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NOTA BENE: Happy anniversary to us! This issue marks the beginning of the twelfth year of publication of *High-T_c Update*. Our first issue was published May 1, 1987. That translates to 265 issues of the newsletter! In this time, the number of hard-copy subscribers have climbed to 1,000, electronic subscriber numbers have zoomed from about 300 in 1993 to 1,600 today, and we are receiving over 20,000 visits to the *HTCU* Web site every month! What does the future hold? We'll have to wait and see. Thank you for your support, encouragement—and preprints!

PrBa₂Cu₃O_{7-δ}

The properties of *PrBa₂Cu₃O_{7-δ}* (*PBCO*) have been of interest for some time because stoichiometric *PBCO* is the only antiferromagnetic insulator in the isostructural *R-123* family of superconducting cuprates ($T_C = 92 \pm 2$ K for *RBa₂Cu₃O_{7-δ}*, *R* = *Y*, *La*, and rare earths). Recently, however, evidence for superconductivity in specially prepared samples of *PBCO* has been found. A possible explanation of this superconductivity involves sample inhomogeneity: certain regions of the sample may be *Ba*-rich (*Ba* atoms replacing *Pr* on *Pr* sites), and in these regions the concentration of mobile Zhang-Rice singlet hole carriers may be raised above the threshold required for superconductivity.

To investigate the validity of this explanation, M. W. Pieper (Hamburg) et al. have used nuclear magnetic resonance of *Pr* and chain-site *Cu* to examine the nature of carriers doped in the *CuO₂* planes of *Pr_{1+x}Ba_{2-x}Cu₃O₇* single crystals when $x > 0$ (*Pr⁺-123*), $x = 0$ (*Pr⁰-123*), and $x < 0$ (*Pr⁻-123*). From the different spectra in the solid solution, the authors found that the holes in *Pr*-rich crystals (*Pr⁺-123*) are localized in states similar to those in stoichiometric samples (*Pr⁰-123*), i.e., in the $4f^2-2p\pi$ hybridization band proposed by Fehrenbacher and Rice. In contrast, the spectra of crystals prepared under conditions favoring *Ba*-rich phases (*Pr⁻-123*) indicate the presence of mobile holes in Zhang-Rice singlets in the *CuO₂* plane. The authors' results thus support the model that superconductivity reported recently in *Pr-123* crystals is due to *Ba*-rich regions in the inhomogeneous samples.

A preprint by W. L. Hults (Los Alamos) et al. reports the observation of superconductivity in some samples of

polycrystalline *PrBa₂Cu₃O_x*. A sample that by x-ray diffraction showed 97% *PrBa₂Cu₃O_x*, 0.3% *PrBaO₃*, and 2.3% *BaCuO₂* exhibited a small magnetically determined superconducting transition at 89 K and another transition at 12 K, each about 1% of the full Meissner fraction. The authors note that it is very difficult to fabricate the superconducting phase with appreciable probability, and that the material prefers to form in the insulating state.

Two preprints by H. A. Blackstead (Notre Dame) and J. D. Dow (Arizona State and NHMFL-Tallahassee) consider consequences of superconductivity in *PrBa₂Cu₃O₇* and argue that the primary superconducting condensate lies not in the *CuO₂* planes but rather in the charge-reservoir layers.

RBa₂Cu₃O_{7-δ}

Measurements by A. Hosseini et al. (UBC) of the surface impedance in *YBa₂Cu₃O_{7-δ}* show that the c-axis penetration depth and conductivity below T_C exhibit behavior different from that observed in the planes. The authors find that the c-axis penetration depth never has the linear temperature dependence seen in the ab plane, and instead of the conductivity peak in the planes, the c-axis microwave conductivity falls to low values in the superconducting state, then rises slightly below 20 K. According to the authors, these results show that c-axis transport remains incoherent below T_C , even though this is one of the least anisotropic cuprate superconductors.

A preprint by S. Kamal et al. (UBC) reports the growth of very high purity (99.995%) *YBa₂Cu₃O_{7-δ}* crystals in *BaZrO₃* crucibles and the measurement of $\Delta\lambda(T)$ and

$R_S(T)$ at 1 GHz in crystals with various oxygen treatments. For oxygen doping $\delta = 0.007$, $\Delta\lambda$ and R_S essentially reproduce the authors' previous results and show no sign of the two order-parameter components recently reported by H. Srikanth et al. [*Phys. Rev. B* **55**, R14733 (1997)] on $BaZrO_3$ -grown crystals. For other oxygen concentrations, the authors in some cases have observed deviations from the linear low-T dependence of $\Delta\lambda$, but never any sign of a second transition.

A numerical analysis of the effect of a rotating square $YBa_2Cu_3O_{7-\delta}$ crystal on the surrounding fluid flow in the pulling method has been performed by M. Egami (SRL-ISTEC and ISAS-Kanagawa) et al. The authors calculated the boundary-layer thickness and crystal growth rates for different rotation speeds.

