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YBCO Coated Conductors

The E-J characteristics and resistive transitions of a $YBa_2Cu_3O_{7-\delta}$ (YBCO) film deposited onto polycrystalline Hastelloy with a biaxially aligned yttria-stabilized-zirconia (YSZ) buffer layer produced by inclined-substrate pulsed-laser deposition (ISPLD) have been examined by R. A. Doyle et al. (IRC-Cambridge). The YSZ films were fabricated on electrochemically polished Hastelloy-C substrates using a 248 nm KrF excimer laser and inclining the substrate normal by 55° relative to the plume axis. The substrate inclination resulted in alignment of the YSZ layer within the surface plane, with a full width at half maximum (FWHM) less than 30°, and c-axis orientation [(001) direction normal to the surface plane]. YBCO films of thickness 1 μm were deposited on the YSZ by pulsed-laser deposition (PLD). The YBCO films had better in-plane alignment (18° FWHM) than the underlying buffer layer but had about a 5° c-axis misalignment.

The authors studied the field dependence of the critical current and irreversibility line of the YBCO films for magnetic fields aligned parallel and perpendicular to the ab-planes. The critical current at 77 K was found to be 8×10^4 A/cm² in zero field and 6×10^3 A/cm² in a 6 T field parallel to the ab-planes. The angular dependence of the E-J characteristics suggests that both intrinsic pinning and pinning by twin planes or low-angle grain boundaries play an important role. The authors note that while the properties of these films are still not as attractive as those obtained using ion-beam-assisted deposition (IBAD), the present results show that the ISPLD sample-preparation method is able to produce films with properties that are superior to those of Bi-2223 conductors at 77 K in high magnetic fields.

The strain sensitivity of YBCO coated conductors has been investigated by C.L.H. Thieme (American Superconductor Corporation) et al. via measurements of the critical current density J_C in self-field at 77 K as a function of applied tensile strain. The YBCO coated

conductor used an Inconel substrate. One side was coated with a biaxially textured YSZ buffer layer using IBAD, and subsequently was coated with a 2.5 μm YBCO layer by PLD. The superconductor was then coated with a silver cap layer. The authors found that at 77 K, a strain of up to 0.5% does not change J_C by more than 3%. This strain dependence is better than the tensile-stress dependence when samples are bent at room temperature.

A preprint by M. W. Rupich (American Superconductor Corporation) et al. reports the properties of metal-oxide ($SrTiO_3$, $LaAlO_3$, and $BaZrO_3$) buffer-layer films grown on single-crystal oxide substrates by solution deposition. The authors used a metal-organic deposition technique using metal alkoxides as the starting precursor materials. The resulting films were extremely smooth and fully dense, and the quality of the films also was examined by depositing YBCO films on them using a pulsed-laser-deposition (PLD) technique. A 0.3 μm YBCO film deposited on a $LaAlO_3$ film, which had been grown at 800°C on a single-crystal $SrTiO_3$ substrate, was epitaxial and had a zero-resistance T_C of 90.4 K and a 77 K self-field J_C of 2.2×10^6 A/cm². The authors report, however, that further optimization of the deposition and growth conditions will be needed to obtain films of this quality on deformation-textured metal substrates.

RBa₂Cu₃O_{7-δ}

As reported by A. Crisan (Southampton and Bucharest) et al., the resistive transitions R(T) and current-voltage (I-V) characteristics in the range 10^{-9} - 10^{-6} V and close to T_C have been measured using a SQUID picovoltmeter in a single grain of melt-textured YBCO and in a detwinned YBCO single crystal with the current parallel to the ab-planes and in zero applied magnetic field. For $T < T_C$, the authors could interpret the lower part of the I-V curves in the framework of the H. J. Jensen and P. Minnhagen [*Phys. Rev. Lett.* **66**, 1630 (1991)] model of current-induced unbinding of thermally created vortex-

antivortex pairs, which leads to $V \propto I(I-I_C1)^{2-1}$. The results also confirm a recently proposed current-temperature (I-T) phase diagram of S. W. Pierson [*Phys. Rev. B* **55**, 14536 (1997)].

A study of the effect of $KClO_3$ and K_2CO_3 additives upon the transition temperature T_C , ac susceptibility, and microstructure of YBCO ceramic superconductors is reported by A. Veneva (Sofia) et al. The authors found that T_C was higher in all $KClO_3$ -doped samples than in both K_2CO_3 -doped and undoped $YBa_2Cu_3O_{7-\delta}$. Measurements of the magnetic susceptibility of $KClO_3$ -doped $YBa_{1.8}K_{0.2}Cu_3O_{7-\delta}$ showed an onset $T_C = 105$ K.

Enhancements of interface pinning and aging of the critical currents in $NdBa_2Cu_3O_{7-\delta}/Nd_4Ba_2Cu_2O_{10}$ (Nd-123/Nd-422) melt-textured ceramic composites have been observed by T. Puig (Barcelona) et al. upon high-oxygen-pressure annealing (up to 180 bar). The authors found that Nd-123/Nd-422 interfaces become the dominant flux-pinning centers when the high-oxygen-pressure treatments are properly chosen, resulting in strongly enhanced critical currents at low and intermediate magnetic fields.

