Session 22EP

Construction of a thermoacoustic Stirling cooler **22EP1**

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In 1999, an efficient thermoacoustic engine was built by Backhaus and Swift, where an acoustic traveling wave executes a Stirling cycle [S. Backhaus and G. W. Swift, Nature **399**, 335(1999)]. They reported that this engine produced the acoustic output power with the efficiency reaching 40% of the ideal Carnot efficiency in spite of the absence of any moving parts. In this work, we exprimentally revealed how the traveling wave performs the energy conversion. On the basis of the results, we inserted a regenerator inside the thermoacoustic engine in order to enable acoustic heat pumping through a Stirling cycle. Our prototype cooler reached -25 °C by using output power resulting from the input heat power of 200 W.

Construction of a ^{3}He cryostat using a charcoal sorption pump **22EP2**

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Recently, pressure induced superconductors were discovered in f-electron materials. Since a superconducting transition temperature of these materials is lower than 1 K, it is desirable to make measurements under high pressure at a temperature as low as possible. For this purpose, we have constructed a highly simple ^{3}He cryostat with large cooling power using a charcoal sorption pump. The temperature is controlled by changing a position of the charcoal pump, instead of using a heater. We found that a sample cools down to 0.31 K within 30 minutes after transferring liquid ^{4}He. We will show specific heat measurement results obtained by using this cryostat.

22EP3 Vibration characteristics of dilution refrigerator with cryogenic cycle

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One of the main advantages of the dilution refrigerators with a cryogenic cycle of circulation is a relatively low level of mechanical vibrations. It can be explained by absence of pumping lines, which transmits vibrations from mechanical pumps to the cryostat. However, there is no experimental data so far to support this opinion. We present results of mixing chamber vibration measurements at base temperature 15 mK of the dilution refrigerator with two adsorption pumps. It was shown that the cryo-valve switching off/on causes short time vibration disturbance, which decays within 0.2 s. During operation of the refrigerator between cryo-valve switchings the amplitude of vibrations is lower than 10 Å. The analysis of vibration spectrum allows us to suggest measures, which can further reduce the amplitude of disturbances.

22EP4 Copper Nuclear Demagnetization Stage for Studies of Quantum Fluids below 100 μK

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For the study of superfluid ^{3}He and ^{3}He-^{4}He mixture below 100μK,we have constructed a massive copper nuclear stage(90.6mole of Cu in 8T). Our stage has been machined from bulk oxigen free copper with purity 99.99$\%$.Heat treatment increased the RRR up to 4000. With this nuclear stage we have managed to cool a Pt-NMR thermometer located in the sample space to 45μK. The total heat leak was found to be 1nW on the 10th day after reaching 4.2K and to be constant during 2months. The measured heat capacities at several fields were consistent with the calculated values between 60μK and 4mK. This indicates that our stage has no extra heat capacity. Due to time-independent and small heat leaks,we can reach the lowest temperature quite soon and maintain temperatures below 100μK for several weeks.

22EP5 Super High Conductivity Effect in Metal - Polymer - Metal Structures

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We have observed that films of poly[4,4'$-bis$(4"-N-phenoxy)diphenyl-sulfone]amic acid of 1,3$-bis$(3',4-dicarboxyphenoxy)benzene - polyimide precursor or co-poly[4,4'$-bis$(4"-N-phenoxy) diphenyl-sulfone-$\alpha,\beta-bis$ (γ- amino propyl)oligodimethylsiloxane] imide of 1,3$-bis$(3',4- dicarboxyphenoxy)benzene with thickness about 1μ placed between two metallic electrodes become highly conducting in a relatively small electric field ($E < 1V/cm$). If the metallic electrodes (Sn, Nb) in sandwich structures were in the superconducting state an effective resistance of zero was recorded. A typical current — voltage characteristic of an $S-P-S$ structure looks like a Josephson type.

Quantum wire networks for superconducting quantum-dot superlattices **22EP6**

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Quantum wire networks have been proposed for fabricating quantum-dot superlattices with the square and the plaquette lattice structures. These artificial lattices are well represented by Hubbard models with parameters determined by the local density approximation. The superconducting transition temperature T_c (=90 mK) for the plaquette lattice is more than two times T_c (=40 mK) for the square lattice and is sufficiently high for achieving superconductivity in experiments.

