ICMC Sessions

Tuesday, 07/17/07 Plenary 8:00am - 9:00am

M1-A Tuesday Plenary Session

M1-A-01 Are New Superconductors ready for Prime Time yet?

***D.C. Larbalestier**, The Applied Superconductivity Ctr., NHMFL, FSU.*

Thirty-seven years ago the first filamentary composite superconductors of Nb3Sn were fabricated, almost simultaneously by laboratories in the UK, Japan and US. That development extended the domain of Nb-Ti (and Nb-Zr) magnets considerably and was quickly applied to the fabrication of high field research magnets. That superconductor, Nb3Sn, is the key to such major high field applications as, KSTAR, ITER, accelerator dipoles and high field NMR as well as promising new applications such as proton therapy. In this talk we compare the initial rapid development of Nb3Sn with the development of both HTS conductors and MgB2 for high field application.

Tuesday, 07/17/07 Poster 9:00am - 10:30am

M1-B Materials Properties

M1-B-01 Characterization of co-precipitated nanosize Co-Ni ferrites

***I.H. Gul**, Quaid-i-Azam University, Pakistan.*

Structural parameters along with magnetic and electrical behaviour of nanosize powders of stoichiometric Co-Ni ferrites, Co1-xNixFe2O4 with x = 0.0-0.5 synthesized by co-precipitation method are reported. The particle size was estimated from X-ray diffraction data using Scherrer's formula. The particle size of the samples was found within the range of 14-21 nm. The ac magnetic susceptibility and DC electrical properties of these ferrites have been measured as a function of temperature. The Curie temperature increases with Ni concentration. DC electrical resistivity measured in the temperature range 380 K to 500 K showed that all the samples are degenerate type semiconductors. The activation energy and drift mobility are determined from the DC electrical resistivity measurements. The dielectric constants as a function of frequency in the range 100 Hz to 1 MHz at room temperature are also reported.

The authors would like to acknowledge Higher Education Commission (HEC) Islamabad, Pakistan and Quaid-i-Azam University Research fund (URF) for providing financial support for this work.

M1-B-02 Hydrogen effect on internal friction of A Fe based austenitic alloy

*J. Zhang, X.Y. Li, **L.J. Rong**, Y.Y. Li, Organization IMR.*

Low temperature internal friction of a Fe-Ni based austenitic alloy caused by hydrogen is investigated at Dynamical Mechanical Analysis (DMA) equipment from -40 Ž to 100 Ž. Two internal friction peaks at -4.5 Žand 18 Ž have been observed in the Fe-Ni based austenictic alloy subjected to hydrogen charging. With the outgassing of hydrogen on aging at room temperature, the first peak at -4.5 Ž gradually decreased to the level of uncharged specimen fs, the second peak at 18 Ž gradually vanished.

The low temperature peak observed at -4.5 Ž at 1Hz for specimens exhibited an activation energy of 79.1kJ/mol, It was associated with hydrogen-induced Snoek peaks. The high temperature peak at 18 Ž were tentatively interpreted as hydrogen-grain boundary relaxation peak. Mechanical tests on charged and uncharged specimens indicated embrittlement induced by hydrogen in accordance with the relaxation. A direct correlation was made between the internal friction and the hydrogen embrittlement. Hydrogen approached grain boundary during high temperature and high pressure gas phase charging process, and reduced the bonding strength of grain boundaries.

M1-B-03 Negative and positive magnetoresistance behaviors at very low temperatures in the variable range hopping regime in insulating n-type InP semiconductor

***A. El kaaouachi**, R. Abdia, A. Nafidi, Research Group in Condensed Matter Physics, Physics department, University Ibn Zohr, Faculty of Sciences, B.P 8106, Hay Dakhla, Agadir, Morocco.; G. Biskupski, Laboratoire de Spectroscopie Hertzienne (CNRS), équipe des semiconducteurs, Université des Sciences et Technique de Lille I, Villeneuve d'Ascq Cédex, France..*

Experimental results are reported on field negative and positive magnetoresistance in insulating n-type InP sample in which range hopping occurs at very low temperatures[0.115 K-2.55 K]. Experimental data are tentatively compared with available models in the insulating regime. For moderate and high magnetic field B, we have observed positive magnetoresistance associated with variable range hopping conduction. For B<1.25 T, the magnetoresistance is found to be negative and we made tentative analysis with a model of localized magnetic moments In both cases the teoretical models are very consistent with experience.

References:

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We are grateful to SNCI in Grenoble, France, for providing access to very low temperature and high magnetic field facilities, which allowed the first experiemnts to be carried out

M1-B-04 Low Temperature Physical Properties of Ge-Doped Manganese Nitrides Negative Thermal Expansion Material

*R.J. Huang, W. Xu, **X.D. Xu**, L.F. Li, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences; X.Q. Pan, Department of Materials Science and Engineering, University of Michigan; D. Evans, Advanced Cryogenic Materials, Abingdon, Oxon U.K.*

The performance of precision devices in cryogenic engineering has been limited by the problem of thermal stress and piston to cylinder wall clearance induced by the thermal expansion between different materials. To avoid this problem, one of the choices is to develop a controllable expansion coefficient material, by compounding isotropic negative thermal expansion material with other materials. Negative thermal expansion is a physico-chemical process, during which materials contract when heated and expand on cooling. Ge-doped manganese nitride negative thermal expansion material discovered by K.Takenaka and H.Takagi is a new material, with the largest negative thermal expansion coefficient. However, further investigation of many aspects of this material at low temperatures is still required. This study is focused on the low temperature physical properties of doped manganese nitrides. Bulk materials with the general formula of Mn(sub3)(Cu(sub1-x)Ge(sub x)N (x=0.3 0.35 0.4 0.45 0.5) and other doped materials were fabricated by mechanical alloying and subsequent sintering. Their physical properties involving expansion coefficient, electrical conductivity and thermal conductivity will be investigated within temperature range 80-300K.

M1-B-05 Low Temperature Thermoelectric Properties of Bi-Sb Alloys with Partial Substitution of Ag for Sb

***R.J. Huang**, F.S. Cai, L.H. Gong, L.F. Li, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences; D. Evans, Advanced Cryogenic Materials, Abingdon, Oxon U.K.*

With no moving parts, a thermoelectric cooler is more compact, reliable and lighter weight than machine type coolers. Low temperature thermoelectric cooling is of great interest for many applications including the cooling of IR detectors, laser diodes and superconductors but use is currently limited because of low efficiency. Therefore, the primary objective of our research was to find improved materials to increase the efficiency of a TE device by creating highly doped, small band gap semiconductors.
In this paper, we study low temperature thermoelectric properties of Bi-Sb alloys with partial substitution of Ag for Sb. Bi-Sb-Ag alloys with the general formula of Bi(sub 85)Sb(sub 15-x)Ag(sub x) (x=0, 1, 3, 5, 7) were prepared by mechanical alloying and subsequent pressure-less sintering (Bi(sub85)Sb(sub15) alloy was used for comparison. The phase structures of the samples were investigated by X-ray diffraction and electrical conductivity, Seebeck coefficient, and thermal conductivity has been investigated in the temperature range 80-300K. The results show that the figure-of-merit of Ag doped Bi-Sb alloy is higher than that of single crystal when temperature is more than 200K, and reached a maximum value of 2.16E-3/K at 219K, which is twice as large as that of the reference sample Bi(sub 85)Sb(sub 15).

