the presence of noble gas atoms affects the electronic transport through atomic contacts. In particular, I will present ab initio results for the conductance of atomic junctions comprising single noble gas atoms (He, Ne, Ar, Kr, and Xe) coupled to gold electrodes. These results show that for the lightest elements (He and Ne) no significant current flows through the noble gas atoms and their effect is to reduce the conductance of the junctions by screening the interaction between the gold electrodes. This explains the observations reported in atomic contacts with adsorbed He atoms. Conversely, the heaviest atoms (Kr and Xe) increase the conductance because of the additional current path provided by their valence p states.

On the other hand, I will address the origin of the anomalous anisotropic magnetoresistance (AMR) observed in different experiments in ferromagnetic atomic-size contacts, which is still under debate. I will present theoretical results that strongly suggest that the anomalous AMR stems from the reduced symmetry of the atomic contact geometries. This reduced symmetry leads to both a great enhancement of the AMR magnitude and an anomalous angular dependence, as compared to bulk devices.

10 min. break.

Topical Talk TT 35.4 Thu 11:40 H 0104
Spin transport through organic molecules — •Wulf Wulfhekel — Physikalisches Institut, Karlsruhe Institute of Technology, Germany

We demonstrate that with the help of spin-polarized Scanning Tunneling Microscopy the spin transport across single organic molecules can be investigated and a molecular GMR junction can be realized. For this, single hydrogen phthalocyanine molecules were contacted by two ferromagnetic electrodes, i.e. a magnetic substrate and a magnetic STM tip. As substrate, ferromagnetic Co nano-islands grown Cu(111) were used, onto which the molecules were deposited. The magnetic state of the islands was determined by spin-polarized Scanning Tunneling Spectroscopy (STS) with Co tips. Then, the tip of the STM was approached in a controlled way towards a single molecule to contact the molecule. Below 0.4 nm distance, an attractive interaction between the tip and the molecule leads to a jump to contact of one of the side groups of the molecule, leading to a well defined molecular junction. Through the contacted molecule a GMR of 60% was observed which is one order of magnitude larger than the magnetoresistance without the molecule. This is explained on basis of ab initio calculations showing a selective hybridization of the molecular states with minority states of the electrodes. Finally, one of the electrodes has been replaced by an antiferromagnet forming an ideally hard magnetic layer. Due to the local character of the hybridization with the molecular states, a significant magnetoresistance can also be observed.

Topical Talk TT 35.5 Thu 12:20 H 0104
Spin-current manipulation of atomic-scale magnets using SP-STM — •Stefan Krause — Institute of Applied Physics, University of Hamburg, Germany

A prerequisite on the way to advanced applications in spintronics is the detailed understanding of current-induced magnetization switching (CIMS). Here, the spin-transfer torque generated by a spin current forces a magnet to reverse its magnetization. Spin-polarized scanning tunneling microscopy (SP-STM) provides an ideal representation of a tunneling magneto-resistance device, with vacuum serving as the tunnel barrier between a biased magnetic tip and a magnetic sample.

In our experiments the ultimate lateral resolution of SP-STM is used for a very local observation and manipulation of individual Fe/W(110) nanoislands in the superparamagnetic regime. Performing a current-dependent lifetime analysis of the magnetic states, three fundamental contributions to CIMS are clearly separated and quantified: spin-transfer torque, Joule heating and Oersted field [1,2].

Lowering the temperature leads to a stabilization of the nanomagnets. In this regime the high spin-polarized tunnel current solely triggers magnetization reversal, and the threshold is determined by ramping the tunnel current. For fast reversal, short high-current pulses are applied, thereby demonstrating the capability of SP-STM for the reliable manipulation of magnetism on the atomic scale[3].

[1] S. Krause *et al.*, Science **317**, 1537 (2007).
[2] S. Krause *et al.*, Phys. Rev. Lett. **107**, 186601 (2011).
[3] G. Herzog *et al.*, Appl. Phys. Lett. **96**, 102505 (2010).