The influence of a high oxygen partial pressure during directional solidification of melt-processed $YBa_2Cu_3O_{7-\delta}$ intended for use in current leads has been studied by Y. Imagawa et al. (SRL-ISTEC). The authors found that high oxygen partial pressure (at 1 bar) permits the growth speed to be increased without degradation of the superconducting properties. A sample grown at 5 mm/h in a 100% O_2 atmosphere had as high a J_C (6.8×10^4 A/cm²) as a sample grown at 3 mm/h in air.

The growth of large $YBa_2Cu_3O_{7-\delta}$ (Y-123) monodomains with diameters up to 7 cm is reported by P. Gautier-Picard et al. (Grenoble). Top-seeded melt texturing (TSMT) was employed, usually with a $SmBa_2Cu_3O_{7-\delta}$ seed. The authors discuss the conditions for achieving large domain diameters without producing too high a level of Y_2BaCuO_5 (Y-211).

Bi Cuprates

Using high-energy x-ray diffraction with 100 keV photons from a synchrotron source, T. Frello (Risø) et al. have monitored the concentration, stoichiometry, and texture of the dominant phases in a Ag-clad BiSCCO tape *in-situ* during the transformation of BiSCCO from $(Bi,Pb)_2Sr_2CaCu_2O_{8+\delta}$ (2212) to $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+\delta}$ (2223). In addition, the authors obtained information about the grain sizes and residual strains. During heating, the $(Ca,Sr)_2PbO_4$ additive decomposes between 700°C and 820°C. Simultaneously, the residual strain in the 2212 grains is relieved, and the c-axis alignment of the grains is substantially improved. Moreover, the Pb content of the 2212 structure increases

continuously. The authors interpret these results in terms of a temperature-dependent solubility limit of Pb in 2212, which leads to a substantial grain growth of the phase. Above 812°C, 2212 partly decomposes to form $(Ca,Sr)_2CuO_3$ and a liquid. At the operating temperature of 835°C, 2212 and $(Ca,Sr)_2CuO_3$ react with the liquid to form 2223. During the conversion, the 2212 lattice expands, indicating that the remaining 2212 grains contain less and less Pb. The final 2212 and 2223 textures are nearly identical, and Avrami plots of the transformation kinetics give exponents m in the range $1 < m < 2$. During the annealing, the 2212 linewidth is constant, indicating that there is neither strain nor finite-size broadening of the 2212 peaks during the transformation. This points to a transformation mechanism where only a few 2212 grains transform at a given time. The authors discuss the implications of their findings in relation to previously proposed intercalation and nucleation-and-growth models.

As noted by P. Skov-Hansen (Nordic Superconductor Technologies) et al., high-temperature-superconducting (HTS) tapes are now commercially available for practical applications such as magnets and cables, but the published data on strength and allowable deformation limits are not in agreement. The authors discuss definitions and concepts regarding stresses and strains in HTS under deformations, and they present criteria for industrial use. When handling HTS tapes, it is necessary to know the limiting values of loading, bending, and twisting to avoid damage, quantified as degradation of current-carrying capability. Most serious is crack formation, which takes place when stress concentrations exceed a certain value. Values of 0.2-0.5% total tensile strain in the ceramic core is quoted as the deformation limit where cracks appear in HTS tapes.

A method to continuously combine and deform silver-clad superconducting strands has been developed by K. DeMoranville et al. (American Superconductor Corporation). The authors used this technique to fabricate multifilamentary superconducting tapes consisting of Bi-2223 precursors in lengths approaching 100 m. Engineering critical current densities as high as 19 kA/cm² (77 K, self-field, 1 μV/cm) have been recorded in short samples.

A preprint by T. G. Holesinger (Los Alamos) et al. reports examinations of high critical current density (J_C) $(Bi,Pb)_2Sr_2Ca_2Cu_3O_{10+\delta}$ (Bi-2223) multifilamentary tapes ($55 \text{ kA/cm}^2 < J_C < 70 \text{ kA/cm}^2$, 77 K and self-field) by transmission electron microscopy (TEM). Filament microstructures within the tapes consist of two distinct regions: a highly aligned, dense colony structure (brick-wall) near the silver interface and a porous, poorly textured interior region (impurity channel), which contains significantly more secondary phases.

Enhancements of the transport critical current density in Bi-2223 tapes by fission tracks are reported by G. W. Schulz

(Atominstitut-Wien) et al. The authors processed $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$ (*Bi-2223*) tapes by the standard powder-in-tube technique, but they added small amounts of UO_4 prior to processing. Both *U*-doped and *U*-undoped tapes were subsequently exposed to a reactor spectrum of neutrons. Whereas the *U*-undoped materials showed moderate enhancements of the critical current density J_C due to the pinning action of the fast-neutron-induced collision cascades, J_C in the *U*-doped tapes increased by factors of 10-20 due to thermal-neutron-induced fission of ^{235}U and the subsequent formation of fission tracks. Since the enhancements due to columnar defects are particularly pronounced when the magnetic field is applied perpendicular to the tape surface, the characteristic J_C anisotropy as a function of the angle of the field relative to the *ab*-planes was found to be strongly reduced in a certain field range. At the same time, the irreversibility field at 77 K doubled for both field orientations.