M1-B-06 Nb3Sn and NbTi multifilamentary wires with enhanced heat capacity

***L.V. Potanina**, A.K. Shikov, A.E. Vorobieva, N.I. Salunin, M.I. Medvedev, Bochvar Institute of Inorganic Materials (VNIINM); V.E. Keilin, I. A. Kovalev, S.L. Kruglov, NRC Kurchatov Institute.*

ITER type multifilamentary superconducting wires (0.81 mm diameter for Nb3Sn and 0.73 mm diameter for NbTi) with several times larger average heat capacity at LHe temperatures have been manufactured and preliminary tested. To increase the heat capacity the corresponding billets were doped with several percents of PrB6 (for Nb3Sn) and Gd2O2S (for NbTi). The volumetric heat capacity of these substances at LHe temperatures is at least two orders of magnitude larger than that for the other components of the wires. The tiny powders of PrB6 and Gd2O2S were incorporated into the billets by PIT method. For comparison the wires without dopants were produced from the same billets using identical heat treatment for each pair of wires. First comparative tests of the wires have demonstrated a noticeable increase of critical energies versus current.

M1-B-07 Thermal Properties of Double-Aluminized Kapton at Low Temperatures

***J.G Tuttle**, M.J. DiPirro, T.P. Hait, NASA/GSFC.*

Double-aluminized kapton (DAK) is commonly used in multi-layer-insulation blankets in cryogenic systems. NASA plans to use individual DAK sheets in lightweight deployable shields for satellites carrying cryogenic instruments. A set of these shields will allow the cold side of an instrument to radiate heat to deep space while reflecting away thermal radiation from the sun, the earth, and the instrument`s warm side. In order to optimally design such a shield system, it is important to understand the thermal characteristics of DAK at low temperatures. We describe experiments which measured DAK`s thermal conductivity and electrical resistivity down to 4 Kelvin and its emissivity down to 10 Kelvin.

M1-B-08 AC and Impulse Breakdown of Liquid Nitrogen at 77 K for Quasi-Uniform and Non-Uniform Field Gaps

*D. R. James, I. Sauers, A. R. Ellis, **S. W. Schwenterly**, E. Tuncer, Oak Ridge National Laboratory; E. Pleva, Waukesha Electric Systems.*

Liquid nitrogen (LN2) is commonly used both as a coolant and electrical insulation in High Temperature Superconductor (HTS) equipment for power applications. Hence it is necessary to know the electrical breakdown characteristics of LN2 under a variety of conditions which are likely to be encountered in practice. AC breakdown and positive and negative polarity breakdown results for lightning impulse (1.2 microsecond rise time/50 microsecond fall time) are presented for LN2 using sphere to plane electrode geometry for sphere diameters of 25 to 150 mm over a gap range of 1 to 150 mm. Voltages up to 80 kVrms were studied for AC breakdown and up to 550 kV peak for impulse. In this work scaling of the breakdown voltage with distance is compared for different electrode diameters. These measurements were conducted in a dewar which could be pressurized from 1 to 2 bar absolute which greatly reduces the spontaneous formation of bubbles that can occur in open LN2 bath experiments and thus potentially reduce the breakdown strength. Results from the pressurized system and open bath are compared.
Research sponsored by the U.S. Department of Energy - Office of Electricity Delivery and Energy Reliability, Superconductivity Program for Electric Power Systems under contract DE-AC05-00OR22725 with Oak Ridge National Laboratory, managed and operated by UT-Battelle, LLC.

M1-B-09 Tests of Cable Insulation Systems for Nb3Sn Wind & React Coils

***R. Bossert**, G. Ambrosio, N. Andreev, M. Whitson, A. V. Zlobin, Fermi National Accelerator Laboratory.*

Tests were performed to assess the viability of several cable insulation systems for use in Nb3Sn accelerator magnets. Insulated stacks of cables were subjected to reaction cycles commonly used for Nb3Sn coils. After reaction and epoxy impregnation, current leakage between turns was measured at pressures up to 180 MPa and turn-to-turn potentials up to 500V. Systems consisting of S-2 glass, ceramic fiber, and e-glass were tested. Several methods of applying the insulation were incorporated, including sleeves and various spiral wrapped configurations. Methods of sample preparation and testing are described and results are reported.

M1-B-10 Gas Evolution from Insulating Materials for Superconducting Coil of ITER by Gamma Ray Irradiation at Liquid Nitrogen Temperature

***A. Idesaki**, N. Koizumi, M. Sugimoto, N. Morishita, T. Ohshima, K. Okuno, Japan Atomic Energy Agency.*

A laminated material composed of glass cloth/polyimide film/epoxy resin will be used as an insulating material for superconducting coil of international thermonuclear experimental reactor (ITER). In order to keep safe and stable operation of the superconducting coil system, it is indispensable to evaluate radiation resistance of the material, because the material is exposed to high radiation field of 10MGy at low temperature of 4K. Especially, it is important to estimate the amount of gases evolved from the insulating material by the irradiation, because the gases affect on the purifying system of liquid helium. In this work, the gas evolution from the laminated material by gamma ray irradiation at liquid nitrogen temperature (77K) was investigated, and the difference of gas evolution behavior due to difference of components in the epoxy resin was discussed. As a result, it was found that the main gases from the epoxy resin by the irradiation were hydrogen, carbon monoxide and carbon dioxide, and that the amount of the gases from epoxy resin containing cyanate ester was 30-40% less than that from the epoxy resin containing tetraglycidyl-diaminophenylmethane (TGDDM).

M1-B-11 Fatigue Properties of Modified 316LN Stainless Steel at 4K for use in the Series-Connected Hybrid Magnet

***V.J. Toplosky**, R.P. Walsh, NHMFL, FSU.*

A Series-Connected Hybrid (SCH) magnet being designed and constructed at the National High Magnetic Field Laboratory (NHMFL) using Cable-In-Conduit-Conductor (CICC) technology will employ a modified 316LN stainless steel (higher nitrogen content than conventional 316LN SS) as the magnet coils conduit. The selection of modified 316LN as the conduit material must take into account several criteria to ensure the magnets reliability and performance. These include: an expected high fatigue life for this series-operated magnet, optimal stress management at cryogenic temperatures and thin walled conduit to reduce coil mass. Based on the required high fatigue life, a series of strength versus fatigue life curves has been generated for both base metal and welded modified 316LN SS at various metallurgical states. The fatigue crack growth rate (FCGR) at 4 K will also be investigated. A comparison of fatigue properties between modified 316LN, conventional CICC materials and candidate materials will be presented.

