Low Temperature Inelastic Properties of Y 1-2-3 Type High Temperature Superconductor Ceramics

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Inelastic properties and thermal expansion of YBaCuO superconductor materials obtained by solid state reaction are studied using the methods of low frequency internal friction and capacitor dilatometer. In the 180-250K temperature range staggered decrease of shear modulus, increase of relative thermal expansion and broadened internal friction maximum are revealed. Intensity of internal friction maximum and shear modulus defects are characterized by sharp dependence from amplitude of torsion oscillation. After annealing at the ~473K temperature mentioned peculiarities of inelastic characteristics are observed by 20-30K increased temperatures. Accordingly critical value of amplitude oscillation at which begins sharp increase intensity of internal friction maximum and shear modulus defects increased by 20-25%. The characters of revealed changes of physical properties of YBaCuO HTSC are explained in the model of interaction of various dislocations with point defects.

The 77 K stress and strain dependence of the critical current of some 2G YBCO coated conductors

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The electromechanical performance of commercially available 2nd generation YBCO tapes are characterized in support of the 32T all superconducting magnet program at the NHMFL. The coated conductors with surround copper stabilizer (SCS) and Hastelloy substrate have been found to be robust in the laboratory stress-strain tests. Here we report the 77 K stress-strain behavior of conductors as determined in axial tensile tests. We also measure the critical current of conductors as a function of applied axial strain at 77 K and self-field. The 77 K current transport properties of soldered lap joints are quantified in lap shear tests. Additionally, critical current of the conductors are measured in the presence of transverse (c-axis) tensile stress.

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Crystal growth of $YBa_2Cu_3O_{7-y}$ coated conductors fabricated by TFA-MOD method

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The crystallization process of TFA-MOD derived YBCO crystals has been investigated to understand the effects of the starting solution composition on superconducting properties. The J_c values of YBCO films fabricated from the Ba-deficient (Y:Ba:Cu = 1.0:1.5:3.0) solution were higher than those fabricated from the stoichiometric (Y:Ba:Cu = 1.0:2.0:3.0) one. The highest J_c values were achieved at 90 min haet-treatment for the conversion of 0.8 μm-thick YBCO films which were independent of the starting solutions. The degradation of J_c values was observed only in the film from the stoichiometric solution with holding time than 100 min. The longer holding times for completing the crystallization reaction derived from the stoichiometric is required than that from the Ba-deficient solutions. The YBCO crystal growth proceeds in two steps. The first is the epitaxial growth from the substrate in a layer-by-layer manner with trapping unreacted particles. In the later stage, the trapped unreacted particles react with H_2O and each other to form YBCO, $BaCuO_2$, BaO, *etc*. (solid-state reaction). Epitaxial growth ended at 80-90 min in the both solutions. The solid-state reaction does not occur within the films derived from Ba-deficient solution. It may affect the the I_c degradation.

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Dislocation network at phase boundaries in HTS films with nanoparticles

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Low-angle domain boundaries consisting of threading edge dislocations determine critical current in superconducting films due to a strong influence on flux pinning and creep, while misfit dislocations in the film plane do not have significant effect. We have developed a model to simulate formation of a dislocation network at the phase boundaries of growing YBCO film (with the substrate and nanoparticles). The free energy of a mismatched boundary can be minimized either by misfit dislocations or by rotation of domains with formation of dislocation low-angle boundaries between them. In the first case atoms of the film are displaced longitudinally along the principal crystallographic directions. However, when chemical binding within the forming layer is much stronger than interaction at the interface, transversal displacement of the film atoms may be energetically beneficial. In this case the film lattice apparently rotates around the *c* axis and divides into domains to reduce the free energy.

Using the suggested model we made computer simulations to model the real structure of boundaries with substrates and nanoparticles and estimated the domain size and distribution. Our model uses certain units of which the film consists rather than individual atoms. The extensive HREM studies of the dislocation network in YBCO films with $BaZrO_3$ nanoparticles have been carried out. The computed patterns are consistent with the observed nanostructure features.

