TT 31: SC: Tunnelling, Josephson Junctions

Time: Thursday 9:30–13:00 Location: H21

TT 31.1 Thu 9:30 H21

Tuning superconductivity by carrier injection — •P. Müller[1], Y. Koval[1], X. Y. Jin[1], C. Bergmann[1], Y. Simsek[1], L. Özyüzer[1], H. B. Wang[2], G. Behr[3], and B. Büchner[3] — [1]Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany — [2]National Institute for Materials Science (NIMS), Tsukuba, Japan — [3]IFW-Dresden, Germany

In layered high-temperature superconductors, like $Bi_2Sr_2CaCu_2O_{8+\delta}$, superconductivity is controlled by carrier doping of the conducting planes. Usually this is achieved by a non-stoichiometric composition. Normally, current flow inside superconductors is never expected to be able to change the material itself. However, we were able to show that by extensive current injection along the c-axis the superconducting properties of $Bi_2Sr_2CaCu_2O_{8+\delta}$ can be changed effectively and reversibly. By injecting current perpendicular to the planes, we show that critical temperature, c-axis resistivity and critical current of intrinsic Josephson junctions can be tuned in a large range from underdoping to extreme overdoping. Apparently, the insulating layers are charged by injected carriers, and work as a floating gate. The result is hole doping of the conducting layers. This flash memory concept seems to be a general property of layered materials where the insulating charge reservoir layers are separated from the conducting planes.

TT 31.2 Thu 9:45 H21

Spectral Features in Current-Voltage Characteristis of Terahertz Wave Emitting $Bi_2Sr_2CaCu_2O_{8+d}$ Mesas — •Lütfi Özyüzer[1], Yilmaz Simsek[2], Hasan Köseoglu[1], Fulya Türkoglu[1], Yasemin Demirhan[1], Zeynep Meric[1], Cihan Kurter[3], Ulrich Welp[3], Ken E. Gray[3], Takashi Yamamoto[4], Kazuo Kadowaki[4], Yuri Koval[2], Huabing Wang[5], and Paul Müller[2] — [1]Izmir Institute of Technology, Izmir, Turkey — [2]University of Erlangen-Nürnberg, Germany — [3]Argonne National Laboratory, USA — [4]University of Tsukuba, Japan — [5]National Institute for Materials Science, Japan

Terahertz electromagnetic radiations are more versatile in sensing, imaging, and spectroscopy applications across the physical and biological sciences. There is still lack of coherent, continuous, tunable and compact solid-state sources of electromagnetic wave at THz frequency range. Although Josephson junctions are potential candidate, the mechanism of terahertz waves from intrinsic Josephson junctions of layered high temperature superconductor $Bi_2Sr_2CaCu_2O_{8+d}$ (Bi2212) mesas is still unresolved. Large area mesas ranging from 100x300 to 40x300 μm^2 with various heights were formed on Bi2212. Current-voltage (I-V) and THz emission characteristics were obtained at various temperatures. Spectral features in I-V curves were investigated to find a correlation between emission frequency and feature energy.

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TT 31.3 Thu 10:00 H21

Terahertz emission from intrinsic Josephson junction stacks in high-Tc superconductors: effects of fabrication technique — •Y. Simsek[1], L. Özyüzer[1,2], S. Preu[3], D. Ploss[3], S. Malzer[3], Y. Koval[1], H. B. Wang[4], and P. Müller[1] — [1]Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany — [2]Department of Physics, Izmir Institute of Technology, Izmir, Turkey — [3]Max Planck Institute for the Science of Light, Erlangen, Germany — [4]National Institute for Materials Science (NIMS), Tsukuba, Japan

It was found recently that large area $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212) mesas show terahertz emission due to intrinsic Josephson junctions (IJJ). We have fabricated large and tall Bi2212 mesas by optical and electron beam lithography, and studied effects of fabrication technique on THz emission characteristics. Monitoring the emission was performed with a Si composite bolometer, while the applied current through the IJJ stacks was slowly swept by a function generator. Emission peaks were observed on I-V return branches while the bias current was decreasing. The frequency of emission was determined by a terahertz interferometer. The observed emission frequencies match the frequency calculated by the cavity resonance condition.

TT 31.4 Thu 10:15 H21

Macroscopic quantum tunneling of $Bi_2Sr_2CaCu_2O_{8+\delta}$ intrinsic Josephson junctions modified by current injection — •X. Y. Jin, Y. Koval, Y. Simsek, C. Bergmann, C. Steiner, and P. Müller — Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany

The properties of $Bi_2Sr_2CaCu_2O_{8+\delta}$ single crystals can be changed in a wide range by current injection along the c-axis. As a result, experiments can be carried out repeatedly on the same sample, only with its critical current density and critical temperature tuned electronically. Macroscopic quantum tunneling experiments were performed on intrinsic Josephson junctions after modification by current injection. A systematic change of the thermal-to-quantum crossover temperature corresponding to the change of critical current density has been observed. Dielectric properties of insulating layers after injection were determined based on microwave spectroscopy experiments. Samples of different structures and geometry have been studied to clarify the current injection mechanism in detail.