Tuesday, 07/17/07 Oral 10:30am - 12:00pm

M1-G Radiation and Materials Evaluation - I

M1-G-01 Effect of Radius of Loading Nose and Supports in Short Beam Test Fixture on Fracture Mode and Interlaminar Shear Strength of GFRP at 77 K

***A. Nishimura**, National Institue for Fusion Science.*

A short beam test is useful to evaluate the interlaminar shear strength (ILSS) of GFRP using a smaller specimen. The test specimen is recommended to be 2.5 mm thick, 10 mm wide and 15 mm long. The supporting span is 12.5 mm and the ratio of span to thickness is 5.0. To investigate the fracture mode under a different radius of the loading nose or supports, the radius was changed from 1 mm to 7 mm, and two kinds of specimens of G-10CR were prepared. One was machined out of a thinner plate of which original thickness was 2.5 mm (non-sliced specimen). The other was taken out of a 13 mm thick plate. The plate was sliced into two plates and then 2.5 mm thick specimen (sliced specimen) was machined. Therefore, the non-sliced specimen had an original surface covered with epoxy resin on the right and back sides, and the sliced specimen had machined surfaces where glass fibers appeared. Three specimens were tested for one test condition in liquid nitrogen.
After the test, the followings were clarified.
(1) The non-sliced specimens showed that the smaller radius generated the local plastic deformation and gave a tendency of the bend fracture. Over 6 mm radius gave higher percentage of the interlaminar shear fracture and the constant ILSS.
(2) The sliced specimen did not show the interlaminar shear fracture even in the larger radius. They showed the cross-laminar fracture and did not give the ILSS.

M1-G-02 Effect of Gamma Ray Irradiation on Interlaminar Shear Strength of Glass Fiber Reinforced Plastics at 77 K

***A. Nishimura**, National Institue for Fusion Science; S. Nishijima, Y. Izumi, The Graduate School of Osaka University.*

The effect of gamma ray irradiation was investigated using the sort beam method and two kinds of G-10CR specimens. The first specimen type was a non-sliced specimen which was machined out of a 2.5 mm thick GFRP plate. The right and back surfaces were covered with original epoxy resin. The second was a sliced specimen which was machined out of the sliced plate from a 13 mm thick plate. The both surfaces were rough and woven clothes appeared. Both type of specimens were irradiated by gamma ray at 0.1, 0.2, 0.5, 1.0, 2.0, 5.0 and 10 MGy and the short beam tests were carried out in liquid nitrogen using the loading nose and supports with 6 mm radius in the test fixture.
The test results are as follows:
(1) In the case of the non-sliced specimen, typical interlaminar fracture occurred at up to 0.2 MGy, and the fracture mode changed to cross-laminar fracture on the plane connecting the loading and supporting points over 0.5 MGy. The ILSS was almost constant up to 0.2 MGy, but dropped gradually over the dose.
(2) All sliced specimens showed cross-laminar fracture. The non-irradiated ILSS of the sliced specimen was lower than that of the non-sliced specimen about 30-40 MPa. The tendency of the change in ILSS against the dose was almost same as the case of the non-sliced.
(3) The thicker G-10CR plate would have a weaker laminate structure of glass clothes than a thinner plate. This difference of the laminate structure would generate the difference of ILSS.

M1-G-03 Cryogenic Mechanical Behaviors of PES Modified Epoxy Resins

*G. Yang, J.-P. Yang, **S.-Y. Fu**, Tech. Inst. Phys. Chem., CAS.*

In this paper, poly(ethersulfone) (PES) was used to modify a bisphenol-F based epoxy resin cured with an aromatic diamine. SEM micrographs of solvent-etched fracture surfaces of the cured blends displayed that phase separation occurred after curing. The cryogenic mechanical behaviors of the unmodified and modified epoxy resins were studied in terms of tensile properties and Charpy impact strength at cryogenic temperature (77K) and compared to their corresponding behavior at room temperature (RT). The results showed that the addition of PES generally improved the elongation at break, tensile and impact strength at both RT and 77 K. The maximum value of tensile and impact strength occurred at 20 phr DGEBF/PES blend, where a co-continuous phase formed. The tensile and impact strength then decreased markedly for blends with the higher PES content. Young's modulus decreased slightly with the increase of the content of PES at both RT and 77K. The changes of mechanical properties were further elaborated through the correlation between the SEM micrographs of impact fracture surfaces and mechanical properties. Finally, the differential scanning calorimetry (DSC) analysis showed that the glass transition temperature (Tg) increased with the addition of PES.

This work was financially supported by the Outstanding Overseas Chinese Scholars Fund of Chinese Academy of Sciences and the National Natural Science Foundation of China (Grant Nos. 10672161 and 50573090).

M1-G-04 Influence of reinforcement anisotropy on the stress distribution in tension and shear of a fusion magnet insulation system

***K. Humer**, R. Prokopec, H.W. Weber, Atomic Institute of the Austrian Universities, Vienna University of Technology, 1020 Vienna, Austria; S. Raff, Institut für Reaktorsicherheit, Forschungszentrum Karlsruhe, 76021 Karlsruhe, Germany.*

A glass fiber reinforced plastic laminate, which consists of half-overlapped wrapped Kapton/R-glass-fiber reinforcing tapes vacuum-pressure impregnated in a cyanate ester/epoxy blend, is proposed as the insulation system for the ITER Toroidal Field coils. In order to assess its mechanical performance under the actual operating conditions, cryogenic (77 K) tensile and interlaminar shear tests were done after irradiation to the ITER design fluence of 1x10^22 m^-2 (E>0.1 MeV). The data were then used for a FEM stress analysis. We find that the mechanical strength and the fracture behavior as well as the stress distribution and the failure criteria are strongly influenced by the winding direction and the wrapping technique of the reinforcing tapes.