Raman spectroscopy has been used by M. N. Iliev (TCSUH) to show that at the microscopic level the structure of $YBa_2Cu_3O_x$ ($6 < x < 7$) compounds consists of coexisting domains of Ortho-I, Ortho-II, T, and T'-type oxygen ordering. Variation of x changes the relative weights of the domains and their contributions to the complex Raman spectra. In the overdoped case ($7 < x < 8$), the microstructure changes significantly as chain-oxygen atoms are shifted from their centrosymmetric sites and produce zig-zag chains instead of linear chains.

Bi Cuprates

A study of the Wohleben effect (WE), the appearance of a paramagnetic moment of the sample when cooled in a constant magnetic field < 0.5 Oe, also called the paramagnetic Meissner effect (PME), in powders of $Bi_2Sr_2CaCu_2O_{8+\delta}$ (*Bi-2212*) consisting of isolated grains with dimensions d in the range $1 \mu m < d < 1$ mm has been carried out by N. Knauf (Köln) et al. The authors found that: (a) The WE was present in all powders studied, even for $1 \mu m$ grains. (b) The field-cooled and zero-field-cooled susceptibilities, as well as the microwave absorption (MWA), are strongly suppressed for $d < 30$ - $50 \mu m$, probably because the grain size becomes smaller than the c -axis penetration depth. (c) In aligned powders, the WE is strongest for magnetic fields parallel to the c axis. The data give evidence that the WE is an intra-grain property (i.e., it is not predominantly determined by intergrain weak links) and that the spontaneous currents flow within the ab planes. The presence of the WE in $1 \mu m$ grains requires that the critical current density of the π contacts, which are generally assumed to explain the spontaneous currents, must be of order 10^5 - 10^6 A/cm², even close to T_C .

A preprint by Y. S. Sudershan (IIS-Bangalore) et al. reports a study of the isothermal magnetic field-dependent rf power dissipation $P(H)$ for $H||c$ and $H_{rf}||a$ in the superconducting state of $Bi_2Sr_2CaCu_2O_{8+\delta}$ (*Bi-2212*) single crystals before

and after irradiation with 250 MeV $^{107}Ag^{17+}$ ions, which produces amorphous columnar defects. The authors observe a change in the behavior of $P(H)$ upon irradiation, and they attribute this change to the strong enhancement of the vortex tilt modulus c_{44} when the pancake vortices in adjacent CuO_2 bilayers are pinned within the columnar defects. The authors also observed that the rf dissipation disappears below 69 K, the temperature at which the vortex core diameter becomes equal to the columnar defect diameter.

A related paper by Y. S. Sudershan (IIS-Bangalore) et al. reports measurements of the magnetic field-dependent rf (20 MHz) power dissipation $P(H)$ vs. H for $H_{rf}||H||c$ in $Bi_2Sr_2CaCu_2O_{8+\delta}$ (*Bi-2212*) single crystals. The magnetic field dependence shows an onset at 102 K, well above the nominal $T_C \sim 82$ K. The authors attribute this effect to superconducting fluctuations.

The development of a cryogenic deformation technique that improves the critical current density J_C of silver-sheathed $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+\delta}$ [*(Bi,Pb)-2223*] superconducting tapes is reported in papers by Y. C. Guo (Wollongong) et al. and S. X. Dou et al. (Wollongong). A typical cryogenic deformation process involves rolling or pressing the wires into tapes at 77 K and then heat treating the tapes at 838-842°C for a period of 40-60 h. The authors found that the cryogenic deformation improves the density, grain alignment, Ag/oxide core interfacial area, and hence the critical current density.

According to a preprint by N. D. Zhigadlo (Minsk) et al., the addition of Cs to $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ [*(Bi,Pb)-2223*] is effective in forming the high- T_C phase and enhancing the superconducting properties. A preprint by H. Maeda (Tohoku and NRIM) et al. reports that V doping of *(Bi,Pb)-2223* enhances the 2223 phase formation without degradation of T_C and leads to increased J_C .

Other Cuprates

As reported by G. Balestrino et al. (Roma), $(CaCuO_2)_m/(BaCuO_2)_n$ and $(SrCuO_2)_m/(BaCuO_2)_n$ superlattices with good crystallographic quality can be engineered by pulsed laser deposition over a wide range of compositions for $n = 2$ and $1 \leq m \leq 6$. The authors report, however, that the Sr- and Ca-based superlattices have qualitatively different electrical transport properties. Superconductivity is found only for the Ca-containing superlattices. The resistivity of the Ca-containing superlattices grown at high oxygen pressure (> 0.2 mbar) was found to be metallic with a full transition to a superconducting state at temperatures as high as 70 K (zero-resistance transition temperature). The authors note that while this value of T_C is the highest yet reported for an artificial structure, it is still lower than that of the related $CuBa_2Ca_{n-1}Cu_nO_x$ compounds ($T_C = 116$ K) obtained by high-pressure synthesis.