The *ab*-plane infrared spectrum of underdoped $Bi_2Sr_2Ca_{1-x}Y_xCu_2O_{8+\delta}$ has been studied by N. L. Wang (Simon Fraser) et al. as a function of temperature. The authors found the gaplike suppression in scattering rate $1/\tau(\omega)$ observed above and below T_C to be related to the shoulder structure in reflectivity $R(\omega)$ and the broad peak or downward suppression from Drude-like shape in conductivity $\sigma_1(\omega)$. The authors conclude that the superconducting gap, which is visible in $\sigma_1(\omega)$, evolves smoothly into the pseudogap. The results obtained are consistent with recent electron tunneling and photoemission measurements.

Hg Cuprates

The synthesis, phase stability, and superconducting properties of *Re*-doped $HgBa_2CaCu_2O_{6+\delta}$ (*Hg-1212*) and $HgBa_2Ca_2Cu_3O_{8+\delta}$ (*Hg-1223*) are reported by P.V.P.S.S. Sastry and J. Schwartz (Florida State). The authors found that $Hg_{0.8}Re_{0.2}Ba_2CaCu_2O_{6+\delta}$ [(*Hg,Re*)-1212] ($T_C = 124$ K) had larger, aligned colonies of grains, while $Hg_{0.8}Re_{0.2}Ba_2Ca_2Cu_3O_{8+\delta}$ [(*Hg,Re*)-1223] ($T_C = 134$ K) had smaller, randomly oriented grains. Both microstructure and magnetization hysteresis measurements suggest that (*Hg,Re*)-1212 is a better candidate for applications.

A preprint by Y. Li (Florida State) et al. describes the synthesis and processing parameters that affect the phase purity and grain growth of *Pb*-doped *Hg*-1223. As-synthesized (*Hg,Pb*)-1223 samples were found to be optimally doped and to exhibit T_C values in the range 130-134 K. Post-annealing the samples in flowing oxygen or argon at 250-300°C resulted in degraded T_C and reduced magnetic hysteresis.

Second peaks were found by S. Lee (Tokyo Tech and Moscow State) et al. in the magnetization hysteresis loops of $(Hg,Pb)(Sr,Ba)_2Ca_2Cu_3O_{8+\delta}$ [(*Hg,Pb*)-1223] polycrystalline

bulks and single crystals. The authors also studied the influence of post-annealing on the peak position H_{Sp} . The authors found that the H_{Sp} vs T curves for *Sr*-rich (*Hg,Pb*)-1223 are at higher fields than those that have been reported for conventional *Hg*-1223 and *Tl*-1223 single crystals, which suggests that the *Sr*-rich (*Hg,Pb*)-1223 compounds have reduced lattice parameters and electronic anisotropy. At 77 K, J_C values of 3×10^5 , 2.8×10^4 , and 1.8×10^4 A/cm² were estimated for the single-crystal sample at $H = 0, 1, \text{ and } 2$ T, respectively. The authors suggest that $(Hg,Pb)(Sr,Ba)_2Ca_2Cu_3O_{8+\delta}$ is a promising candidate for high-current applications.

$La_{2-x}Sr_xCuO_4$

Recent neutron-scattering experiments on $La_{2-x}Sr_xCuO_4$ single crystals by Wakimoto et al. have revealed that elastic magnetic peaks appear at low temperatures in both insulating ($x = 0.02-0.05$) and superconducting ($x = 0.06$) samples. A new preprint by S. Wakimoto (Tohoku) et al. reports further investigations of the elastic incommensurate peaks for $x = 0.06$. The authors found that the integrated intensity drastically changes across the low-temperature insulator-superconductor boundary; the intensity for $x = 0.06$ is one-fourth that of $x = 0.05$, while the intensity in the insulating region is constant.

Neutron-scattering experiments have been performed by H. Kimura (Tohoku) et al. to search for possible elastic incommensurate magnetic peaks in superconducting $La_{2-x}Sr_xCuO_4$ with $x = 0.10, 0.12, \text{ and } 0.15$. Dramatic effects were found for $x = 0.12$, where the peak intensity first appears at the onset of superconductivity ($T_C = 31$ K). The resolution-limited peak width indicates that the static magnetic correlation length exceeds 200 Å isotropically in the CuO_2 planes. Weak elastic peaks also were observed at low temperatures for $x = 0.10$, while for $x = 0.15$ any incommensurate elastic scattering is below the limit of detectability. Elastic peaks also were observed in *Zn*-substituted nonsuperconducting $La_{1.88}Sr_{0.12}Cu_{0.97}Zn_{0.03}O_4$. However, in this case, the *Zn* substitution degrades the magnetic order; the peak appears at lower temperature (17 K), and the correlation length (80 Å) is shorter than that in the *Zn*-free $x = 0.12$ sample.