TT 31.5 Thu 10:30 H21

Macroscopic quantum properties of Josephson junctions with ferromagnetic interlayer — •Georg Wild[1,2], Christian Probst[1], Achim Marx[1], and Rudolf Gross[1,2] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching — [2]Physik-Department, Technische Universität München, Garching

Josephson junctions with ferromagnetic interlayer have attracted much interest due to their potential application as π-phase shift elements in flux qubits. However, up to now it is not clear whether magnetic excitations in the ferromagnetic interlayer induce noise and thus prevent the application of these junctions in quantum circuits. To elucidate this question we have fabricated π-coupled Nb/AlO_x/NiPd/Nb superconductor/insulator/ferromagnet/superconductor Josephson junctions and investigated the escape rate out of the zero voltage state into the voltage state. At high temperatures this escape is dominated by thermal activation, while below the crossover temperature $T^\star$ it is due to quantum tunneling. In this work we compare the experimentally determined crossover temperature $T^\star_{\rm exp}$ to the theoretically expected value $T^\star_{\rm th}$ to clarify the question whether low-lying excitations in the junction influence its quantum properties. We analyze the only free parameter, the plasma frequency ω_p, by means of Fiske resonance studies and via microwave spectroscopy experiments at mK temperatures.

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TT 31.6 Thu 10:45 H21

Optimization of Nb/Al-AlO_x/Nb Technology for the Investigation of Fluxon Dynamics in Long Josephson Junctions — •Johannes M. Meckbach[1], Christoph Kaiser[1], Konstantin Il'in[1], Michael Siegel[1], Kai Buckenmaier[2], Tobias Gaber[2], Uta Kienzle[2], Hanna Sickinger[2], Edward Goldobin[2], Reinhold Kleiner[2], and Dieter Koelle[2] — [1]Institut für Mikro- und Nanoelektronische Systeme, KIT, Germany — [2]Physikalisches Institut - Experimentalphysik II, Universität Tübingen, Germany

Underdamped long Josephson junctions (LJJs) are ideal systems for the investigation of fluxon dynamics. In LJJs the Josephson phase may vary on the length scale of λ_J, the Josephson penetration depth, and thus is very sensitive to defects in the structure. Inhomogeneities in the barrier can lead to a locally suppressed critical current density and parasitic resonances in the microwave spectra of the JJ. We have developed and optimized the process for Nb/Al-AlO_x/Nb based LJJs exhibiting an exceptionally high quality. We show spectroscopic measurements which confirm the uniformity of the AlO_x barriers.

In very long linear JJs, the bias current peaks at the edges while the central part of LJJs is left almost unbiased. This results in unusual $I_c(H)$ dependences with reduced $I_c(0)$ and hampers the control of (semi)fluxons situated near the center of LJJs. To optimize the bias feed circuitry, we have investigated a variety of bias line geometries (multiple lines, resistors, etc.) measuring the scaling of the maximum critical current over the JJ length. We discuss advantages and drawbacks of these designs.

TT 31.7 Thu 11:00 H21

Spectroscopy of fractional Josephson vortex molecules — •Edward Goldobin, Tobias Gaber, Kai Buckenmaier, Uta Kienzle, Hanna Sickinger, Dieter Koelle, and Reinhold Kleiner — Physikalisches Institut – Experimentalphysik II and Center for Collective Quantum Phenomena, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

Using tiny current injectors we create κ discontinuities of the Josephson phase in a long Josephson junction. The junction reacts at the discontinuities by creating fractional Josephson vortices of size λ_J pinned at them. Such vortices carry the flux Φ, which is a fraction of the magnetic flux quantum $\Phi_0 \approx 2.07 \times 10^{-15}$ Wb. Being pinned, a fractional vortex has an eigenfrequency (localized mode), which depends on κ and applied bias current, and which lays within the plasma gap. If one considers a molecule consisting of several coupled fractional vortices, the eigenfrequency will split into several modes. We report on spectroscopy of a fractional vortex molecule performed in the thermal regime.

15 min. break

TT 31.8 Thu 11:30 H21

Charge transport across a single-Cooper-pair transistor coupled to a resonant transmission line — •Juha Leppäkangas[1,3], Yuri Pashkin[2], and Erkki Thuneberg[3] — [1]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [2]NEC Nano Electronics Research Laboratories and RIKEN Advanced Science Institute, Tsukuba, Ibaraki 305-8501, Japan — [3]Department of Physical Sciences, University of Oulu, FI-90014 Oulu, Finland

We have investigated charge transport in ultrasmall superconducting single and double Josephson junctions coupled to a transmission-line resonator. The microstrip resonator is naturally formed by the on-chip leads and the sample holder. We observe equidistant peaks in the transport characteristics of both types of devices and attribute them to the process involving simultaneous tunneling of Cooper pairs and photon emission into the resonator. The experimental data is well reproduced with the orthodox model of Cooper pair tunneling that accounts for the microwave photon emission into the resonator.