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Effect of nanoparticle types on J_c and nonlinear microwave response of YBCO Films

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DC and microwave properties of PLD HTS $YBa_2Cu_3O_{7-x}$ films with $BaZrO_3$ (BZO) additives have been studied. HREM reveals two types of nanoparticles: tiny $Ba_xY_{1-x}ZrO_y$ (BYZO) “nanopancakes” 1-4 nm in diameter and few atomic layers thick and much larger $BaZrO_3$ “nanorods”. Nanopancakes are surrounded with a developed network of edge dislocations, which provide additional flux pinning and retard relaxation of the dislocation structure during deposition. They seem to be responsible for J_c enhancement in Zr doped films. At higher substrate temperatures and/or slower deposition nanopancakes evolve to much wider (≤ 40 nm) and longer BZO nanorods. In this case strains relax by a slight inclination of the *c*-axis of nanoparticles rather than by misfit dislocations.

I-V curves measured for the films with 1.5% Zr have been found to be well approximated by an exponential law, which is typical for a regime of collective vortex creep or superconductors with extended linear or planar defects. This confirms that at perpendicular field vortex pinning occurs mainly at threading edge dislocations, whereas at parallel orientation pinning seems to occur at planar defects such as stacking faults with partial dislocations surrounding them. BZO nanoparticles appreciably improve microwave properties of the YBCO films. A nonlinearity threshold of film with 3% Zr is about 3 times greater and a slower raise of nonlinear surface resistance is observed above the threshold.

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Coil geometry influence on shielding factor of 4 cm wide YBCO tape superconductor coils

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Shielding factor studies on shield coils made of 4 cm wide 2G High Temperature Superconducting coated conductor were performed at various AC magnetic field amplitudes, frequencies, and magnetic field orientations. The shielding factor expresses the percentage of the external magnetic field that is shielded inside the shield. Magnetic field measurements on coils axis were performed using the Hall probe and Lock-in technique. External magnetic field generated by copper magnet was perpendicular or parallel to the coil axis. Sets of coils were prepared in a form of coils with different diameter and length. Our study was mainly focused on influence of coil dimensions on shielding factor at various external magnetic field values. All measurements were performed in liquid nitrogen bath at 77 K and at reduced temperatures down to 68 K achieved by nitrogen gas pumping.

Electromagnetic separation of high temperature superconductors [ICMS-20]

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It was developed a unique process for selecting prime particles with the greatest critical current for use in fabricating **HTSC** materials. This process, known as Electromagnetic Separation (**EMS**), has shown great promise in its ability to obtain superior superconducting materials in addition to qualifying as an effective method in testing and analyzing final powders to determine if synthesis adjustments are necessary in order to achieve optimal material properties.
HTSC are manufactured from multi-component ceramic powders composed of fine electro-physical particles with superconducting capability. Materials components undergo several phase transformations during the synthesis process that causes the stoichiometry of a particle to deviate, weakening stability and inevitably leading to structural mechanical defects.
For example, the composite $\mathbf{YBa_2Cu_3Ox}$ requires additional synthesis phases (i.e. $\mathbf{Y_2Cu_3O_5}$ and $\mathbf{Y_2BaCuO_5}$), that can lead to oxygen impoverishment of the iso- structural micro-section resulting in poor quality materials. Premium **HTSC** materials are ideally characterized as homogeneous powders with the greatest critical current. Unfortunately, even the most advanced techniques commercially available are unable to produce homogeneous **HTSC** powders. **EMS** is a superior process that has been developed to improve the homogeneity of **HTSC** powders. The process is based on the interaction of **HTSC** particles and an alternating magnetic field at temperatures close to those of **HTSC** transition by extracting particles with optimal electro-physical qualities from the mechanical compound, creating a concentration of enriched particles with greater critical current.
In addition, the method of **EMS** allow for a more accurate analysis of powders after separation for the evaluation and testing of their properties in order to determine if adjustments are needed during the synthesis process. **HTSC** -powders are supplied into the world market with the sizes of 1-5 µm. They can differ one from another not only by inner defects, but also by physical properties (as a result of the above mentioned deviation from the known chemical composition and of the amount of the admixture defects). Such physical properties may be: temperature of the superconductivity transition Tc, critical current ***J***cr, and critical magnetic field that destroy the superconductivity. Thus, it becomes obvious a necessity of the powder quality improvement. The latter means as much as possible eliminating non- uniformity of the composition and of the structure and saving new better qualities of the powder in the end products (cables, thick films, HTSC - shields, HTSC -surfacing, waveguides, etc.)
The method of EMS, developed by the author allows improving statistically the uniformity of the HTSC powders: to decrease the quantity of the defective areas in the structure of the separated powders, the number of non -valid phases, admixtures, and to increase Tc, ***J***cr, ***H***cr.
The method is based on the electromagnetic interaction HTSC particles and extracting of the concentrate rich with particles (granules), which have the high critical current (with less content defects) from the mechanical mixture of the powders.