A preprint by R. J. Birgeneau (MIT) et al. describes a neutron-scattering study of the instantaneous spin-spin correlations in La_2CuO_4 ($T_N = 325$ K) over the temperature range 337-824 K. Incident neutron energies varying from 14.7 meV to 115 meV were employed to guarantee that the energy integration was carried out properly. The results obtained for the spin correlation length as a function of temperature agree quantitatively with previous results for the two-dimensional tetragonal material $Sr_2CuO_2Cl_2$ and with quantum Monte Carlo results for the nearest-neighbor square-lattice $S = 1/2$ Heisenberg model.

Vortices

Magnetic-flux turbulence has been observed via magneto-optical imaging by T. Frello (Oslo and Risø) et al. in single crystals of $NdBa_2Cu_3O_{6+x}$ near optimal doping ($x \approx 1$) and underdoped $YBa_2Cu_3O_{6+x}$ ($x = 0.50, 0.82$). Such turbulent behavior had previously been reported only for high-quality $YBa_2Cu_3O_{6+x}$ single crystals with optimal doping. The authors discuss the influence of the critical current density J_C , anisotropy γ , and oxygen content and superstructure upon the turbulent behavior. The authors conclude that turbulence in states containing magnetic flux of opposite polarities is a general phenomenon.

Vortex flow across a strip containing an array of pinning centers has been studied by K. E. Bassler (Houston) et al. using a cellular model. The vortex flow makes rivers that are strikingly similar to aerial photographs of braided fluvial rivers, such as the Brahmaputra. The vortex rivers form an intricate braided pattern with interconnected channels. The authors find agreement between the scaling properties of the braided vortex rivers and those of naturally occurring braided fluvial rivers. The authors argue that in both cases the underlying dynamical mechanism is avalanches of stick-slip events, either sliding sediment or vortices, which organize the system into a critical braided state.

To determine the effect of sample shape on the magnetization of $Bi_2Sr_2CaCu_2O_{8+\delta}$ (*Bi-2212*) single crystals, R. A. Doyle (IRC-Cambridge) et al. have measured the magnetic moments of differently shaped crystals using a SQUID magnetometer. In platelet-shaped samples, the results show a pronounced geometrical barrier (GB) or shape effect at low fields and high temperatures. In both prism and semi-ellipsoidal-shaped samples, the low-field magnetic hysteresis is reduced significantly at high temperatures due to modification of the geometrical barrier. At lower temperatures, the prism and semi-ellipsoidal samples show enhanced low-field hysteresis relative to the platelet, suggesting an increasing role of nongeometrical surface barriers (SB). The authors discuss these results in terms of the competing roles of bulk-pinning, surface-barrier, and geometrical-barrier effects.

Results of numerical calculations are presented by T. B. Doyle (Natal) et al. for the field-distribution profiles in a reversible (bulk-pinning-free) type-II superconductor of disk geometry in the vortex-lattice-melting regime. The authors assume the melting transition is a first-order transition between solid and liquid states, which have different constitutive equilibrium $B(H)$ behaviors. The authors simulate an intermediate-state structure of varying scales by imposing hysteresis on the melting transition $H_m(T)$. Particular calculations ranging from a fine-scale to an extremely coarse-scale two-zone intermediate-state limit, which previously has been assumed for the transition, are presented for comparison with global magnetization and local surface induction

measurements on *Bi-2212* single crystals in the vortex-melting regime. The authors discuss their results in relation to the determination of the entropy of the melting transition from such measurements and to the nature and curvature of the solid-liquid interface.

A preprint by A. V. Kuznetsov (Moscow State) et al. theoretically considers (a) vortex penetration into thin superconducting films and (b) edge barriers arising in a transverse magnetic field. The authors calculate the vortex Gibbs energy using V. G. Kogan's solution [*Phys. Rev. B* **49**, 15874 (1994)] for a Pearl vortex near the film edge. The authors calculate the penetration field and the magnetization in the critical state, and they estimate the influence of the edge barrier on the magnetization of high- T_C thin films.

Using torque magnetometry, A. V. Pan (Leipzig) et al. have investigated the transverse magnetization in niobium films of thickness 120 nm and 1.2 μm at different angles θ between the applied field and the main surface of the films. Torque measurements at angles $2^\circ \leq \theta \leq 10^\circ$ in the 120 nm film reveal nearly temperature-independent anomalies in the magnetization at matching fields that are compatible with the rearrangement of vortices in one or two in-plane rows, while in the 1.2 μm film these anomalies are not observed. Surprisingly, at very small angles ($\theta < 0.5^\circ$), the matching effects vanish. At these small angles and for both films, the observed behavior can be understood if vortices due to the perpendicular field component experience a pinning barrier of geometrical origin for flux entry or exit. The authors also suggest that the results in both *Nb* films indicate the simultaneous presence of two flux-line lattices, one parallel and one perpendicular to the main surface of the film.

