TT 22: Poster Session: Disordered and Granular Superconductors: Fundamentals and Applications in Quantum Technology

Time: Thursday 13:30–15:30 Location: P

TT 22.1 Thu 13:30 P

Superinsulators: "localization" and granularity without disorder — •cristina diamantini[1] and carlo trugenberger[2] — [1]Department of Physics and Geology, University of Perugia, via Pascoli snc, Perugia, Italy — [2]SwissScientific Technologies SA, rue du Rhone 59, Geneva, Switzerland

It is often believed that suppression of transport in condensed matter systems requires many-body localization (MBL) by strong disorder. There is by now, however a vast body of literature showing that this is not the case: MBL-like phenomena can arise in absence of disorder by confinement, the phenomenon preventing quarks to "exit" from protons. I will discuss the example of the superinsulators, a new state of matter where condensation of magnetic monopole instantons generates an "endogenous emergent disorder" leading to an infinite resistance (even at finite temperatures) by the confinement of electric charge, Cooper pairs playing the role of quarks. The granularity of these materials around the superconductor-to-superinsulator transition is also emergent, due to the competition of two quantum phase transitions and is not due to disorder. I will present recent experimental evidence that rules out disorder-driven MBL as a cause of the infinite resistance, while confirming its endogenous instanton origin.

TT 22.2 Thu 13:30 P

Collective excitations in weakly-coupled disordered superconductors — •Bo Fan[1], Abhisek Samanta[2], and Antonio Miguel Garcia-Garcia[1] — [1]Shanghai Center for Complex Physics, School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China — [2]Physics Department, Technion, Haifa 32000, Israel

Isolated islands in two-dimensional strongly-disordered and strongly-coupled superconductors become optically active inducing sub-gap collective excitations in the ac conductivity. Here, we investigate the fate of these excitations as a function of the disorder strength in the experimentally relevant case of weak electron-phonon coupling. An explicit calculation of the ac conductivity, that includes vertex corrections to restore gauge symmetry, reveals the existence of collective sub-gap excitations, related to phase fluctuations and therefore identified as the Goldstone modes, for intermediate to strong disorder. As disorder increases, the shape of the sub-gap excitation transits from peaked close to the spectral gap to a broader distribution reaching much smaller frequencies. Phase-coherence still holds in part of this disorder regime. The requirement to observe sub-gap excitations is not the existence of isolated islands acting as nano-antennas but rather the combination of a sufficiently inhomogeneous order parameter with a phase fluctuation correlation length smaller than the system size. Our results indicate that, by tuning disorder, the Goldstone mode may be observed experimentally in metallic superconductors based for instance on Al, Sn, Pb or Nb.

TT 22.3 Thu 13:30 P

Andreev bound states in disordered superconductors — •Idan Tamir — FU Berlin

At strong enough disorder, superconductivity losses its uniformity and exhibits local gap variations. These are considered a precursor for the eventual breakdown of superconductivity. Using high resolution tunneling spectroscopy to locally study amorphous superconducting films, we observe an abundance of sharp in-gap excitations. We relate these excitations to Andreev bound states induced by either large superconducting gap variations or the interaction with native magnetic impurities. Both possibilities are not accommodated in current theoretical models.

TT 22.4 Thu 13:30 P

Dielectric properties of amorphous indium oxide on the insulating side of the superconductor-insulator transition — Nikolaj Ebensperger[1], Paul Kugler[1], •Anastasia Bauernfeind[1], Martin Dressel[1], Benjamin Sacépé[2], Mikhail Feigel'man[3], and Marc Scheffler[1] — [1]1. Physikalisches Institut, University of Stuttgart, Stuttgart, Germany — [2]Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, Grenoble, France — [3]L.D. Landau Institute for Theoretical Physics, Chernogolovka, Russia

Amorphous indium oxide (a:InO) plays a prominent role in the study of strongly disordered superconductors. In particular, the disorder-driven transition (SIT) between superconducting and insulating states can be realized. Compared to the superconducting side of the SIT, the insulating side has been explored much less experimentally due to the lack of appropriate experimental means. Here we present dielectric measurements on insulating a:InO, performed at GHz frequencies and at temperatures down to the mK regime, on a set of samples with varying disorder. We obtain the real and imaginary parts of the dielectric function (corresponding to frequency-dependent conductivity) as function of disorder, temperature, and frequency. We analyse these data based on theory for hopping in disordered systems, and we trace the evolution of the dielectric function, e.g. the increase of its real part upon approaching the SIT.

TT 22.5 Thu 13:30 P

Decoupling of superconducting layers in $[(\mathrm{SnSe})_{1+\delta}]_n[\mathrm{NbSe2}]_m$ ferecrystals — •O. Chiatti[1], K. Mihov[1], M. Trahms[1], T. Griffin[1], C. Grosse[1], D. Hamann[2], K. Hite[2], M. B. Alemayehu[2], D. C. Johnson[2], and S. F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Solid State Chemistry, University of Oregon, Eugene, OR 97403-1253, U.S.A.