M1-G-05 Thermal-Mechanical Response of Cracked Satin Weave CFRP Composites at Cryogenic Temperatures

***S. Watanabe**, Y. Shindo, F. Narita, Tohoku University; T. Takeda, Hitachi Ltd..*

The use of carbon fiber reinforced polymer (CFRP) woven laminates for a lightweight cryogenic tank structure of reusable launch vehicles has been explored for a number of years. When the composite materials are cooled to cryogenic temperatures, residual thermal stresses develop. These stresses arise because of the mismatch in coefficient of thermal expansion between the fibers and the epoxy matrix in the laminates. When residual thermal stresses are combined with mechanical loads, microcracks may initiate well below the ultimate strength of the laminates, and large numbers of microcracks could have an important influence on their performance. These cracks can be eventually related to phenomena of fuel leakage, which is very dangerous for tank safety. Therefore, much effort needs to be devoted to gaining a better understanding of the thermal-mechanical behavior of cracked CFRP woven laminates at cryogenic temperatures.

The purpose of this paper is to report a numerical investigation of the thermal-mechanical response of satin weave CFRP laminates with internal and/or edge cracks and temperature-dependent material properties under tension at cryogenic temperatures. A two-dimensional finite element method is used to evaluate the effects of residual thermal stresses and cracks on the mechanical behavior of CFRP woven laminates. Numerical calculations are carried out for the Young`s modulus and stress distributions near the crack tip, and the results are shown graphically.

M1-H MgB2 Properties

M1-H-01 Commercialization of MgB2 Multifilamentary Strands and Research Directions for Transport-Property Improvement*

***E.W. Collings**, M. Bhatia, S.D. Bohnenstiehl, M.D. Sumption, LASM, MSE Dept., The Ohio State University; M. Tomsic, Hyper Tech Research, Inc..*

Magnesium diboride strand is now being manufactured in km-class lengths by the Ohio company Hyper Tech Research assisted on the materials research side by Ohio State University's superconductivity center LASM. With critical current densities (J_c) characterized by (8±6)x10^4 A/cm^2 at 5T, 4.2 K the in-situ-powder-in-tube-process multifilamentary strand is now suitable for moderately large scale applications. Numerous racetrack and solenoidal coils have already been wound and tested. But based on reported thin-film results there is much room for Jc improvement (higher values and reduced scatter) towards which substantial effort is presently being directed. Accordingly we have chosen to discuss the results of studies currently under way on: (i) the effects of dopants, (ii) reaction pathways and kinetics in response to changes in B powder purity, crystallinity, and particle size, (iii) the effect of powder-core densification, (iv) the role of intergrain connectivity in restricting the attainable J_c.

M1-H-02 Enhancement of Critical Current of MgB2 Conductors by Codoping with SiC and CaB6

***S.I. Schlachter**, B. Liu, W. Goldacker, A. Jung, H. Orschulko, B. Ringsdorf, Forschungszentrum Karlsruhe, ITP.*

Although the superconducting properties of MgB2 PIT conductors for technical applications have been continuously optimized, the current carrying capability of the conductors is still far below the depairing current density. It was shown that carbon doping, e.g. with nano-SiC, leads to improvement of upper critical field and flux pinning. In particular in high magnetic fields and at low temperatures carbon doping enhances the current carrying capability strongly. For enhanced Jc in low magnetic fields and at elevated temperatures, reduction of secondary phases and improvement of grain connectivity are indispensable.

This work describes efforts to improve the current carrying capability of MgB2 conductors by codoping with SiC and CaB6. We observed that doping with 10 wt% CaB6 leads to enhanced current carrying capability and decrease of the normal state resistivity which can be interpreted as increase of the effective cross section contributing to current transport. At 12 T and 4.2 K wires codoped with 5 wt% SiC and 5 wt% CaB6 showed even higher Jc than wires doped with 10 wt% SiC. The mechanisms leading to the improved Jc will be discussed.

M1-H-03 Dual reaction model for understanding of the doping effect in MgB2

S. X. Dou, *W. K. Yoeh, O Shcherbakova, J. H. Kim, Institute for Superconducting and Electronic Materials, University of Wollongong, Wollongong, NSW 2522 Australia; M Sumption, E. W. Collings, Department of Materials Science and Engineering, Ohio State University; C. Senatore, R. Flukiger, Department of Physics, University of Geneva, Geneva, Switzerland ; E. Babic, Department of Physics, Faculty of Science, University of Zagreb, Zagreb, Croatia.*

A systematic study on the effect of sintering temperature on the lattice parameters, carbon content and electromagnetic properties allows us to demonstrate a dual reaction model, according to which the optimal doping effect can be achieved when the C substitution and MgB2 formation take place at the same time at low temperatures. The C substitution is responsible for the enhancement in Hc2 while its induced defects together with low temperature processing improve flux pinning and hence Jc. The Hirr for the SiC doped sample reached the benchmarking value of 10 T at 20 K, exceeding that of NbTi at 4.2 K. This model not only can explain the unique features of SiC doping in MgB2, but also provide reasonable assessment on many other dopants as well as predict what would be desirable dopants for enhancing the performance properties of MgB2. The understanding of dual reaction model has led to the discovery of the advantages of carbohydrate doping in MgB2, resulting in a significant enhancement in Jc, Hirr, and Hc2. Carbohydrates decompose at temperatures near that of MgB2 formation, thus producing highly reactive C, not dissimilar to the case of SiC doping. The model has a significant ramification to the fabrication of other carbon containing compounds and composites.

The authors thank Dr. R. Klie for his assistance in EELS analysis, and Drs. H. Kumakura, T. Silver and Mr M. Tomsic for helpful discussion. The work is supported by Australian Research Council, Hyper Tech Research Inc, and CMS Alphatech International Ltd.

M1-H-04 Normal State Resistivity and Connectivity in MgB2

M Bhatia, *M.D. Sumption, E.W. Collings, The Ohio State University.*

The measured Jc, of MgB2 superconductor falls short of the ideally achievable Jc because of the problems of grain connectivity, grain boundary blockages and high porosity within in-situ reacted samples. Hence, it becomes important to be able to measure the degree of connectivity in order to be able to achieve the possible high Jcs. In this paper we have attempted to build up on the model of connectivity proposed by Rowell et al [1]. We have measured the normal state resistances of MgB2 bulk samples (pure and doped) prepared in-house in the temperature range of 40 K- 300 K using the four point probe technique and fitted the resistivity data to the Bloch-Gruneissen equation. These samples have been made by powder mixing and compaction followed by heat-treatment in Argon atmosphere. The dopants include SiC, C, ZrB2, TiB2 and NbB2. Data obtained from various other literature sources, both single crystal and thin films was also analysed in the similar manner and compared to the OSU samples. While it is understood that MgB2 is a two band gap system in principal, and there are validity problems in applying B-G model to it and so we will explore the various aspects of the validity and alternative approaches. Values of residual resistivity, connectivity and Debye temperature have been obtained from the fitting. These values of Debye temperature will also be validated using the Quantum design PPMS in order to further validate the predictability of the model.