Vibrating-reed, torque, and SQUID measurements have been performed by P. Esquinazi et al. (Leipzig) on *Nb* networks of strand widths between 200 nm and 550 nm and on *Nb* films of thickness 120 nm and 1.2 μm . The results indicate that in samples with thickness $\sim 10 \xi_{GL}$ a flux-line lattice exists in the entire field range $B_{C1} \leq B_a \leq B_{Cu}$, where $B_{Cu}(T, \theta=0^\circ) = B_{C3}(T)$, the surface superconductivity critical field, $B_{Cu}(T, \theta=90^\circ) = B_{C2}(T)$, the upper critical field, and θ is the angle between the field and the main surface. Magnetization measurements revealed a second magnetization peak (SMP) well below the upper critical field, similar to that measured in $Bi_2Sr_2CaCu_2O_{8+\delta}$ (*Bi-2212*) crystals. The authors argue that the SMPs measured in *Nb* and *Bi-2212* are due to a thermomagnetic flux-jump instability and are not related to a critical-current-density enhancement produced by a flux-line-lattice phase transition in an increasing magnetic field.

ac Losses

Measurements of the ac losses in several high-temperature superconductor (HTS) prototype multistrand

conductors (PMCs) of length 1 m have been performed by J. O. Willis (Los Alamos) et al. using a temperature-difference calorimeter. Both single-phase and three-phase losses were examined with ac currents up to 1000 A rms in the PMC. The three-phase losses indicate a significant interaction between phases and show a smaller dependence on the tape I_C than expected.

Electrical measurements of the dc current distribution and self-field ac losses of three HTS cable models are reported by C. M. Friend et al. (BICC Superconductors). Each cable consisted of one or two layers of spirally wound *Bi-2223* tape. Nonuniform distributions of the current were found, which could be attributed to variations in terminal resistances and tape degradation during winding. The authors discuss three different configurations for the voltage leads and the disadvantages of each.

A paper by F. Gömöry et al. (Pirelli) demonstrates how the hysteretic transport ac losses in multifilamentary superconducting tapes can be determined in a contactless way using a pickup coil attached to the tape's wide face. The assumption of uniformly distributed current density gives results that are correct to within 25%. Since the coil signal is directly proportional to the number of turns, the method provides increased sensitivity compared with voltage contacts, which can be helpful when investigating tapes with extremely low ac losses.

As noted in a paper by V. Sokolovsky and V. Meerovich (Ben-Gurion University of the Negev), because of the low thermal conductivity of high-temperature-superconducting materials, ac losses can lead to pronounced heating of the interior parts of a bulk sample. The authors show that the heating increases (decreases) the losses in magnetic fields below (above) the complete penetration field. The authors note that calculations of the ac losses neglecting heating can have large errors.

The low-frequency surface impedance of melt-textured superconductors has been studied theoretically and experimentally by L. M. Fisher (Moscow) et al. The authors use a model assuming that the main pinning of the vortex system is due to intercrystalline boundaries.

Microwave Response

Nonlinear microwave emission by $Ba_{0.6}K_{0.4}BiO_3$ crystals has been studied by A. Agliolo Gallitto et al. (Palermo). The authors suggest that harmonic emission at temperatures far from T_C is due to nonlinear processes in weak links or flux motion, but they attribute nonlinearity near T_C to time variation of the order parameter induced by the microwave field.

The microwave surface impedance of a high-purity crystal of $YBa_2Cu_3O_{6.99}$ has been measured by A. Hosseini et al. (UBC) at five frequencies between 1 and 75 GHz. The data reveal the main features of the conductivity spectrum of the thermally excited quasiparticles in the superconducting state. Below 20 K, there is a regime of extremely long quasiparticle lifetimes, due to both the collapse of inelastic scattering below T_C and the very weak impurity scattering in the high-purity $BaZrO_3$ -grown crystal used in this study. Above 20 K, the scattering increases dramatically, initially at least as fast as T^4 .

A quantitative study of the effect of a-axis grains (for which the a axis is perpendicular to the substrate plane) on the microwave surface resistance in epitaxial $YBa_2Cu_3O_{7-\delta}$ films is reported by C. Dubourdieu (St. Martin d'Hères) et al. The films were grown by metal organic chemical vapor deposition (MOCVD) on *MgO* and *LaAlO₃* substrates. The authors found a clear correlation between the 87 GHz surface resistance R_S at 0.85 T_C and the volume fraction of a-axis grains. The authors argue that this is a direct consequence of the penetration-depth anisotropy.

The propagation of microwaves along $YBa_2Cu_3O_{7-\delta}$ microstrip lines of different widths has been modeled by M. S. Boutboul et al. (Paris). The authors used the two-fluid model to calculate the surface impedance $R_S + jX_S$ and the propagation constant $\alpha + j\beta$, accounting for losses in the dielectric and the metallic ground plane. The authors applied the model to analyze experimental results on a 5.3 GHz cutoff frequency low-pass filter, consisting of $YBa_2Cu_3O_{7-\delta}$ microstrip lines of widths 190 μm and 2000 μm deposited on a *LaAlO₃* substrate.