TT 31.9 Thu 11:45 H21

Non-linear current-voltage characteristics of NS-tunnel junctions prepared by focused ion beam induced deposition — •Dirk Klingenberger, Oleksandr Foyevtsov, Fabrizio Porrati, and Michael Huth — Physikalisches Institut, Goethe-Universität, Max-von-Laue-Str.1, 60438 Frankfurt am Main.

We used a focused Ga-ion beam and the precursor W(CO)6 –injected into a vacuum chamber nearby the focal area of the beam– to create tungsten containing superconducting deposits with a critical temperature of about 5.2 K. The deposits were fabricated onto oxidized aluminum contacts pre-patterned by UV-photolithography. I-V- and V-dI/dV- measurements have been performed between 0.3 K and 6 K using a He3-cryostat. For selected beam energies used during deposition the samples show Josephson-junction like behaviour or tunneling of quasiparticles for temperatures below the superconducting transition of aluminum at about 2 K. In the temperature range between the superconducting transitions of the two electrodes Andreev-reflection was observed.

TT 31.10 Thu 12:00 H21

Analytical calculation of the excess current in the Octavio-Tinkham-Blonder-Klapwijk theory — •Gabriel Niebler[1,2], Gianaurelio Cuniberti[2], and Tomáš Novotný[1] — [1]Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 121 16 Prague 2, Czech Republic — [2]Institute for Materials Science and Max Bergmann Center of Biomaterials, Dresden University of Technology, D-01062 Dresden, Germany

We present an analytical derivation of the excess current in Josephson junctions within the Octavio-Tinkham-Blonder-Klapwijk theory for both symmetric and asymmetric barrier strengths. We confirm the result found numerically by Flensberg *et al.* for equal barriers [*Physical Review B* **38**, 8707 (1988)], including the prediction of negative excess current for low transparencies, and we generalize it for differing barriers. Our analytical formulae provide for convenient fitting of experimental data, also in the less studied, but practically relevant case of barrier asymmetry.

TT 31.11 Thu 12:15 H21

Small charge solitons in 1D arrays of Josephson junctions — •Alexander Shnirman[1], Stephan Rachel[2], Jens Homfeld[1], and Ivan Protopopov[1] — [1]Institut für Theorie der Kondensierten Materie and DFG Center for Functional Nanostructures, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Department of Phyiscs, Yale University, New Haven, USA

We identify the new parameter regime within the Coulomb blockade (insulating) phase of a 1D array of coupled JJs. It is defined by the condition $\Lambda E_J > E_C > E_J$, where E_C and E_J are the charging and the Josephson energies of the junction, respectivly, and Λ is the bare screening length (measured in number of junctions). In this regime we investigate the dynamics of charge solitons and demonstrate two surprising features: i) flattening of the dispersion relation in the outer region of the Brillouin zone; ii) broadening of the soliton in the flat band regime in contrast to the expected and observed Lorenz contraction in the regime of regular dispersion relation.

TT 31.12 Thu 12:30 H21

Temporal dynamics of a chain of Josephson junctions in the Coulomb blockade regime. — •Jared Cole and Michael Marthaler — Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, Karlsruhe, Germany

Recent experiments have studied the transport of individual charge carriers through a one-dimensional array of small Josephson junctions, in the limit of small Josephson coupling. Modern time resolved charge detection techniques allow the direct measurement of temporal correlations between these carriers. We study such a system theoretical with the aim of understanding the transport properties within the array, in both the normal and superconducting regimes. Of particular interest are the effects of Coulomb repulsion between the carriers and the resulting transport through the array.

TT 31.13 Thu 12:45 H21

Dynamical bistability in driven Josephson circuits - the WKB limit and beyond. — •Vittorio Peano and Michael Thorwart — FRIAS Albert-Ludwigs-Universität, Freiburg, Deutschland

Driven and dissipative nonlinear quantum oscillators can be operated in a regime where a bistability is induced dynamically. Prominent examples are the Josephson bifurcation amplifier and the driven circuit QED set-up of the superconducting transmon qubit. Josephson circuits with their large quality factors and scalable nonlinearities are the perfect playground to explore this phenomenon from the classical limit down to the quantum scale. We show that the WKB approximation is an excellent tool in all these regimes. We explore its limit of validity, focusing thereby on the quantum Duffing oscillator and the driven circuit QED.