Reference

[1] J.M.Rowell, Supercond. Sci. and Technol., Volume 16, Issue 6, pp. R17-R27 (2003)

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M1-H-05 Nature of pinning in Neutron irradiated Magnesium Diboride bulk samples

C. Ferdeghini, *C. Tarantini, P. Manfrinetti, A. Palenzona, M. Putti, A. Martinelli, I. Pallecchi, V. Braccini, A. Malagoli, A. Tumino, M. Vignolo, C. Bernini, CNR-INFM/LAMIA.*

We measured the upper critical field and the critical current density on neutron irradiated Magnesium diboride bulk samples and we studied the effects of damaging on pinning mechanisms. We observed a strong enhancement of the upper critical field and great improvement of the critical current magnetic field dependence in an intermediate range of fluence. We demonstrated that the critical current increase is not only due to the Hc2 improvement but the irradiation substantially changes the pinning force improving the critical current density at high magnetic field. In particular, by increasing irradiation level the maximum of pinning force shifts toward high reduced magnetic field, giving a clear evidence of the changing of pinning mechanisms from grain boundaries to point defects and finally to other ones such as the variation of the order parameter. In the most irradiated samples grain boundaries pinning is newly the most effective, and the critical current is strongly suppressed by the reduced connectivity between grains. Finally we correlated the increased critical currents with the defects on nanometric scale produced by neutron irradiation; these defects are well evidenced by TEM analyses.

Tuesday, 07/17/07 Poster 1:30pm - 3:00pm

M1-K Material Evaluation and Testing: HTS and LTS - I

M1-K-01 Mechanical Properties of Laminate Alloys and Laminate-Stabilized 2G YBCO/Ni-W Tape

R.L. Holtz, *Naval Research Laboratory.*

YBCO coated conductor tapes have been shown to be resistant to degradation of critical current with strains as high as 0.4%, which is well past the yield point of the Ni-W substrates [N. Cheggour, et al, Appl. Phys. Letters, 83, 4223 (2003)]. In this strain range, however, Ni-5%W substrates exhibit large cyclic stress-strain hysteresis as well as creep and stress relaxation effects that can complicate the prediction of the mechanical state of the tapes under time dependent loading. Laminating such 2G tapes with selected reinforcement foils stabilizes the mechanical properties. Further, tailoring the trade-off between conductivity of the laminates and their mechanical properties allows optimization of composite HTS tapes according to application. Here we report on room temperature and 77K longitudinal stress-strain properties for both monotonic and cyclic loading, of several laminating materials and laminated 2G tape provided by American Superconductor Corp, as well as the solder used to apply the laminations. Laminates examined in this study include heat-treated and as-received copper foils, several copper alloys, beryllium-copper alloy, and stainless steel.

M1-K-02 The mechanical properties of the MgB2 bulk materials obtained by Reactive Liquid Infiltration

G. Giunchi, *EDISON SpA; T. Cavallin, CNR IENI; S. Guicciardi, CNR ISTEC.*

The Reactive Liquid Infiltration technique allows to produce very dense MgB2 bulk material, useful as superconductor in many electrotechnical devices [1]. The resulting MgB2 product presents a composite structure characterized by large grains, reminiscent of the grain size of the precursor Boron powders, embedded in a matrix of the same material with smaller grains, of the order of a micron in size. This composite structure of the product presents peculiar mechanical properties characterized by a very high fracture toughness, as far as a ceramic materials is concerned, and very high hardness. We have measured the room temperature mechanical properties as a function of the main manufacturing parameters of the materials, as the grain size of the precursor B powders and the residual content of impurities in the materials. The obtained values compare favourably with that of the same material produced by other manufacturing techniques and with that of the other HTS bulk materials.

[1] – G.Giunchi et al. , Advances in Science and Technology Vol. 47 (2006) pp. 7-16

M1-K-03 Pure Bending Strand Test of High Performance Nb3Sn wires

*D.L. Harris, A.A. Allegritti, **M. Takayasu**, J.V. Minervini, MIT, PSFC.*

Degradation due to mechanical strain and bending of large Nb3Sn superconducting cables like those to be used for ITER conductors have been investigated in various ways. We have developed a variable bending device for characterizing the critical currents of superconducting strands under pure bending. This device is able to apply a bending strain over a large range of up to 0.9%. The principal mechanical mechanism is similar to that developed by W. Goldacker, et al. [1] for characterization of high temperature superconductors under bending. The challenge to our device development was to establish a given uniform bending to a strand over a large range of applied strain under a large electromagnetic force which was generated by the background magnetic field and the transport current of the test sample. This device permits application of pure bending strain during test operation in liquid helium. This paper will discuss the design of the pure bending device for critical current measurements, and reports test results of recent high performance Nb3Sn wires.

1. W. Goldacher, et al., Advances in Cryogenic Engineering, 48B, p.469, 2002.

This work was supported by the U.S. Department of Energy, Grant No. DE-FC02-93ER54186. A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by NSF Cooperative Agreement No. DMR-0084173, by the State of Florida, and by the DOE.

M1-K-04 A Nb3Sn Conductor via Cu5Sn4 Powder-In-Tube Process for High Field Magnet Applications.

*L.R. Motowidlo, **G.M. Ozeryansky**, Supramagnetics, Inc..*

A new Nb3Sn conductor via a Cu5Sn4 powder-in-tube process is presented. The new process replaces the conventional NbSn2 powder and utilizes low-cost copper and tin powder components to form Cu5Sn4 as the tin source. The Cu5Sn4 powder is processed to micron particle size and introduced into Cu-clad Nb or Nb-alloy tubing followed by mechanical processing into a multifilament wire. At final wire diameter, the new PIT Nb3Sn wire contains filament diameters in the range of 10 to 20 microns. The A-15 microstructure for optimized temperature and time with the corresponding critical current performance will be discussed.

High Energy Physics, Department of Energy Grant No. DE-FG02-05ER84381

M1-L BSCCO Improvements

M1-L-01 Quasi-2D effects on the magnetization curves of (Bi,Pb)-Sr-Ca-Cu-O samples

***V. Mihalache**, National Institute for Materials Physics; D. Miu, National Institute for Laser, Plasma, and Radiation Physics.*

Magnetization loop measurements at 77.3 K were performed on (Bi,Pb)-Sr-Ca-Cu-O/2223 polycrystalline specimens of different nominal composition, obtained through different technological routes, irradiated and non-irradiated. An anomalous increase of the irreversible magnetization with increasing applied magnetic field, the second magnetization peck (SMP), has been observed. The analysis of the origin of the SMP was done in connection with the results of ac susceptibility measurements, in which the crossover between three-dimensional (3D) and quasi-two dimensional (2D) behavior of the superconducting (Bi,Pb)2Sr2Ca2Cu3O10+delta (Bi-2223) grains was detected. Our suggestion for the origin of the SMP in investigated high temperature - low field domain is the decoupling of superconducting layers in the thick stacks (consisting of a large number of superconducting layers), namely, the transition from the vortex dynamics in the stacks having 3D properties to the vortex dynamic in the stacks with certain 2D-effects.