Thin Films

The microstructure of interface-engineered ramp-edge Josephson junctions in *YBCO* has been studied by Y. Huang (Argonne) et al. using transmission electron microscopy (TEM). The junctions are found to be distinctly different from those found in heterophase SNS junctions, and the structural difference can be related directly to the improved electrical properties of interface-engineered junctions. The main factors responsible for the improved junction properties and their good reproducibility are: small barrier thickness, small thickness variation, weak interfacial strain fields, flat and nearly defect-free barrier/*YBCO* interfaces, and good epitaxy of the second *YBCO* layer with few defects.

Measurements of the resistive broadening and the critical current density of an epitaxial $YBa_2Cu_3O_{7-\delta}$ film are reported by Z. H. Wang (Shanghai) et al. at several fixed magnetic fields as a function of the angle between the applied field and the surface of the film. The authors

attribute the pinning to intrinsic pinning for fields parallel to the ab-planes, and to twin planes and 2D defects along the c axis for fields parallel to the c axis.

The conditions required for the deposition of nonsuperconducting, cubic ($Y_{0.33}Ba_{0.67}CuO_x$) by high-speed pulsed-laser deposition (PLD) have been investigated by J. D. Suh (Taejon) et al. Recently, cubic YBCO has attracted attention because it has essentially the same perovskite crystal structure and stoichiometry as those of orthorhombic $YBa_2Cu_3O_{7-\delta}$ and thus has promise as a barrier layer in SNS edge-type Josephson junctions. The authors found that cubic YBCO thin-film growth could be produced by PLD at high deposition rates of 12.2 nm/s.

High-temperature-superconducting/ferroelectric thin-film devices are of interest because of their possible application in voltage-tunable devices. Two preprints listed in this issue discuss research on this topic. R. A. Chakalov et al. (Chalmers University of Technology) report on the fabrication and investigation of $YBa_2Cu_3O_{7-\delta}/Ba_{0.05}Sr_{0.95}TiO_3$ structures, including a coplanar waveguide, which was tested as an electrically tunable phase-shifter. Field-induced phase shifts of more than 180° were obtained by a 35 V dc bias at 20 GHz. D. Mou et al. (Royal Institute of Technology) report on the electrical properties of heterostructures of $YBa_2Cu_3O_{7-\delta}/PbTiO_3$. Schottky and Frenkel-Poole effects were found to dominate the leakage current of the heterostructure.

Applications

A hybrid bilayer device, a controllable Josephson junction consisting of a thin, microstructured ferromagnetic film spanning a superconducting strip, is described in a preprint by T. W. Clinton and M. Johnson (NRL). Locally strong magnetic fringe fields at the edge of the ferromagnet quench the superconductivity, creating a weak link. The strength of the weak link can be varied between on and off by controlling the orientation of the in-plane magnetization of the ferromagnet. The authors observed Shapiro steps, a manifestation of the ac Josephson effect in the quenched state. In this switchable device, energy is required only to change states, which thereafter remain in metastable equilibrium. The effect has been demonstrated in *Pb* ($T_C = 7.2$ K), but it also should occur with many other superconductors. The authors note that the switch could be used as an intrinsic nonvolatile memory cell, a pressing need in superconducting electronics, but they suggest that applications as a high-speed switch, amplifier, and controllable weak link also are possible.

The fabrication of PLD Ag-doped YBCO thin films on both sides of three-inch-diameter sapphire wafers is described in a preprint by M. Lorenz (Leipzig) et al. Such films are under development as microwave filters for future communi-

cation systems. The authors report that reproducibly deposited YBCO:Ag films of about 250 nm thickness show critical current densities of 4 MA/cm^2 at 77 K and exhibit laterally homogeneous maps of microwave surface resistance R_S of about 45 m Ω at 145 GHz and 77 K measured by an open resonator technique. The R_S at 8.4 GHz and 77 K determined in the center position of the YBCO:Ag films with a sapphire resonator technique remains constant at about 380 $\mu\Omega$ up to a microwave surface magnetic field of 7-10 mT.

As reported by G. Snitchler (American Superconductor Corporation) et al., a 7.25 T laboratory magnet using Bi-2223 conductor has been designed, built, installed, and tested at the Naval Research Laboratory. Operating at 21 K at full field, the coil provides field homogeneity of $\pm 1\%$ in a 2-inch warm bore. The system is conduction-cooled with a pair of Leybold single-stage cryocoolers, which allow cooldown in less than 36 hours and permit extended fast-ramp operation. Operation at a total refrigerator input power of 6 kW is facilitated by the use of ASC CryosaverTM HTS current leads. The fully integrated system consists of the magnet, cryogenic system, control and protection system, and power supply.

In particle accelerators and other high-energy physics applications, over one-third of the liquid-helium consumption results from the use of conventional resistive cryogenic current-lead technology. As noted by A. J. Rodenbush et al. (American Superconductor Corporation), these and other applications can benefit greatly by incorporating high-temperature-superconducting leads. These leads consist of a vapor-cooled resistive upper section and an HTS section cooled by a separate gas stream. This topology reduces the helium consumption to one-tenth of that required by a resistive lead. The authors describe the design, fabrication, and testing of several HTS current leads including 5 kA and 13 kA leads for accelerators.