Van-der-Waals superlattices with two-dimensional (2D) superconducting layers of a transition-metal dichalchogenide (TMD) embedded between other materials have recently received a lot of attention [1]. Embedding the TMD layers protects them from exposure to air and makes it possible to observe 2D superconductivity. Here, we examine $[(\mathrm{SnSe})_{1+\delta}]_n[\mathrm{NbSe2}]_m$ ferecrystals [2] with $n = 1$ and varying m. The ferecrystals are stacks of polycrystalline layers grown with atomic layer precision, but without an epitaxial relationship between the layers [2]. For $m \leq 9$ we observe a superconducting phase below a critical temperature, which decreases with increasing distance between the $\mathrm{NbSe_2}$ monolayers. For $m \geq 9$ an insulating behavior is observed. The Ginzburg-Landau (GL) coherence lengths are determined from the upper critical magnetic fields. The perpendicular GL coherence length decreases with increasing distance between the $\mathrm{NbSe_2}$ monolayers, indicating a decoupling of the superconducting layers [3].

[1] A. Devarakonda *et al.*, Science **370**, 231 (2020)
[2] C. Grosse *et al.*, Sci. Rep. **6**, 33457 (2016)
[3] M. Trahms *et al.*, Supercond. Sci. Technol. **31**, 065006 (2018)

TT 22.6 Thu 13:30 P

Resonant microwave spectroscopy close to the superconductor to insulator transition — •Maximilian Kristen[1,2], Jan Nicolas Voss[2], Micha Wildermuth[2], Yannick Schön[2], Andre Schneider[2], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2,3,4] — [1]Institut für QuantenMaterialien und Technologien (IQMT), Karlsruher Institut für Technologie — [2]Physikalisches Institut, Karlsruher Institut für Technologie — [3]Russian Quantum Center, Skolkovo, Moscow, Russia — [4]National University of Science and Technology MISIS, Moscow, Russia

High kinetic inductance circuits in the vicinity of the superconductor to insulator transition (SIT) are an interesting research topic not only for applications like quantum circuits or detectors, where the SIT poses a limit on the maximum available kinetic inductance of a wire, but also as a tool to study fundamental aspects of superconductor physics.
We perform microwave measurements on resonators made from highly resistive films. As a material of choice, we use granular aluminum at high oxide levels, due to the low intrinsic loss and the possibility to approach the SIT from the superconducting side. We focus on the low frequency noise behavior of these resonators and present the latest experimental results

TT 22.7 Thu 13:30 P

Growth of superconducting granular aluminum films on cryogenically cooled substrates — •Aniruddha Deshpande, Jan Pusskeiler, Martin Dressel, and Marc Scheffler — 1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany

Granular aluminum (grAl) consisting of nanometer-sized aluminum grains separated by aluminum oxide has peculiar superconducting properties. The critical temperature can be substantially enhanced compared to pure bulk aluminum up to 3.7K and the low superfluid density of grAl is promising for applications in quantum circuits. The material properties of grAl can be tuned during thin-film growth by parameters such as oxygen pressure and substrate temperature. Here we use thermal evaporation of aluminum and deposition in low-pressure oxygen environment onto cryogenically cooled substrates to reduce the grain size compared to room-temperature growth, and we characterize the grAl films for their temperature-dependent sheet resistance and their superconducting critical temperature.

TT 22.8 Thu 13:30 P

Modified properties of disordered superconducting films with amorphous and granular structure — •Mariia Sidorova[1,2], Alexej Semenov[1], Stephan Steinhauer[3], Samuel Gyger[3], Val Zwiller[3], Xiaofu Zhang[4], Andreas Schilling[4], and Heinz-Wilhelm Hübers[1,2] — [1]DLR, Institute of Optical Sensor Systems, Berlin, Germany — [2]Humboldt-Universität zu Berlin, Berlin, Germany — [3]KTH Royal Institute of Technology, Stockholm, Swede — [4]University of Zürich, Zürich, Switzerland

Thin disordered superconducting films are intensively exploited in various superconducting devices, for instance, superconducting single-photon detectors (SSPDs) and hot-electron bolometers (HEBs). The dimensionality of such films usually duffers with respect to various physical phenomena, for instance, it is two-dimensional (2d) to superconductivity and weak localization, three-dimensional (3d) to normal conduction, and approach a 2d-3d crossover with respect to phonons. Properties of low-dimensional systems differ from bulk materials and their either theoretical or empirical description remains very limited.

We have studied several superconducting films with thicknesses below 10 nm and different morphology: amorphous WSi and polycrystalline granular NbN and NbTiN. Employing magnetoconductance and calorimetric measurements, we derived an electron-phonon scattering rate and determined sound velocities and phonon heat capacities. Our results indicate a systematic reduction of the sound velocity in all films as compared to the corresponding bulk crystalline material, and a significant impact of the film morphology on the phonon heat capacity.

TT 22.9 Thu 13:30 P

Multifractal correlations of the local density of states in dirty superconducting films — •Matthias Stosiek — Sophia University, Physics Division, Tokyo, Japan

Mesoscopic fluctuations of the local density of states encode multifractal correlations in disordered electron systems. We study fluctuations of the local density of states in a superconducting state of weakly disordered films. We perform numerical computations in the framework of the disordered attractive Hubbard model on two-dimensional square lattices. Interactions are taken into account within mean-field approximation. Our numerical results are explained by an analytical theory. The numerical data and the theory together form a coherent picture of multifractal correlations of the local density of states in weakly disordered superconducting films. [1]

[1] M. Stosiek, F. Evers, I. S. Burmistrov, arXiv:2107.06728 (2021)