M1-L-02 Ag -sheathed Bi2Sr2CaCu2O8 square shape wire insulated with oxidized Hastelloy knitting cloth

***K. Watanabe**, G. Nishijima, S. Awaji, Tohoku University; Y. Hikichi, T. Hasegawa, Showa Cable Systems.*

Oxidized Hastelloy X (Hx) cloth knitted into a braid tube has been demonstrated to work well as a good electric insulation of Ag-sheathed Bi2Sr2CaCu2O8 (Ag/Bi-2212) wires. In order to develop a wind-and-react processed Ag/Bi-2212 superconducting magnet with a high coil current density, we fabricated a test coil employing 45 m long Ag/Bi-2212 square shape wire with 50 μm Hx filament cloth. A test coil, whose size is 73 mm outer diameter, 64.5 mm inner diameter, and 74 mm coil winding height, consisted of 4 layers and 210 turns, and was heat-treated at around 890 C in oxygen gas. The critical current Ic of the test coil was 245 A at 4.2 K in a self-field, corresponding to a 67 % value of the short sample Ic heat-treated at the same time for comparison. Coil inductance was calculated to be 1.9 mH, and as a result, the same inductance value was obtained in the test coil. It was found that a Hx cloth kitting method enables us to insulate sufficiently between wires in Ag/Bi-2212 square shape wire.

M1-L-03 Thermal conductivity of BSCCO tapes for current lead applications

***M. Schwarz**, K.P. Weiss, R. Heller, W.H. Fietz, Forschungszentrum Karlsruhe.*

Current leads, e.g. for magnet coils, are an important application for high temperature superconductors (HTS), which is realized quite often today. The HTS material offers an economic possibility to conduct high currents without transferring much heat from the warm end to the cold device. A bulk HTS conductor provides the lowest heat conduction but has to deal with other difficulties, e.g. mechanical and electrical stability. Therefore BSCCO tapes stabilized with Ag offer a good choice. To decrease the high thermal conductivity of the stabiliser material doping or alloying with Au or Mg is commonly used. The thermal conductivity of several BSCCO single tapes as well as stacks from different suppliers has been measured and compared. Furthermore the influence of the solder material used in stacks is investigated.

M1-L-04 Preparation and Characterization of Ag-added Bi1.67Pb0.34Sr2Ca2Cu3Ox Superconductor wires

***H. Salamati**, P. Kameli, D. Sohrabi, I. Abdolhossieni, Isfahan University of Technology.*

Although there exist a large variety of thermo-mechanical and phase assemblage procedures for preparing Bi-2223 wire, primarily because of variation in precursor characteristic, the fabrication of Bi-2223 superconducting wire still requires the finesse of optimizational approach on processing, such as heat treatment, precursor phase assemblage and particle size, addition and substitution of elements and so on, to maximize the engineering current density (Jc) and ultimately improve high field performance for application. Superconductor wire of Bi1.67Pb0.34Sr2Ca2Cu3Ox with the addition of silver varying from 0 to 25 wt% were prepared and systematically studied using X-ray diffraction (XRD), scanning electron microscopy (SEM), electrical and a.c. susceptibility technique. We have used the PIT technique to form Bi-2223 superconductor wire. It was shown that Ag addition has not only affected the formation of desire Bi-2223 phase and the microstructure of these wires thereby influencing on the critical current density (Jc), it is also reduce the normal resistivity. These variations have been found to be Ag content dependent. An optimized value of 15 wt% has been found to be the best quality wire showing reproducible and high Jc.

Authors would like to thank Isfahan University of Technology for supporting this project.

Tuesday, 07/17/07 Oral 3:00pm - 4:15pm

M1-O Properties of Cable-in-Conduit Conductor for Jacket Alloys

M1-O-01 Fracture Toughness Measurements and Assessment of Thin Walled Conduit Alloys in a CICC Application

***R. P. Walsh**, J. Toth, V. J. Toplosky, K. Han, NHMFL/FSU.*

The Series-Connected Hybrid Magnets under construction at the NHMFL use Cable-in-Conduct-Conductor (CICC) technology. The conduit's 4 K mechanical properties are extremely important to the performance and reliability of the magnets. We have measured tensile and fracture toughness of two conduit alloys (Haynes 242 and modified 316LN) in various metallurgical states, with emphasis on their final state of production. To assess the material in it's final production state, non-standard specimens are removed directly from the round-corner rectangular conduit (1.5mm wall, nominal outside dimensions of 13.7 mm by 16 mm) and tested after exposure to a simulated Nb3Sn reaction heat treatment. The non-standard middle-tension (MT) specimens enable fracture toughness evaluation of the base metal, welds and weld/base metal interface region. We also discuss and compare the results of Finite Element Analysis (FEA) conducted on the (MT) specimen tests.

This work is funded by National Science Foundation

M1-O-02 Development of jacketing technologies for ITER CS and TF conductor

***K. Hamada**, H. Nakajima, K. Matsui, K. Kawano, K Takano, F. Tsutsumi, K. Okuno, O. Techima, Japan Atomic Energy Agency; N. Fujitsuna, Kobe Steel, LTD; T. Fujimoto, Nippon Steel Engineering Co., LTD.*

The ITER Toroidal Field (TF) coil and Central Solenoid (CS) use Nb3Sn cable-in-conduit conductor. Conductors are fabricated by following procedure;
(1) Fabrication of jacket with a unit length of ~10 m.
(2) Butt welding of jacket to make a long tube (CS: 880 m, TF: 760 m) and insertion of superconducting cable into jacket.
(3) Compaction and temporary winding for transportation.
Japan Atomic Energy Agency (JAEA) has developed jacketing technologies in the cooperation with industries.
Major achievements are as follows;
(1) Full scale TF and CS jackets were fabricated using low carbon SUS316LN and boron added (~40ppm) high manganese stainless steel (0.025C -20Mn -13Cr -9Nr -0.12N: JK2LB), respectively. The jackets satisfied ITER mechanical and dimensional requirement.
(2) Butt welding condition using Tungsten Inert Gas (TIG) was studied to obtain good internal surface condition at welded joint.
(3) Compaction machine having four rollers was constructed. As results of compaction test of TF and CS jacket, compacted jacket dimensions satisfied ITER requirement.
Therefore, JAEA developed jacketing technologies for ITER conductor fabrication.