Electronic Raman scattering measurements are reported by A. Sacuto (ENS-Paris) et al. for $HgBa_2Ca_2Cu_3O_{8+\delta}$ (*Hg-1223*) single crystals in the superconducting state. Pure electronic Raman spectra with no phonon structures hindering the analysis of the electronic continuum were obtained. Below T_C , two electronic structures at $2\Delta \approx 6.4 k_B T_C$ and $2\Delta \approx 9.4 k_B T_C$ were seen. Both were observed simultaneously in pure A_{1g} symmetry, the one with higher energy being located at the energy of the B_{1g} maximum. The two maxima do not soften significantly as the temperature is raised up to T_C , but they disappear at and above T_C . The low-energy frequency dependence of the B_{1g} electronic response is linear for various excitation lines in the 476.5 to 647.1 nm range. The authors assert that such experimental data cannot be reconciled with pure $d_{x^2-y^2}$ symmetry. Instead, the data favor an anisotropic superconducting gap with two distinct gap maxima and nodes existing outside the $[110]$ and $[\bar{1}\bar{1}0]$ directions in k space. The authors discuss the simplest model order parameter that is compatible with their experimental findings.

Vortices

The first-order vortex-lattice phase transition has been observed by T. Sasagawa et al. (Tokyo) in $(La_{1-x}Sr_x)_2CuO_4$ (*LSCO*) single crystals ($0.046 \leq x \leq 0.077$). A scaling law, $H_{pt}(T) = 2.85\gamma^2 s^{-1}(T_C/T - 1)$ Oe, was found to hold for the phase transition lines not only in this system but also in $YBa_2Cu_3O_{7-\delta}$ (*Y-123*) and $Bi_2Sr_2CaCu_2O_{8+\delta}$ (*Bi-2212*) for fields $H \parallel c$. Here, $\gamma^2 = m_c/m_{ab}$ is the anisotropy factor, and s is the superconducting layer spacing: $s = 6.6 \text{ \AA}$, 11.7 \AA , and 15.4 \AA for *LSCO*, *Y-123*, and *Bi-2212*, respectively. The authors assert that this form of scaling provides strong evidence that the first-order phase transition in high- T_C superconductors manifests itself as vortex-lattice sublimation, rather than melting. In other words, at fields and temperatures above the phase transition, the vortex lines split up into a pancake-vortex gas with no correlation between pancake vortices along the c direction.

The resistive transitions into a glassy vortex state in oxygen-deficient $YBa_2Cu_3O_{7-\delta}$ twinned single crystals of varying anisotropy γ ($8.7 \leq \gamma \leq 35$) have been studied by B. Lundqvist et al. (Royal Institute of Technology, Stockholm) with an applied magnetic field along the c axis. For $B \geq 1$ T, the authors found the glass line to be well described by the empirical relation $B_g = B_0[(1 - T/T_C)/(T/T_C)]^\alpha$, where $\alpha \approx 1$ and $B_0 \approx 1.85 \phi_0/(\gamma s)^2$. The values obtained for five single crystals were $\alpha = 1.21$, $T_C = 91.3$ K, and $\gamma = 8.7$; $\alpha = 1.05$, $T_C = 86.2$ K, and $\gamma = 13$; $\alpha = 0.98$, $T_C = 73.2$ K, and $\gamma = 19$; $\alpha = 1.06$, $T_C = 62.2$ K, and $\gamma = 28$; and $\alpha = 1.27$, $T_C = 51.8$ K, and $\gamma = 35$. The authors also found good fits to data on thin films of *Tl-2212* ($\alpha = 1.59$ and 1.82) and *Bi-2223* ($\alpha = 1.82$).

By applying a Lindemann-like criterion used previously by Kierfeld et al. [*Phys. Rev. B* **55**, 626 (1997)], J. Kierfeld (Köln) has estimated the magnetic field and temperature at which a topologically ordered vortex-glass phase in a high- T_C superconductor becomes unstable to disorder-induced formation of dislocations. The author shows that the criterion used is equivalent to a conventional phenomenological Lindemann criterion, including values of the numerical factors, such as the Lindemann number c_L .

A model of the effective interaction between 2D pancake vortices in layered superconductors has been derived by Z.-X. Cai (Brookhaven) et al. using the Lawrence-Doniach model. The authors show that the intralayer interaction energy of the logarithmically interacting pancake vortices can be evaluated analytically with the help of the Ewald summation technique. Using Langevin dynamics simulations, the authors evaluated the isothermal shear modulus c_{66} of flux-line lattices for various values of the interlayer coupling strength.

The vortex response to various ac drives has been studied by V. Metlushko (Argonne) et al. in high-quality $YBa_2Cu_4O_8$ single crystals. Well within the vortex solid phase, the authors observed a re-entrant resistive state, characterized by long relaxation times. The pulsed-current response and I-V characteristics reveal that in this state the driven vortex system relaxes in such a way as to increase the effective pinning force. The authors propose a phenomenological model to account for the observed features, in particular the clockwise hysteresis of the I-V curves and the increase of the apparent critical current with applied current amplitude.