The performance of a small saddle coil for quadrupole magnets made in industry from Bi-2223 HTS tape at 4.2 K and 77 K is reported by M. D. Manlief (American Superconductor Corporation) et al. The coil was made to help develop methods for winding the ends of small-aperture magnets.

The United States Air Force and the Ballistic Missile Defense Organization are developing a 1-Megawatt exciter/generator for airborne applications. The exciter is constructed with an eight-pole external field winding and rotating hydrogen-cooled armature with integral rectifier. The exciter was originally designed with high-purity aluminum field coils cooled by liquid hydrogen. The Air Force is presently investigating the possibility of replacing the aluminum field coils with HTS field coils cooled by hydrogen. A. J. Rodenbush and S. J. Young (American Superconductor Corporation) describe the design, construction, and testing of the field coils, and they discuss the potential of this technology for airborne applications.

The status of a 1,000 hp synchronous motor with HTS field windings is summarized in a preprint by D. Aized (American Superconductor Corporation) et al. The objectives of this development effort include saving half the losses of conventional motors in a package with half the volume. The authors review the overall design characteristics of the motor, discuss the status of the field coils and refrigeration system, and describe the other components of the system. Present schedules call for the motor to be tested in mid-1999.

A paper by S. K. Singh (Westinghouse Science & Technology Center) et al. describes the conceptual design of the HTS generator for mobile radar (MR) applications. The power system for MR consists of a diesel engine, a generator, and power conditioning electronics. Significant advantages in power density, performance, and efficiency are expected if the generator and power electronics are cryogenically cooled.

Theory

Order-parameter fluctuation effects in the superconducting state have been studied by H.-J. Kwon (Florida) as a possible explanation of the pseudogap. Using a low-energy effective theory in the d-wave BCS model, the author self-consistently calculates the single-particle properties and finds that the fluctuations reduce the spectral gap, deform the shape of the gap, and produce a precursor to the formation of Fermi arcs. The author also discusses the angle dependence of the quasiparticle lifetime due to fluctuations.

Time-reversal-symmetry-breaking superconductivity with $\Delta_{\mathbf{k}} = \Delta_x^2 - y^2(\mathbf{k}) + e^{i\theta} \Delta_\alpha$ ($\alpha = s$ or d_{xy}) symmetries has been studied by H. Ghosh (Rio). The author shows that, depending on the minor component (α) and its phase at lower temperatures, the behavior of such superconductors could be qualitatively different, which can have important consequences for transport and Josephson physics.

To investigate relations among long-range antiferromagnetic (AF) order, superconductivity, and two-particle triplet collective excitations, D. Marinaro and O. Sushkov (New South Wales) have considered a modified two-dimensional t-J model at doping close to half filling. The model includes additional hopping t'' and nearest-site Coulomb repulsion V , allowing the authors to control closeness of the system to the AF instability. The authors demonstrate the possibility of coexistence of long-range AF order and d-g-wave superconductivity. In the phase with long-range AF order, the authors find superconducting gaps and spin-wave renormalization. Near the AF instability, the authors find a spin-triplet collective excitation with energy below the superconducting gap.

A preprint by S. Fratini and P. Qu  merais (Grenoble) describes an examination of the stability of a Wigner crystal

in an ionic dielectric, in which the authors found two important competing effects due to polaron formation: (a) the screening of the Coulomb force $1/\epsilon_{\text{gr}}$, which destabilizes the crystal, compensated by (b) the increase of the carrier (polaron) mass. The authors study the competition between the two effects and examine the quantum melting of the polaronic Wigner crystal as the density is varied at zero temperature. By calculating the quantum fluctuations of both the electron and the polarization, the authors show that there is a competition between dissociation of the polarons at the insulator-to-metal transition (IMT) and melting towards a polaron liquid. The authors find that at strong coupling, a liquid state of dielectric polarons cannot exist, and the IMT is driven by the polaron dissociation.

The cooperative Kondo effect in the two-channel Kondo lattice has been studied by P. Coleman (Rutgers) et al. The authors find that additional screening channels destabilize the Fermi liquid, ultimately leading to a superconducting state with long-range composite order. The authors discuss possible implications for heavy-fermion superconductivity.

Overviews

The fundamentals governing the penetration of magnetic flux into the high-temperature superconductors are discussed in an overview by J. R. Clem (Ames Laboratory State). The author discusses (a) the internal magnetic structure when magnetic flux penetrates into a superconductor (anisotropic, pancake, and Josephson vortices) and (b) the process by which vortices nucleate at the edge and penetrate to the sample's interior (geometric and surface barriers) (101 refs.).

A preprint by A. Furusaki (Kyoto and Stanford) reviews the dc Josephson effect in superconducting point contacts, where supercurrent flows through a small number of channels. The author emphasizes the central role of Andreev levels, which carry the entire supercurrent in short symmetric Josephson junctions, including tunnel junctions. The author also explains the dc Josephson effect in a quantum point contact in terms of multiple Andreev reflections, and points out that the Josephson critical current is quantized in multiples of $e\Delta_0/\hbar$ at zero temperature (39 refs.).