M1-O-03 Effects of Winding Strain and Heat Treatment on Properties of 316 LN and Haynes 242

***K Han**, R.P. Walsh, V.J. Toplosky, R.E. Goddard, I.R. Dixon, National High Magnetic Field Laboratory.*

The outer coils of the hybrid magnets at the NHMFL use Cable-in-Conduct-Conductor (CICC) technology. This technology requires us to wind the coils before the heat treatment is undertaken. The winding introduces both tensile and compressive stresses to the conduit alloys. The subsequent heat treatment has to be done when the conduit alloys are under the pre-stress. We have simulated the conduit heat treatments with the alloys under various stress levels, and undertaken the tensile tests at 4 K and microstructure examinations. The results indicate that the pre-stress before the heat treatment influences the microstructure and therefore tensile test properties of the conduit alloys at 4 K. The tensile test property changes are related to the grain boundary precipitation variation introduced by pre-stress.

M1-O-04 The 4K mechanical properties of modified SS316LN for jacket materials in superconducting fusion magnets

***J.H. Kim**, J Feng, MIT Plasma Science and Fusion Center.*

Modified stainless steel 316LN (SS316LN) is designed as ITER TF jacket materials for the application at 4K. The mechanical properties of modified SS316LN have been measured at both room temperature and 4K in order to evaluate its suitability as the candidate materials for ITER TF jacket. The efforts of chemical composition variation, cold work, and aging heat treatments have also been studied. It is found that both base and weld materials of the modified SS316LN after cold work and aging satisfy the designed requirement of mechanical properties for ITER TF jacket.

M1-O-05 Physical properties of a Ni-Mo-Cr alloy Haynes 242 at cryogenic temperatures

***J. Lu**, K. Han, E.S. Choi, Y. Jo, L. Balicas, Y. Xin, NHMFL.*

Haynes 242 is a Ni-Mo-Cr based superalloy. High strength and high fracture toughness at low temperatures makes Haynes 242 an attractive choice for cryogenic applications such as the conduit material for the cable-in-conduit-conductor of superconducting magnets. In this work, its low temperature physical properties including magnetization, specific heat, electrical resistivity, thermal conductivity, and Seebeck coefficient are measured from 2 to 300 K. Haynes 242 shows Curie paramagnetism with a Curie constant C = 0.0289 K. The electrical resistivity has a minimum at ~ 12 K, and shows weakly linear T dependence at high temperatures as expected. The specific heat Cp between 10 and 40 K can be fitted by sum of electronic and phonon contributions. Below 10 K, an upturn in Cp/T with decreasing T is interpreted by the existence of very small ferromagnetic clusters which is supported by our magnetization data. The thermal conductivity is analyzed by separating the electronic and phonon contributions. The relatively strong phonon thermal conduction at temperatures <100 K results in effective Lorenz number a few times larger than the ideal Lorenz number. Our results suggest that Haynes 242 is suitable for many cryogenic applications including conduit for large superconducting magnet and low temperature probe.

Financial support of the National Science Foundation under grant of DMR-0084173 is gratefully acknowledged.

M1-P Coated Conductor - I: Processing

M1-P-01 Advanced Characterization Supporting Manufacturing of Long-lengths of High-Performance Second-generation HTS Conductors at SuperPower

***A. Rar**, J. Reeves, V. Selvamanickam, SuperPower Inc.*

Integration of second generation (2G) high temperature superconducting (HTS) material into cryogenic devices such as HTS cables, motors, and generators requires long lengths of the superconductor with high critical current, good mechanical properties, and a decrease in the cost of the production. SuperPower Inc. has demonstrated high-throughput Pilot-scale manufacturing of 2G HTS conductor in piece lengths exceeding 400 m with critical current levels of 200 A/cm. From its Pilot Manufacturing operation SuperPower delivered nearly 10,000 m of 2G HTS conductor to Sumitomo Electric in 2006 to construct a 30 m 2G cable for the Albany Cable project. Important ingredients of our operation that enabled us to reach these milestones were the knowledge about the structure of the coated superconductor and its relationship to the product performance and processing parameters, strict on-line control, and detection of defect origin. For these purposes, we have developed a unique set of instruments for both off-line advanced characterization and for on-line quality control of the tape during the different production steps.
In this presentation we will discuss advanced characterization on each layer of the 2G HTS using ellipsometry, glow discharge optical emission spectroscopy, XRD, and electron and optical microscopy to study the relationships between material structure and performance. On-line quality control techniques used in our Pilot Manufacturing operations will be also discussed.

M1-P-02 Progress in the Development of Second Generation HTS Wire at American Superconductor

*Y. Huang, X. Li, W. Zhang, T. Kodenkandath, M. Rupich, **D. Vereblyi**, C. Thieme, American Superconductor Corp.*

Second Generation (2G) high temperature superconductor wire is being developed for use in a broad range of commercial and military applications targeted for operating between 50 – 77K in fields up to 3 T. The exceptional performance of the 2G wire is the result of the ability to engineer specific microstructural properties into the YBCO film which enhance pinning in the presence of both parallel and perpendicular magnetic fields. Doping the YBCO matrix with rare earth (RE) based materials produces a nanoparticle dispersion that generates uncorrelated pinning centers, resulting in a significant increase in pinning in all orientations of applied magnetic field. In addition, the density of 124-type intergrowths can be engineered to create to a peak in Ic with respect to magnetic field orientation around the plane of the tape. Variation in the composition and density of the nanoparticles additions can be exploited to selectively engineer the properties of the 2G wires for specific temperature and magnetic field requirements. In this presentation, we will describe the low temperature, magnetic field properties of the 2G conductors as a function of the nanoparticle composition and density. We will also present a hybrid YBCO film in which the pinning can be engineered for specific operating conditions.

M1-P-04 YBCO Nucleation and Epitaxial Growth in The Modified TFA-MOD Process

***Y. Xu**, H. Peng, S. Matson, M. Massey, R. Bhattacharya, UES Inc; C. Lei, UIUC.*

Metallorganic deposition (MOD) of YBa2Cu3O7-d (YBCO) films is one of the most cost-effective methods for the fabrication of long coated conductor (CCs) wires. Although this process has shown success for films below 1 mm, Critical current (Ic) over 500 A/cm has not been demonstrated even on small samples. Increasing Ic through further improvement of critical current density (Jc) is not viable because the present Jcs are comparable to that of the intragrain Jc, which is believed to be the theoretical limit of the high temperature superconductor.
Thicker YBCO films through MOD approaches with pinning center enhancement are yet to be fully explored to attain higher Ics. In this paper, we present a multiple coating process to make thicker YBCO films through modified TFA-MOD approach. Thicker films of 1-2 mm with Ic over 280A/cm were successful grown by control of processing conditions. High growth rate up to 1 nm/s was realized on small samples. The mechanisms of nucleation and epitaxial growth of YBCO films were investigated for the modified TFA-MOD process. The growth transition from planar to cellular microstructure was observed. Interfacial nucleation and layered growth are crucial for high critical current density YBCO films.
This work was sponsored by Air Force Office of Scientific Research SBIR Phase I and II under contract number of FA8650-05-M-2510 and FA8650-05-C-2627.