Reference:
1. Electromagnetic separation (EMS) of the HTSC materials by method E.Broide US Patent N-5919737,06.079.199)
2. E.L.Broide, Superconductor and Cryoelectronics, summer 1998 issue, p .33(1998)
3. E.L.Broide, G.E.Shter and G.S. Grader, Enrichment of NdBCO supercond.powders by Electromagnetic Separation, Abstract Intern, Conference, 1999, Barcelona, Spain
4. E.L Broide, Electromagnetic separation of the YCu2Ba3OX, Nd-HTSC and Bi-HTSC powders. J. of Superconductivity and Novel Magnetism, Springer, January 17, 2008
5. E.L.Broide, G.E.Shter and G.S.Grader, Enrichment of NdBCO HTSC- powders by Electromagnetic Separation, J. of Superconductivity and Novel Magnetism, Springer,2008.

The microstructural causes of magneto-optically detected lines in industrial coated conductor tapes

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The quality of industrial YBCO coated conductor tapes were investigated by applying different experimental techniques: light microscopy, magneto-optical (MO), SEM, transport and magnetization measurements. Different types of defects were found to be locally present in most available tapes by MO imaging technique. Some of those defects have different shapes and location, while others propagate along the tape axis. Such longitudinal defects, where magnetic flux penetrates more easily, are well visible on MO images like narrow channels with bright contrast. Using combination of SEM (Zeiss 1540 XB) and Focused Ion beam (FIB) we found that longitudinal defects have highly misoriented grains on YBCO surface associated with imperfections in buffer/substrate layers. The loss of integrity of buffer/substrate layers are well visible in different FIB sections in the form of breakages. Transport and MO measurements reveal the strong anisotropy of critical current along and perpendicular to tape axis due to these defects, which reduce critical current to 30-50% in transverse direction and as a result limit current capabilities in Roebel YBCO cables as well in electromagnetic coils in high field magnets.

Preform Optimized Infiltration Growth Process to achieve high current density to high fields in YBCO/Ag superconductors

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ABSTRACT:

Bulk $YBa_2Cu_3O_{7-\delta}$ (YBCO)/Ag composites with a homogenous distribution of fine and spherical particles of metallic silver and Y_2BaCuO_5 (Y-211) have been fabricated employing Preform Optimized Infiltration Growth Process (POIGP). Various processing parameters like the compaction pressure, the sintering temperature and the method of addition of Ag was optimized to achieve samples with engineered microstructures supporting high current densities to high fields.

It is found that the optimized YBCO/Ag sample in which silver was introduced through liquid phases could overcome major macro-defects like voids, pores, macro-cracks and platelet gaps. Current densities (J_c's) in excess of 10 kAcm^{-2} up to fields of 4 T and better than 4 kAcm^{-2} up to applied fields of 9 T have been achieved in the optimized sample at 77 K. The problems reported in literature with respect to inhomogeneity in the distribution of both Y-211 and Ag particles in the Y-123 matrix and the associated spatial non-uniformity in the current density are successfully resolved in the present work. The causes for the remarkably high J_c's to high fields in POIGP samples were investigated through a systematic study of microstructures obtained under different compaction pressures and Ag contents. Various factors influencing the $J_c(H)$ with a special emphasis to twinning will be discussed. The outcome of this work has a tremendous impact on various technological applications possible with bulk high temperature superconductors.