Infrared observation of the CDW amplitude decreasing due to hole doping in $Ba_{1-x}K_xBiO_3$ **22EP7**

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Optical reflectivity mesurements in a frequency range from 50 -1000cm^{-1} have been done for semiconducting BKBO single crystals. The amplitude of the CDW estimated from the oscillator strength of the transverse optical phonon is substantially large in BBO. The amplitude value decreases with increasing x and tends to approach zero at a critical composition of the metal-semiconductor transition. We found that the dynamical charge transfer with the vibration of the Bi-O bonds is quite large in this system and a decrease of the amplitude leads to the superconducting as well as metallic states.

Three channels non-force magnetic SQUID microscope **22EP8**

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Scanning magnetic microscope (SMM)without force and appreciable magnetic influence on research object was developed. SMM contains three measuring channels. First of them is special fluxgate with relatively low magnetic sensitivity for a preliminary magnetic study of the object surface. The second channel has been developed on a base HTc SQUID with ferromagnetic concentrator and it is intended for detailed (with 0.1-1 micron resolution) study of ”warm” objects at T=300K. The third channel also has as the detector HTc SQUID with ferromagnetic concentrator of a magnetic flux, but it is intend for detailed study of the ”cold” objects at T=77K.

22EP9 Development of High-T_c SQUID Microscope

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We have developed a SQUID microscope using a high-T_c SQUID sensor (Sumitomo Electric Hightechs). The SQUID sensor has a sensitivity of 1pT and the effective sensor area is 0.2 mm^2. An X-Y stage (Suruga K201-30LMS) moves 30$\times$ 30 mm area and its resolution is 0.05 μm. The SQUID sensor is cooled by liquid nitrogen, and can be held at 77 K for 1 h. The distance between the sensor and a sapphire window is less than 100 μm. The sample temperature is limited to room temperature. The device is controlled by LabVIEW-6i and the motion controller (National Instruments UMI-7764). The performance of the SQUID microscope is examined by a regular array of Ni dots.

22EP10 NMR powder spectra in case of strong quadrupole interaction

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Many new materials are available only in form of powders and in case of large quadrupole splittings NMR spectra become extremely broad. An example is copper NMR in high-Tc superconductors. In this case nuclear Zeeman term of Hamiltonian is in speaking terms with quadrupole one and perturbation theory is not valid for the spectra calculation. We suggest the straightforward numerical simulation of the spectra alghorithm which exhibits a good fit of the experimental data even in case of moderate computing resources. It is shown that asymmetry parameter of the nuclear quadrupole interaction, quadrupole frequency and Knight shift can be evaluated from the powder spectrum. The distribution of spin-lattice relaxation rates over the spectra in case of quadrupole and magnetic relaxation is discussed.

22EP11 Transport Properties of In_2Bi and InBi Single Crystals

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We have made measurements of specific heat, resistivity, thermopower and magnetization of a superconductor, In_2Bi, and a normal metal, InBi, using single crystals at temperatures from 2 to 300 K and fields up to 7 T. Applying an external field at the specific heat measurement of In_2Bi enabled us to estimate an energy gap between the normal and superconducting states, which can be compared with that from the BCS theory. Magnetization of In_2Bi at 2 K showed the de Haas-van Alphen oscillations at the c-axis, but no such oscillation was observed at the a-axis. An origin for the different transport properties of these compounds was considered focusing on the coefficients of electronic specific heat and the Debye temperatures.

Negative resistance in I-V characteristics and 2D vortex dynamics in amorphous W/Si multilayer superconductors with periodic antidot arrays **22EP13**

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We have examined the vortex dynamics in W/Si multilayers, where the arrays of antidots with 1 μm diameter are fabricated in the form of square and triangular lattices with the distance of 2 μm. In the measurements of I-V characteristics as a function of temperature T and magnetic field H, we find a specific regime at high H, where the I-V curves coincide irrespective of T. Especially the I-V curves show a negative slope in the multilayer with triangular arrays. The elastic flows of the vortex lattices in the narrow paths between the arrays and their interaction with the vortices around antidots are discussed.