The stability of the square vortex lattice, which recently has been observed in experiments on the borocarbide superconductors, has been investigated theoretically by K. Park and D. A. Huse (Princeton). To take into account the tetragonal symmetry, the authors added four-fold symmetric fourth-derivative terms to the Ginzburg-Landau free energy. The authors used nonperturbative numerical calculations to locate the boundary in the H-T phase diagram between the distorted hexagonal and square vortex lattices.

Thin Films

An extensive study of the optimal oxygenation of $YSr_2Cu_{2.75}Mo_{0.25}O_z$ thin films has been carried out by J. P. Sydow et al. (Cornell). The authors found that optimization of oxygen content can be accomplished globally by ozone anneals at 1 atm and locally by electromigration of chain-oxygen vacancies out of thin-film microbridges. Both techniques lead to a maximal $T_C = 75$ K, substantially higher than has been achieved previously in this material.

In principle, magneto-optical investigations of flux penetration into type-II superconductors allow the determination of the local critical current density \mathbf{J} by inversion of the Biot-Savart law. Because of the computational effort, however, this method has been limited to relatively low spatial resolution of the current density. Using fast Fourier transforms, Ch. Jooss et al. (MPI-Stuttgart) have developed a fast inversion scheme that images the current distribution in the entire sample with high spatial resolution. The authors demonstrate the power of their method by imaging the local current density in a $YBa_2Cu_3O_{7-\delta}$ square and in a disk in increasing and decreasing external magnetic fields. The authors also image the perturbations of the local current density near macroscopic defects in a square and a disk.

A paper by K. Fujino et al. (Sumitomo) reports the investigation of double-sided deposition of large-area $YBa_2Cu_3O_{7-\delta}$ thin films. The authors used pulsed laser deposition equipment with an off-axis geometry to deposit films on $LaAlO_3$ substrates with a diameter of 3 in. The resulting films exhibited 77.3 K J_C 's in excess of 10^6 A/cm² over the entire area of the double-sided film.

Spectroscopic ellipsometry has been used by M. E. Bijlsma et al. (Twente) to do *in-situ* investigations of the optical properties of high-quality $YBa_2Cu_3O_6$ thin films deposited by off-axis magnetron sputtering. The optical transitions at 4 eV of films that were not exposed to the atmosphere were found to have a magnitude that is twice as high as previously reported and to be described by a single Lorentz oscillator throughout the temperature range 20-700°C.

Measurements of the critical temperature of $YBCO/ YBa_2Cu_3-xCo_xO_{7+\delta}$ superconductor/normal bilayer films are reported by E. Polturak (Technion) et al. The authors found that, depending on the morphology of the S-N interface, the coupling between S and N layers can be turned up to depress the T_C of S by tens of degrees, or turned down so that the layers appear to be almost completely decoupled. This novel effect can be explained by the mechanism of quasiparticle transmission into an anisotropic superconductor.

Electron-beam irradiation has been used by F. Tafuri (Napoli) et al. to produce controllable variations in the properties of $YBa_2Cu_3O_{7-\delta}$ biepitaxial grain-boundary Josephson junctions. The authors found that electron irradiation changes the current-voltage (I-V) characteristics by modifying the oxygen content in the vicinity of the grain boundaries.

The electrical transport properties of symmetrical [001] tilt $Nd_{1.85}Ce_{0.15}CuO_{4-y}$ bicrystal grain-boundary Josephson junctions fabricated on $SrTiO_3$ bicrystal substrates with misorientation angles of 24° and 36.8° have been studied by S. Kleefisch (Köln) et al. The authors found that the

superconducting properties of these junctions are very similar to those of grain-boundary junctions fabricated from hole-doped high-temperature superconductors. This suggests that the symmetry of the order parameter, which most likely is different for the electron- and hole-doped high-temperature superconductors, has little influence on the characteristic properties of the symmetrical [001] tilt grain-boundary Josephson junctions.

Two papers by R. N. Bhattacharya (NREL) et al. report on the properties of electrodeposited (ED) $TlBa_2Ca_2Cu_3O_9$ (*Tl-1223*) films. One of these reports $J_C(77K,0T)$ above 1.6×10^5 A/cm² for strongly biaxially textured *Tl-1223* films electrodeposited on *Ag*-coated single-crystal $LaAlO_3$. The authors suggest that electrodeposition offers a promising and economic approach for fabricating superconducting wire or tape, and they project costs upon scale-up at or below \$10/kAm for an ED-based *Tl*-oxide tape process.