The status of and prospects for high-temperature-superconducting (HTS) *Bi-2223* oxide-powder-in-tube (OPIT) wire technology in the context of commercial requirements, as well as alternative wire approaches such as *YBCO* coated conductors, are summarized in a paper by A. P. Malozemoff et al. (American Superconductor Corporation). The author reports that short rolled multifilamentary *Bi-2223* OPIT wire has reached a core critical current density J_C over $73,000 \text{ A/cm}^2$ (77 K, self-field, $1 \mu\text{V/cm}$) in multiple samples, with engineering (full-cross-

section) current density J_e of 22,800 A/cm². Regular production wires several hundred meters long show average engineering current density over 10,000 A/cm², a benchmark for commercial electric power applications such as cables and motors. Cost studies indicate that cost performance below \$10/kA-m is attainable for full-scale production levels.

The author notes that next-generation YBCO coated-conductor technology offers further potential cost-performance improvements (16 refs.).

Contributed by John R. Clem

Contents: Preprints begin on page 8 and Coming Events begin on page 15.

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.

PREPRINTS

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COMING EVENTS

(An * indicates a previously listed event.)

Jan. 12 - 13, 1999: 7th Annual HTS Wire Development Workshop, sponsored by the U.S. Department of Energy, Doubletree Hotel, Cocoa Beach, Florida. This two-day meeting brings together the leading U.S. scientists and engineers involved in research and development of high-temperature superconducting wire and electric-utility applications for the wire. In order to identify and address key research needs, discussion sessions are planned around the following themes: first-generation HTS wire, second-generation HTS wire, ac losses, projected performance and cost, and user requirements for HTS wires. Optional tour of the NASA-Kennedy Cryogenics and Materials Characterization Laboratories will be conducted the afternoon of January 13. For more information contact Zia Haq, Energetics, Inc.; telephone (202) 479-2748, ext. 115; e-mail zhaq@energeticsinc.com or Dean Peterson, Los Alamos National Laboratory, telephone (505) 665-3030; e-mail dpeterson@lanl.gov.

Feb. 3 - 5, 1999: The 23rd Annual Condensed Matter Physics Meeting, Convention Centre, Charles Sturt University, Wagga Wagga, Australia.

Emphasis on poster papers, plus invited keynote and post-graduate speakers on a wide range of research topics. Contributed and invited papers can cover any aspect of condensed-matter physics. **Abstract deadline, December 11, 1998.** For further information, contact Robert G. Clark, Conference Chairman, School of Physics, UNSW; phone +61 2 9385 4574; fax +61 2 9385 6138; e-mail r.clark@unsw.edu.au. Or contact Renata Jones, Conference Secretary, phone +61 2 9385 4644, fax +61 2 9385 6138, e-mail renata@jupiter.phys.unsw.edu.au.

May 31 - June 4, 1999: The Second International Conference on New Theories, Discoveries and Applications of Superconductors and Related Materials (New3SC-2), Circus Circus Hotel, Las Vegas, Nevada. Conference will carry out "open-door" policy in accepting contributions. Will focus on new ideas, new concepts, and new models of the mechanism and origin of superconductivity, especially those new results that appear to exhibit a breakthrough either conceptually or in the applications they generate. The intent is to highlight the contributions of young and lesser-known researchers as well as those of senior scientists. Organizers will encourage and foster friendly and peaceful debates at the conference concerning whether or not a new physical picture is needed to fully understand both low- and high-temperature superconductivity. For more information, contact J. D. Fan, New3SC-2 Chair, P.O. Box 9767, Baton Rouge, LA 70813; telephone and telefax (225) 771-3926; e-mail new3sc@grant.phys.subr.edu; Web site <http://www.phys.subr.edu/conference/new3sc.htm>.

June 27 - 30, 1999: 1999 International Workshop on Superconductivity (4th Joint ISTE/C/MRS Hawaii Workshop), Kauai, Hawaii. Co-sponsored by ISTE/C and MRS. Fourth in the series. Theme will be "High-Temperature Superconducting Materials and Devices for Electronics Applications." In particular, topics concerning thin films and processing, and HTS junctions and integration technology will be emphasized. Workshop will consist mainly of a series of single-session meetings with a significant amount of time allotted for the discussion of each paper and extra amounts of time put aside to encourage informal interactions among the participants. Topics of interest (including, but not restricted to the following) are: HTS superconducting materials; characterization (surface roughness, surface resistance, etc.) and processing of thin films (MOCVD, LEP, sputtering, laser ablation, evaporation, etc.); substrates; HTS junctions; devices (microwave & mm-wave devices, SQUIDS, RSFQ/SFQ, JJs, etc.); applications (telecommunication, computing, switching devices, medical, etc.); and others. **Contributed Summary deadline, January 15, 1999.** For information, contact Tetsuji Kobayashi, Director, International Affairs Department, International Superconductivity Technology Center (ISTEC), Eishin Kaihatsu Bldg. 6F, 34-3, Shinbashi 5-chome, Minato-ku, Tokyo, 105-0004 Japan; phone +81 3341 4044; e-mail t-kobayashi@istec.or.jp.



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