Superconductivity of Metals in Porous Matrices **22EP14**

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Studies of superconductivity for gallium, mercury, tin, and indium embedded into porous glasses and artificial opals are presented. Magnetic properties and resistance of porous matrices filled with metals were measured from 1.7 to 10 K. Size effects on the superconducting phase transitions were found. Double-step resistivity and magnetization were obtained in some samples dependently on filling factors and pore geometry. Most superconducting properties were treated within the framework of the model of granular superconductors. Properties, which were also found in high-temperature superconductors, like flux jumps and the paramagnetic Meissner effect were observed for porous glasses filed with tin.

Magnetic response of hard type-II superconductors with a semicircular indentation **22EP15**

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The magnetic response of superconductors with a semicircular indentation in parallel field is studied. The indentation is placed in the corner of a long supercondutor. The Meissner and vortex fields are calculated for any indentation radius in the London background. This allowed us to obtain the energy and the forces acting on a vortex in a given position inside the superconductor. The entrance magnetic field dependence on the indentation radius is calculated and compared with the entrance field for an identation free semi-infinite superconductor. The role of the indentation on the surface barrier and on the vortex dynamics is also discussed.

22EP16 Fluxoid distributions in superconductive honeycomb networks

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We have studied fluxoid distributions and superconducting transition temperature of honeycomb superconductive networks with edges in the magnetic field making use of the de Gennes-Alexander equation. In honeycomb networks with edges, the suppression of superconducting transition temperature in the magnetic field is smaller compared with that of edgeless periodic boundary networks. In the weak magnetic field, fluxoids emerge from center of the network. As magnetic field increases, fluxoids are distributed in the shape of edge lines of the network.

22EP17 Dimensional Crossover from Two to One Dimension in Small-Josephson-Junction Arrays

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We have fabricated two-dimensional (2D) small-Josephson-junction arrays with different array widths, including a 1D array, on a substrate simultaneously. For such a group of arrays with nominally the same junction parameters ($E_J/E_C \approx 1$), we observe a crossover from superconducting to insulating behavior as the array width is reduced, which is explained by an enhancement of quantum fluctuations due to the dimensional reduction. I will also talk about scaling behavior in current-voltage characteristics of the arrays.

22EP18 Vortex motion channeling effects in Nb with mesoscopic arrays of Ni lines

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Electron Beam Lithography and Ion Beam Etching allow us to fabricate ordered array of submicrometric Ni lines in sputtered Nb films. Optical lithography and etching define a cross-shape bridge which allows to apply the transport current paralle or perpendicular to the array of Ni lines. Magnetotransport (r,H) and (I,V) curves were measured close to the critical temperature. The experimental results show anisotropic vortex motion with clear channeling effects with matching features between the periodic array of pinning potentials and the driving vortex lattice.

Microwave nonlinear effects in He-cooled superconducting microstrip resonators 22EP19

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Thermally induced nonlinear phenomena in superconducting niobium microstrip resonators filled by liquid helium are studied in microwaves (10 GHz). With increasing input power a resonance curve of the resonator revealed the nonlinear behaviour and its form depended on the rate and direction of the microwave generator frequency sweep. The found nonlinear resonance is explained by thermally induced variations of the helium dielectric permittivity caused by the microwave power losses in superconductor. A number of interesting manifestations of this thermal instability have been observed including the parametric pulse generation of the monochromatic microwave signal, generation of acoustic pulses, stimulated Mandelshtam-Brillouin scattering like effect.
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Spin diffusion in a superconductor through mesoscopic ferromagnet/superconductor interfaces 22EP20

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We observed the suppression of the superconductivity in a mesoscopic Al wire (74 nm thick and 400 nm wide) in contact with an overlaid ferromagnetic Co wire (66 nm thick and 270 nm wide). A specimen was fabricated by using a combination of e-beam mircropatterning and e-gun evaporation. A spin-polarized current was injected to the Al wire from the Co wire through the interface and the transport properties of a few μm-long portion of Al wire from the interface were measured by the conventional lock-in technique. The estimated spin diffusion length in Al wire increased as T approached T_c from below and showed a strong correlation with the temperature dependence of the G-L superconducting coherence length.