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Simulation of AC loss and temperature distribution in multifilamentary high temperature superconducting tape

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Abstract

Commercial application of high temperature superconductors in power apparatus needs proper investigation of thermal stability of HTS tapes used in them. Superconductors exhibit energy loss known as AC loss due to time varying external magnetic field and transport current. Temperature inside the superconductor increases owing to AC loss. Unless the heat from the superconducting tape is removed by means of proper cryogenic action, some hot spot inside the HTS tape may lead to thermal run away of it. Since high temperature superconductor poses highly non-linear and anisotropic material characteristics, determination of AC loss and corresponding temperature evaluation is very much important from design perspective. Here AC loss due to the external AC magnetic field and AC transport current is evaluated in Ag sheathed Bi-2223 multifilamentary tape having anisotropic electrical conductivity and field dependent critical current density using finite element method. Simulated AC loss values show good agreement with analytical values. Using these AC losses as the heat sources, the temperature distribution inside the tape is evaluated numerically using FEM with proper boundary conditions and anisotropic thermal conductivity. The results are verified using COMSOL Multiphysics. It is observed that the temperatures at certain spots are increased initially but with proper heat removal to the cryogen through silver sheath, the temperature attains a steady state value below the critical one.

Magnetization AC Loss Measurements on Wide 2G Superconducting Tapes

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Magnetization loss measurements on 40 mm wide second generation (2G) High Temperature Superconducting (HTS) coated conductor were performed at various field amplitudes, frequency, and field orientation. Measurements were performed using the pick-up coil technique with the magnetic field parallel and perpendicular to the tape surface. Calorimetric measurements were used to measure the losses at various field angles from 0 to 90 degrees. The results of both techniques were compared to assess the relative accuracy of the two techniques. The data are used to estimate the heat load in the applications such as magnetic shielding and inductive fault current limiters. Details of the measurement techniques and data on single tapes and stacks of tapes with and without insulation between them are presented.

Thermal conductivity of materials used for preparation of the hybrid layered conductors based on high temperature superconductors

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In recent years, high temperature superconductors (HTS) have been developed intensively for different applications such as transformers, high field superconducting magnets, fault current limiters, or current leads. HTS based conductors used for these applications are hybrid materials where a superconductor could be a layer within a multilayered structure, and at the same time could be coated by a metal, e.g. by Cu, or stainless steel. Depending on the constituents, the thermal conductivity of the whole conductor could vary over several orders of magnitude. For the modeling of conductors with desired thermal properties the thermal conductivities of individual layers have to be known. For this goal, thermal transport properties of each constituent have to be measured separately. This paper presents results of thermal conductivity measurements of the commonly used substrates for the HTS, namely, the NiW films.

Investigation of twisted stacked-tape cable conductor

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We have been developing a High Temperature Superconductor (HTS) tape cabling method having a “twisted stacked-tape” geometry to provide a simple, high average current density and scalable cabling method applicable to a large scale magnet achieving high field and high current. This technique will be attractive for various large magnets such as fusion, SMES, compact superconducting cyclotron, as well as electric power transmission cables. HTS, especially 2G YBCO coated tapes, have excellent high current capabilities at high magnetic fields. HTS cables carrying currents up to about 3 kA have already been fabricated by either helically winding the tapes in one or more layers annularly on a cylindrical mandrel, or by a specially cut, stacked and transposed multi-tape conductor of ROEBEL Assembled Coated Conductor (RACC). However, these cabling concepts are not suitable to manufacturing processes for high current, high current density conductors and Cable-in-Conduit Conductors (CICC). In this paper presents experimental and analytical results for sub-scale twisted stacked-tape cables made of 2G YBCO tapes, and also for prototype cables fabricated by a scalable manufacturing method developed recently. The experiments were performed at 77 K and 4.2 K at up to 2 T. The critical currents and the current distributions in the cable will be presented. AC losses and methods of joining conductor segments will also be discussed.

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