As reported by W. N. Kang (Kansas and TCSUH) et al., mixed-state Hall-effect measurements of $HgBa_2CaCu_2O_{6+\delta}$ (*Hg-1212*) thin films after radiation with high-energy *Xe* ions reveal that the Hall scaling exponent β in $\rho_{xy} = A\rho_{xx}^\beta$ not only increases from 1.0 ± 0.1 to 2.0 ± 0.05 with increasing fields up to 8 T, but also increases from 1.0 ± 0.1 to 1.5 ± 0.05 as the angle between the columnar tracks and the magnetic field of 4 T decreases from 75° to 0°. The observation of $\beta = 1$ is consistent with a recent theory based on d-wave superconductivity [N. B. Kopnin and G. E. Volovik, *Phys. Rev. Lett.* **79**, 1377 (1997)], where it is predicted that the Hall angle has a universal behavior independent of the mean-free path in the low-field region.

The thermal peeling stress in a thin high- T_C superconducting film resulting from the temperature decrease from high processing temperatures to cryogenic operating temperatures has been calculated by B. Gu and P. E. Phelan (Arizona State) using finite element analysis. The method reveals a stress singularity at the very edge of the film that is not predicted by analytical calculations.

Intrinsic Josephson Junctions

A paper by K. Schlenga (Erlangen-Nürnberg) et al. presents a detailed discussion of the current-voltage characteristics of intrinsic Josephson junctions in $Bi_2Sr_2CaCu_2O_{8+\delta}$ (*Bi-2212*) and $Tl_2Ba_2Ca_2Cu_3O_{10}$ (*Tl-2223*). In these materials, Josephson tunnel junctions are formed naturally between adjacent superconducting CuO_2 bilayers or trilayers. The current-voltage characteristics of every individual junction exhibits pronounced structures in the subgap regime. These structures are best explained by a recently proposed resonant coupling mechanism between infrared active optical c-axis phonons and oscillating Josephson currents.

The collective switching of stacked intrinsic Josephson junctions in the current-voltage characteristics of $(\text{Bi,Pb})_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10+\delta}$ [(Bi,Pb)-2223] thin films has been studied by M. Sakai et al. (Matsushita Electric). In a current-biased measurement, collective switching has been observed, while in a voltage-biased measurement, clear branching structure has been observed. The authors explain these effects by taking effective heat diffusion into account.

Applications

The properties of YBCO/SrTiO₃ thin-film K-band tunable bandpass filters on LaAlO₃ substrates are reported by G. Subramanyam (Northern Iowa) et al. The two-pole filters were designed for a center frequency of 19 GHz and 4% bandwidth. Tunability is achieved through the nonlinear dc electric field dependence of the relative dielectric constant of SrTiO₃. Center frequency shifts of more than 2 GHz were obtained at a 400 V bipolar dc bias at temperatures below 77 K, with minimal degradation in the insertion loss of the filters.

The operation and testing of a high-temperature superconducting (HTS) high-gradient magnetic separator (HGMS) are reported by J. A. Selvaggi (Eriez Magnetics) et al. The separator magnet is made of 624 m of Ag/Bi-2223 wire and has overall dimensions of 18 cm OD, 15.5 cm height, and 5 cm ID. HTS current leads are used to reduce the heat leak to the magnet. The system operates in a vacuum and is cooled by a two-stage Gifford-McMahon cryocooler. HGMS experiments were performed using this system to demonstrate the performance of HTS magnetic separators.

Theory

A new method for calculating the free energy of an inhomogeneous superconductor has been developed by I. Kosztin (Illinois-Urbana and Chicago) et al. The method is based on the quasiclassical limit (or Andreev approximation) of the Bogoliubov-de Gennes (or wave-function) formulation of the theory of weakly coupled superconductors. The method is applicable to any pure bulk superconductor described by a pair potential with arbitrary spatial dependence in the presence of supercurrents and an external magnetic field. The local density of states and the free-energy density of an inhomogeneous superconductor can be expressed in terms of the diagonal resolvent of the corresponding Andreev Hamiltonian, which obeys the Gelfand-Dikii equation. The authors point out the connection between this approach and the well-known Eilenberger equations for the quasiclassical Green's function. The results are used to construct a general algorithm for calculating the gauge-invariant gradient expansion of the free-energy density of an inhomogeneous superconductor at arbitrary temperatures.

A new parameterization of the Eilenberger equations of superconductivity in terms of solutions of a scalar differential equation of the Riccati type has been found by N. Schopohl (Tübingen). The author shows that the quasiclassical propagator and the local density of states may be reconstructed, without explicit knowledge of any eigenfunctions or eigenvalues, by solving a simple initial-value problem for the linearized Bogoliubov-de Gennes equations. The Riccati parameterization of the quasiclassical propagator leads to a stable and fast numerical method for solving the Eilenberger equations.

The anomalous proximity effect between a d-wave superconductor and a surface layer with small electronic mean free path has been studied theoretically by A. A. Golubov (Twente and ISSP-Chernogolovka) and M. Yu. Kupriyanov (Twente and Moscow State). The authors calculate the angular and spatial structure of the pair potential and the quasiclassical propagators in the interface region self-consistently. The authors find that an isotropic gapless superconducting state is induced in the disordered layer.