The Gradient Expansion Theory of Inhomogeneous Superconducting Thin Films 22EP21

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We pay attention to inhomogeneous superconducting thin films in external magnetic field. As inhomogeneities introduced by the impurity Coulomb potential and the external magnetic field can be considered small over a distance comparable to an electron de Broglie wavelength, the observables should possess an expansion in powers of the gradient operator which measures the inhomogeneities. Based on formulation of the finite-temperature normal and superconducting Green's functions, we evolve the gradient expansion theory for the inhomogeneous superconducting thin films.

22EP22 Dynamic response of Josephson junction arrays on a dice lattice

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We report the results of ac conductance (G) measurements performed on Josephson junction arrays with a dice lattice structure. In these systems the subtle interplay between lattice geometry and magnetic field B leads to localization phenomena (Aharonov-Bohm cage) when B corresponds to half a flux quantum per unit tile, *i.e.*, when the array is fully frustrated ($f = 1/2$). At $f = 1/2$, the superfluid component $\omega ImG(B)$ exhibits a deep minimum, whereas the dissipative one $Re[1/G(B)]$ shows a pronounced maximum, thereby providing compelling evidence for magnetic localization. In swept-frequency measurements performed over a broad spectral range the dynamic response at $f = 1/2$ was compared to that at other levels of frustration to search for the glass-like features seen in numerical simulations. Glass-like behavior was indeed observed, but can not be unambiguously attributed to magnetic localization.

22EP23 Evidence for finite-temperature glass transition in two dimensions

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Large-scale simulations have been performed in the current-driven two-dimensional XY gauge glass model with resistively-shunted junction dynamics, by meanse of a very effecient algorithm proposed before [1]. It is found that the linear resistivity at low temperatures tends to zero, which shows a finite temperature glass transition. Dynamical scaling analysis demonstrates that a nearly pefect collapse of current-voltage data can be achieved if the transition temperature $T_c = 0.22$ (in units of the Josephson coupling strength), dynamical critical exponent $z = 2.0$, and the static exponent $\nu = 1.2$, which agrees quite well with recent findings by an equilibrium simulation [2].
(1) Q H Chen, L H Tang, P Q Tong, Phys. Rev. Lett. 87 , 067001 (2001)
(2) B J Kim, Phys. Rev. B 62, 644(2000)

22EP24 Superconductor-normal metal quantum phase transition in ultrathin cylinders

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We have carried out experiments on ultrathin superconducting cylinders which revealed the existence of a destructive regime, predicted by de Gennes to occur around half-integer flux quanta in doubly connected samples with a diameter smaller than the zero-temperature superconducting coherence length [Y. Liu, *et al.*, *Science* 294, 2332 (2001)]. More recently we have done measurements on the superconductor-normal metal (S-N) quantum phase transition tuned by magnetic flux in these cylinders, and studied the effects of thermal and quantum phase slips near the S-N transition.

Indirect RKKY Exchange and Magnetic Phase Transitions in Ferromagnetic Insulator/Superconductor Multilayers **22EP25**

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An exchange model of the proximity effect for layered ferromagnetic insulator/superconductor (FI/S) structures is proposed. This model, along with direct exchange inside FI layers, includes long-range antiferromagneic RKKY exchange between localized spins on FI/S boundaries via S layer conduction electrons. Within this framework, possible mutual accommodation scenarios (layered antiferromagnetism as well as cryptoferromagnetism) for the superconducting and magnetic order parameters are found, the corresponding phase diagrams are plotted, and experimental results explained.

Dimensional crossover and hidden incommensurability in Josephson junction arrays of periodically repeated Sierpinski gaskets **22EP26**

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Josephson junction arrays of pediodically repeated Sierpinski gaskets are model superconductors sharing essential geometrical features with truly percolative systems. When exposed to a magnetic field B, their euclidian (E) or fractal (F) behavior depends on the level of frustration imposed by B and has been explored with high-resolution measurements of the sample magnetoinductance $L(B)$. The EF crossover is reflected in a radical change of the fine structure of $L(B)$, which is well described by theory. Anomalies in the symmetry of $L(B)$ are attributed to a hidden incommensurability, which arises from the asymmetric diamagnetic response of the superconducting islands and perturbs the self-similarity of the gaskets.