The effect of nonmagnetic impurities in the superconducting state of the t-J model has been studied by H. Tanaka (Kobe) et al. The authors derived the Bogoliubov-de Gennes equation using a slave-boson mean-field approximation and solved it numerically at $T = 0$. The $d_{x^2-y^2}$ order parameter is suppressed near an impurity, and its spatial variation induces an extended s-wave component. The authors also find a local charge-density-wave-like feature due to Friedel oscillations, and this leads to a splitting of the expected zero-energy Andreev bound state. Because the zero-energy state is removed, a transition to a state that violates time-reversal symmetry or produces antiferromagnetic order is unlikely to occur.

A preprint by I. Zutic and O. T. Valls (Minnesota) considers an unconventional superconductor in a low-frequency harmonic magnetic field. In the Meissner regime at low temperatures, a nonlinear magnetic response arises from quasiparticle excitations near minima in the energy gap. As a consequence, various physical quantities acquire higher harmonics of the frequency of the applied ac field. The authors discuss how examination of the field and angular dependence of these harmonics allows determination of the structure of the energy gap. In particular, the authors show how to distinguish nodes from small finite minima (quasinodes).

As shown by T. V. Ramakrishnan (IIS-Bangalore), the interaction between planar quasiparticles in a $d_{x^2-y^2}$ superconductor and quantized vortices associated with a magnetic field perpendicular to the plane induces a pair potential with d_{xy} symmetry, out of phase with the $d_{x^2-y^2}$ order. The author argues that the resulting fully gapped state may be the high-field, low-temperature phase

observed by K. Krishana et al. [*Science* **277**, 83 (1997)] in magnetothermal conductivity measurements in superconducting single-crystal *Bi-2212*.

A phase diagram for a quasi-2D metal with variable carrier density has been derived by V. M. Loktev (Kiev) et al. The phases present are the normal phase where the order parameter is zero, the pseudogap phase where the absolute value of the order parameter is nonzero but its phase is random, and two superconducting phases. One of these is the quasi-2D Berezinskii-Kosterlitz-Thouless phase, and the other is a phase with long-range order.

Pairing effects in the edge states of paired fractional quantum Hall states have been studied by K. Ino (ISSP-Tokyo) using persistent edge currents as a probe. The author finds that the currents are flux periodic with period hc/e at higher temperatures but that anomalous oscillations develop at low temperatures, converging to a sawtooth function with period $hc/2e$ at zero temperature, indicating pair condensation.

A macroscopic Coulomb blockade model of density-wave transport has been developed by J. H. Miller, Jr. (TCSUH). In this model, an electric field E induces the creation, by quantum tunneling, of pairs of oppositely charged solitons and antisolitons in a density wave. The author suggests that some aspects of the theory may apply to tunneling of vortices in superconductors and long Josephson junctions.

Other Activities

The interference of proximity-induced superconducting correlations in mesoscopic metallic rings is sensitive to the magnetic flux Φ inside these rings. This is the reason for magnetoconductance oscillations in such systems. Using devices with superconducting *Al* and normal *Ag* elements, V. N. Antonov (NTT) et al. have detected experimentally and explained theoretically a novel effect: The phase of these oscillations can switch between 0 and π depending on the resistance of intermetallic interfaces and temperature. The effect is due to a nontrivial interplay between the proximity-induced enhancement of the local conductivity and the proximity-induced suppression of the density of states at low energies.

Overview

A book chapter by A. Hoffmann (UCSD-La Jolla) et al. discusses persistent photoconductivity. Upon

illumination, underdoped $YBa_2Cu_3O_{7-\delta}$ for example, shows a decrease of resistivity and an increase of T_C . The photo-induced changes are persistent at low temperatures but relax at room temperature. A possible explanation is that electrons of photoinduced electron-hole pairs are trapped at localized states spatially separated from the conduction layer. The authors recently observed persistent photoconductivity in $Tl_2Ba_2CuO_{6+\delta}$ (*Tl-2201*) and Y-doped $Bi_2Sr_2CuO_6$ (*Bi-2201*), which suggests that persistent photoconductivity might be a common phenomenon in high- T_C superconductors (37 refs.).

Ph.D. Theses

The Stuttgart Ph.D. thesis of B. Lederle reports theoretical and experimental determinations of the phonon Raman scattering efficiency of several high- T_C superconductors. Included are studies of $YBa_2Cu_3O_{7-\delta}$, $YBa_2Cu_4O_8$, $Y_2Ba_4Cu_7O_{15-\delta}$, $PrBa_2Cu_3O_{7-\delta}$, and $Ba_{1-x}K_xBiO_3$. The thesis contains Raman measurements of the absolute scattering efficiencies of all c-polarized phonons vs. laser frequency, and comparisons with extensive LMTO-ASA band-structure calculations of the corresponding Raman tensors. The author was able to observe interference effects between the complex components of the Raman tensors for polarizations that are off the crystal axes (208 refs.).

A thorough investigation of crystal-field effects in the f-electrons of *Nd* and other rare-earth-based 123 and 214 cuprates is described in the Ph.D. thesis of T. Strach (Stuttgart). Special attention is given to the interaction of phonons with crystal-field f-levels. Having determined the eigenvectors of the 115 cm^{-1} and 150 cm^{-1} phonons of 123 materials by isotopic substitution, the author discusses the results theoretically (209 refs.).

The Jena Ph.D. thesis of G. Kaiser (Dresden) reports the results of theoretical and experimental investigations of the conditions for successful operation of high-temperature superconducting (HTS) sensors with small-scale closed-cycle cryocoolers. The author introduces models to describe the influence of cryocooler disturbances on HTS dc SQUID magnetometers, gradiometers, bolometers, and double bolometers, and reports measurements of these disturbances (134 refs.).

Contributed by John R. Clem

Contents: Technology News is on page 7; Preprints begin on page 7; and Coming Events begin on page 14.

High-T_c Update is available without charge to interested persons. Recipients are expected to participate in this information exchange by sending us preprints, reprints, meeting news, research news, etc. Contributions to defray the cost of newsletter printing and mailing are welcome.

TECHNOLOGY NEWS

(Also see *Applications* section of *Nota Bene*.)

This section describes progress in manufacturing, product development, and technology transfer in the high-T_c superconductivity field. Please send your contributions (product development information, news regarding technology transfer efforts, or any information you would like to share about your corporation or laboratory) to the editor.

Using the PIT (powder-in-tube) technology, Alcatel Cable (France) have successfully produced 1000 meters of Bi-based superconducting wire with current densities that exceed 200 A/mm² at liquid-nitrogen temperatures. The production of this wire is the first step towards the construction of high magnetic field coils. Eventually the company plans to use the wires for superconducting power cables. For further information, contact Wendy Wilmouth, Alcatel Cable France, S.A. 30, rue Pierre Bérégovoy, BP 309, F-92111 Clichy Cedex, France; telephone +33 1 47 56 66 20; telefax +33 1 47 56 69 24; e-mail wendy.wilmouth@accyd.alcatel.fr.

A key player in the development of wireless communications filter products utilizing superconducting materials and cryogenic technologies, Superconductor Technologies Inc. (STI) recently announced that it has scheduled field trials of its SuperFilter™ system with more

than 20 different wireless carriers, which include eight of the top ten cellular service providers in the U.S. These trials will be conducted at more than twenty-five cell sites during the next four months. STI also announced that it had received orders for fifteen SuperFilter™ systems in the first quarter of 1998, giving it a backlog of twenty-three systems at quarter end, the majority of which will be shipped during the second quarter of 1998. Additionally, revenues for commercial products for the first quarter of 1998 are expected to exceed commercial revenues realized during the entire year of 1997. According to officials at STI, interest by carriers in superconducting filter technology is increasing rapidly as customers see more evidence of its capabilities to solve problems of range and call quality that are becoming more important as competition increases. For information, contact Superconductor Technologies Inc., 460-F Ward Drive, Santa Barbara, CA 93111-2310; telephone (805) 683-7646; telefax (805) 967-0342; e-mail info@suptech.com.

Contributed by Sreeparna Mitra

PREPRINTS

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COMING EVENTS

(An * indicates a previously listed event.)

***May 26 - 28, 1998:** 10th International Cryocooler Conference, Monterey Conference Center, Monterey, Calif. Invited technical topics include Stirling and pulse-tube cryocoolers, J-T and sorption cryocoolers, G-M and TEC cryocoolers, new concepts, component developments, modeling and test techniques, performance and life test data, applications and integration issues, and low-cost coolers. Oral and poster sessions. For information, contact Peter Kittel, ICC10, MS-244-10, NASA/Ames Research Center, Moffett Field, CA 94035-1000; telephone (650) 604-4297; telefax (650) 604-1094; e-mail pkittel@mail.arc.nasa.gov; Web site <http://www.cryosource.com/ic10.html>.

July 14 - 17, 1998: Seventeenth International Cryogenic Engineering (ICEC 17), Bournemouth International Centre, Bournemouth, United Kingdom. Purpose is to bring together people from universities, research institutions, and industry to stimulate the fruitful exchange of information and ideas in cryogenic engineering, to outline actual trends, and to discuss present and future developments. Subjects for ICEC 17 are expected to include: large- and small-scale refrigeration, liquefaction, and gas-separation technology; space applications of cryogenic engineering; materials and fluid properties and their influence on the design of low-temperature equipment; high-temperature ceramic superconductors and low-temperature metallic superconductors – their manufacture and applications; active/passive superconducting devices – their manufacture and applications; cryoelectronics including superconducting and nonsuperconducting circuitry; cryogenic wind tunnels; applications of cryogenics to medicine, biology, and food preservation; liquid helium, hydrogen, and neon technology; centenary of hydrogen liquefaction; and significant contributions dealing with other aspects of cryogenic engineering. For information, contact ICEC 17 Conference Office, Kryos Associates, 22 Brookvale Road, Southampton SO17 1QP, United Kingdom; telephone +44 1 703 579762; telefax +44 1 703 579762; e-mail ICEC17@soton.ac.uk; Web site <http://www.soton.ac.uk/~crenergy/ICEC17/index.html>.