Controlling distribution functions through supercurrent **22EP27**

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Josephson supercurrent in a normal-metal weak link can be accurately controlled by varying the quasiparticle distribution in the weak link through a voltage between the superconductors and extra normal-metal probes. This has been recently realized experimentally. We show that the opposite is also possible: the control of the quasiparticle distribution function via the supercurrent driven through the weak link. We suggest an experimental setup for probing this phenomenon.

22EP28 Positive cross-correlations induced by ferromagnetic contacts in hybrid NS structures

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Due to the Fermionic nature of carriers, correlations between electric currents flowing through two different contacts attached to a conductor present a negative sign. Possibility for positive cross-correlations has been demonstrated in hybrid NS structures under certain conditions. In this paper we show that positive cross-correlations can be induced, if not already present, in such structures by employing ferromagnetic leads with magnetizations aligned anti-parallel to each other. We consider three-terminal hybrid structures and calculate the mean-square correlations of current fluctuations as a function of the bias voltage at finite temperature.

22EP29 Anomalous Resistive Oscillations in Mesoscopic Al Superconucting Wire

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Differential resistance oscillations were observed in quasi-one dimensional mesoscopic aluminum wires under weak AC currents. The amplitude of the oscillation decreases with increase of the current and eventually changes into an abnormal peak near T_c in R-T curves. The oscillations vanish when magnetic field larger than 1 mT. With a small DC bias current the oscillations can be depressed. However, with increasing bias, oscillations become extremely large and negative differential resistance appears. The above anomaly was also confirmed by our I-V characteristics measurements. Preliminary interpretation of the anomalous oscillations suggests that the anomalies be related to the moving of the normal-superconducting boundaries between the voltage probes as temperatures close to T_c.

22EP30 Size Effect on Vortex States in Superconducting Mesoscopic Aluminum Disks

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We have measured the non-periodic resistance peaks in superconducting Al disks under the magnetic field, whose sizes are much smaller than the superconducting coherence length (ξ_0) of Al bulk. In circular and square disks with the size of 600 nm, there is no remarkable difference in the field intervals (ΔH) of the resistance peaks. However, in the disks of 500 nm, we found significant difference in ΔH. These results suggest that new vortex states depending on the sample topology appear when the size is sufficiently smaller than ξ_0.

Paramagnetic supercurrent in a mesoscopic superconducting disk **22EP31**

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We report an experimental evidence for the paramagnetic supercurrent in a mesoscopic superconducting disk. The sample is an Al superconducting disk with a thin (0.1 μm width) drain lead. The radius of the disk is 0.75 μm and the thickness is 33 nm. Four Cu leads are connected to different parts of the ring periphery through highly resistive tunnel junctions. From voltage drop across a tunnel junction, we study the change in local superconducting energy gap as a function of perpendicular magnetic field. We find that the energy gap at each point decreases simultaneously with decreasing the magnetic field, showing that the circulating supercurrent is paramagnetic. The condition for the observation is the same as that for the paramagnetic Meissner effect [A. K. Geim *et al.*, Nature **396**, 144 (1998)], strongly indicating that the origin of the paramagnetic Meissner effect is the paramagnetic supercurrent.

Pauli Paramagnetic Effect and Spin-Orbit Scattering Time in Nb/Al_2O_3 Superconducting Multilayers **22EP32**

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The parallel critical field $H_{c2//}$ of a thin film superconductor is inversely proportional to the film thickness *d* and $H_{c2//}$ can be made arbitrary large for small enough *d*. In case of such a large orbital critical field, the Pauli paramagnetic effect controlled by the spin-orbit scattering becomes the main origin to limit $H_{c2//}$ of the film. Then the analyses of $H_{c2//}$ can provide an effective method to evaluate the spin-orbit scattering time τ_{s0}. $H_{c2//}$ was calculated for various τ_{s0} values and the thickness dependence of $H_{c2//}$ of sputtered Nb/Al_2O_3 multilayers was analyzed. The effective values of τ_{s0} were determined for Nb sublayers, which accounted for about 1/30 of the total electron scattering.