July 19 - 24, 1998: SPIE's 43rd Annual Meeting: International Symposium on Optical Science, Engineering, and Instrumentation, San Diego Convention Center and Marriott Hotel and Marina, San Diego, Calif. Will include sessions on superconducting superlattices (native and artificial) and the physics and nanoengineering of superconducting and related oxides. For information, contact SPIE, P.O. Box 10, Bellingham, WA 98227-0010; telephone (360) 676-3290; telefax (360) 647-1445; e-mail sd98@spie.org; Web site <http://www.spie.org/info/sd/>.

***July 19 - 24, 1998:** Gordon Research Conference on Correlated Electron Systems, Plymouth State College, Plymouth, N.H. Conference will survey significant experimental and theoretical developments in the study of electronic correlations in the cuprates and related materials, heavy-fermion systems, and two-dimensional electron gases. Co-Chairs: Laura H. Greene and Subir Sachdev. A substantial block of time will be set aside for discussions to be coordinated by the session chair. Will include formal invited sessions and contributed poster sessions; discussion on posters will be integrated into the formal sessions. Topics are: spin chains and ladders, mesoscopic superconductivity, broken time-reversal symmetry, correlated fermions in adsorbed layers, one-dimensional conductors, heavy fermions, and two-dimensional electron gas. All prospective attendees (including invited speakers) must submit an application. **Application deadline, June 5, 1998.** For information,

contact Gordon Research Conferences, University of Rhode Island, P.O. Box 984, West Kingston, RI 02892-0984; telephone (401) 783-4011; telefax (401) 783-7644; e-mail app@grcmail.grc.uri.edu (for application form requests) or grc@grcmail.grc.uri.edu (for general information). Information also available at Web site <http://sachdev.physics.yale.edu/grc/index.html>.

***July 20 - 31, 1998:** Tenth Trieste Workshop on Open Problems in Strongly Correlated Electron Systems, Miramare, Trieste, Italy. Workshop will include both experimentalists and theorists, and will foster the interaction between these two components of the field. Topics include: disorder and strong correlations, realizations of correlated electron physics in mesoscopic devices, non-Fermi-liquid physics, experimentally motivated aspects of cuprate physics, old and new puzzles in heavy fermion physics, and other new phenomena in transition metal oxides. Workshop is open to research workers from all countries that are members of the United Nations, UNESCO, or IAEA. No registration fee. For information, contact the Abdus Salam International Centre for Theoretical Physics, P.O. Box 586, I-34100 Trieste, Italy; telephone +39 40 2240111; telefax +39 40 224163; e-mail smr1068@ictp.trieste.it; Web site <http://www.ictp.trieste.it/>.

***Sept. 10 - 15, 1998:** XXII International School of Theoretical Physics – Quantum Coherence in Superconductors and Nanostructures, Ustron, Poland. Topics include quantum coherence in nanostructures, Coulomb blockade in quantum dots, strongly correlated electrons in high-temperature superconductivity, and coherent phenomena in superconductors. **Abstract deadline, May 30, 1998; registration deadline, June 30, 1998.** For information, contact Elzbieta Zipper, Institute of Physics, University of Silesia, ul. Uniwersytecka 4, 40-007 Katowice, Poland; telephone +48 32 583653; telefax +48 32 588431; e-mail thschool@us.edu.pl; Web site <http://server.phys.us.edu.pl/thschool/>.

***Sept. 13 - 18, 1998:** The 1998 Applied Superconductivity Conference (ASC), Marriott's Desert Springs Resort, Palm Desert, Calif. Conference will include papers in three major areas of applied superconductivity: electronics, materials, and large-scale applications. For 1998, the theme *Superconductivity – Coming to Market*, will be developed through a series of plenary and invited talks. Selected papers will be published in *IEEE Transactions on Appl. Supercond.* For general information contact Centennial Conferences, 4800 Baseline Rd., A-112, Boulder, CO 80303; telephone (303) 499-2299; telefax (303) 499-2599; e-mail centennial@orci.com; Web site <http://www.ascinc.org>. For technical information, contact Ron Scanlan, Applied Superconductivity Conference, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd., MS 46-161, Berkeley, CA 94720; telephone (510) 486-7241; telefax (510) 486-5310; e-mail rmscanlan@lbl.gov; Web site <http://www.ascinc.org>.



Dr. Sreeparna Mitra
A219 Physics
Ames Laboratory
Iowa State University
Ames, Iowa 50011-3020

ADDRESS CORRECTION REQUESTED



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Dr. Sreeparna Mitra
A219 Physics
Ames Laboratory
Iowa State University
Ames, Iowa 50011-3020
Telephone: (515) 294-3877
Telefax: (515) 294-1134
E-mail: MITRA@AMESLAB.GOV
MITRA@IASTATE.EDU

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