Suppression of Ferromagnetism due to Superconducting Proximity Effects **22EP33**

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Superconducting proximity effects in a ferromagnetic metal are directly observed by means of ^{59}Co NMR in Co/Al bilayers. Below the superconducting transition temperature, the resonant frequency decreases and the nuclear spin-lattice relaxation rate divided by temperature, $1/T_1T$, increases. These results indicate the reduction of magnetic moment in the Co layer. We discuss the spatial variation of the local magnetic moment and its temperature dependence by analyzing the resonant line shapes.

22EP34 Superconductivity at 20 mK in Compacted Submicrometer Platinum Powders

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The superconducting transition temperature and critical magnetic field observed in compacted Pt powder samples with *sub*micrometer grain size are as high as 20 mK and 18 mT and thus more than one order of magnitude larger than for those with larger (micrometer) grain size. The submicrometer samples exhibit strong lattice strain and significantly smaller Debye temperatures compared to bulk platinum. Moreover, the ferromagnetic spin fluctuations of the conduction electrons are partially quenched in these compacts.

22EP35 Interference of Nonequilibrium Quasiparticles Injected into a Superconducting Loop

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Various nanostructures consisting of an aluminium loop overlapped by a copper electrode through a tunnel barrier were fabricated. At temperatures well below 1 K the tunnel current at fixed voltage bias is periodically modulated by external magnetic field. The period of the oscillations corresponds to one flux quantum enclosed by the area of the loop. The amplitude of the current modulation reaches maximum at bias voltages corresponding to the gap energy, and decreases with increase of the voltage bias. For a given voltage bias the amplitude of the current oscillations decreases with increase of the temperature. Oscillations of the tunnel current in magnetic field are hysteretic.

22EP36 Temperature distribution in a superconductor during pulsed magnetization

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We calculate the temperature and field distributions in a bulk superconductor during a pulsed-field magnetization process. Heat is released inside the superconductor due to magnetic flux motion and radiates from the surface. The temperature profile is found by solving the heat diffusion equation with proper boundary conditions. Due to a temperature dependence of the critical current density, the trapped flux is less for larger heating. We calculate the trapped flux for different magnetization rates and different values of the maximum applied field, B_M. Optimal values of B_M corresponding to maximum trapped flux are found for different sets of parameters typical for YBaCuO trapped-field magnets. Evolution of field and temperature distributions during the complete magnetizing process is presented.

Magneto-optical imaging of magnetic pinning of individual vortices to a Bloch wall **22EP37**

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Recently, a system for magneto-optical imaging (MOI) of individual vortices was developed in our laboratory. Reported here is a direct observation of the interaction between vortices and a Bloch wall in the indicator ferrite garnet. The Bloch wall separates two domains of opposite in-plane magnetization, and acts as a miniature bar magnet. We observe that the individual vortices can be pinned magnetically to the wall and follow the wall as it moves in a controlled way. The force acting on a single vortex in a $NbSe_2$ single crystal from the domain wall has been determined. The results are compared with model calculations, and show a good agreement. Our direct demonstration of a fast and controlled vortex manipulation and monitoring has an interesting potential for practical applications.

Spectral Properties of the Flux-Flow Noise at the Peak Effect **22EP38**

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Large voltage noise commonly observed in the vicinity of the peak-effect in superconductors is ascribed to a novel mechanism consisting in a dynamic admixture of two thermodynamically distinct metastable vortex phases. In the frequency domain the peak effect noise exhibits $1/f^{\alpha}$-like spectra. The response function of dynamically coexisting metastable vortex phases is shown to be similar to that of a first-order filter. The roll-off frequency at which the power exponent α changes is controlled by the time-of-flight of vortices across the region occupied by the disordered vortex phase.

New Evaluation Method for Optical Conductivity of Superconducting Thin Films **22EP39**

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A symmetry X optical setup has been developing for the absolute measurements of reflectance and transmittance of specular samples in the infrared region. Both the transmittance spectra and the geometric mean of the reflectance spectra were measured within the uncertainty of 0.4%, respectively. The solution of two simultaneous equations with the measured reflectance and transmittance determines the optical conductivities of the sample. These conductivities by the new method are compared with those by the the ordinary method using Kramers-Kronig relations with a measurement of either reflectance or transmittance.