M1-P-05 Processing and Characterization of Metal-Organic Deposition - SmBa2Cu3O7 for Enhanced Pinning

***F. Lu**, Materials Science Program and Applied Superconductivity Center – Univ. of Wisconsin-Madison; E.E. Hellstrom, Dept. of Materials Science and Engineering and Applied Superconductivity Center – Univ. of Wisconsin-Madison.*

The standard coated conductor architectures uses YBa2Cu3O7 superconductor. Here we report using metal-organic deposition (MOD) to fabricate SmBa2Cu3O7 and investigate different doping schemes to improve flux pinning. We chose SmBCO because it has a higher Tc than YBCO, and PLD deposited Sm-rich SmBCO has been reported to have a pinning force of 20 GN/m^3 at 77K. Here we report optimizing the MOD deposition of SmBCO on an American Superconductor Corp. substrate with a 5W/Y2O3/YSZ/CeO2 architecture. We found that highly textured SmBCO requires growth at 850C, which is significantly higher than needed for YBCO, and that it takes at least 45 minutes at 850C for the texture to develop. The doping studies include Sm-rich MOD Sm1+xBa2-xCu3O7+delta, which is the composition with the 20 GN/m^3 pinning force prepared by PLD. We investigate if it is possible to achieve this high pinning force using MOD processing. We also report electromagnetic properties of Sm-rich Sm1+xBCO and SmBCO doped with BaZrO3.
This work was supported by DOE-OETD and AFOSR-MURI.

M1-P-06 Growth of Textured Oxide Films by Ebeam Evaporation and Inclined Substrate Deposition (ISD)

***Y. Xu**, P. He, M. Massey, R. Bhattacharya, UES Inc; C. Lei, UIUC; B. Ma, ANL.*

Inclined substrate deposition (ISD) is an attractive technique for the rapid production of high-quality template for the development of coated conductor (CC). Single ISD MgO layer has been confirmed to be a good textured template; while, other oxides such as CeO2 and YSZ are desirable buffer materials for CC. In this paper, we present the development of textured CeO2 short samples and long length MgO template by ebeam evaporation and ISD techniques. Biaxially textured MgO films have been successfully grown on Hastelloy tapes at room temperature in a reel-to-reel system at various substrate inclination angles (a) from 25 to 55° with high deposition rates of 30-100 Å/s. The in-plane texture analysis shows that FWHM of 12° for phi scan on a meter-long MgO template deposited in the moving mode at a=55° has been achieved. For CeO2, no texture was observed when deposited at room temperature regardless of inclination angle. Once the substrate was heated to above 200°C, single textured CeO2 with (111) orientation was formed at high inclination angles. AFM image and XRD pole figure analysis confirmed the formation of well textured CeO2 films. The mechanism of texture formation in the inclined substrate deposition process is also discussed.
This work was sponsored by Air Force Office of Scientific Research SBIR under contract number of F49620-03-C-0004 and by DOE SBIR project under contract number of DE-FG02-06ER84656.

Wednesday, 07/18/07 Poster 9:00am - 10:30am

M2-B New Concepts in Superconductors

M2-B-01 Experimental Investigation of Trapped Flux Stability in Bulk YBCO

*J.E. Pienkos, **P.J. Masson**, C.A. Luongo, FSU-FAMU College of Engineering; J. Leveque, B. Douine, University of Nancy, France.*

Bulk high temperature superconductor's unique capability of trapping magnetic flux enables the development of many applications such as high power density rotating machinery or magnetic bearings in which stability of the trapped flux is paramount. Previous simulations have been performed to estimate the magneto-thermal instabilities in high quality, single crystal bulk YBCO; we propose to carry out an experimental investigation that would verify this work. The study uses two types of YBCO disks in which flux is trapped through field cooling, regular single domain material, and YBCO plates in which holes have been drilled during fabrication. Using temperature controlling and magnetic field generation equipment, experiments to study the stability of trapped flux have been designed. We propose to look at the trapped flux stability for two different cooling procedures: field cooling at constant temperature and operating a few degrees above the optimum temperature (relaxation) to remove stress on the vortex network. Varying the operating temperature of the YBCO plate from 100 Kelvin to 4 Kelvin and applied magnetic field cooling of the material from 0.5 Tesla to 7 Tesla, we will investigate instabilities such as flux jumping and minimum quench energy. Forcing instabilities on the plates can be done by averaged or localized surface heating, or by embedded heaters through holes in the YBCO disks. The results from the experiments will be presented.

M2-B-02 Superconductivity in the Ni based ternary compound La2NiGe3

***J. W. Chen**, S. Y. Guan, C. H. Wang, Department of Physics, National Taiwan University.*

The crystal structure, electrical, and magnetic properties of the Ni based ternary compound La2NiGe3 have been investigated by means of the powder X-ray diffraction, ac electrical resistivity, and ac magnetic susceptibility measurements. Powder X-ray diffraction pattern reveals that this compound crystallizes in the AlB2-derived hexagonal structure with lattice parameters a = 4.188(1) Å and c = 4.339(1) Å. A sudden drop to zero value in the resistivity curve reveals that La2NiGe3 becomes superconducting with a midpoint transition temperature Tc of ~ 0.45 K and a superconducting transition width of ~ 0.2 K. The diamagnetic behavior observed in the ac susceptibility curve at the corresponding temperature indicates bulk superconductivity in this compound. Detailed results about this new superconductor will be presented.

This work was supported by the ROC National Science Council under Grant No. NSC 95-2112-M002-049-MY3

M2-B-03 Spin-Glass Formation in Na0.7Co1-xAlxO2

***Y. Zhang**, Southwest Jiaotong University.*

The single phase polycrystalline samples Na0.7Co1-xAlxO2 have been synthesized by solid reactions. Zero-field-cooled (ZFC) and field-cooled (FC) DC magnetization and AC susceptibility at different frequencies of Na0.7Co1-xAlxO2 were measured. A sharp peak at about 13 K of the ZFC and AC susceptibility temperature dependence curves and the great divergence of the ZFC and FC curves below 13 K suggests a spin-glass transition. The peak fs amplitude of AC susceptibility decreases as the increase of AC field frequency, and its position does shift to higher temperature. The results verify that Na0.7Co1-xAlxO2 ix=0.05 C 0.25 j is spin glass with a freezing temperature of about 13 K.

KEYWORDS: spin-glass state; zero-field-cooled (ZFC) magnetization; field-cooled (FC) magnetization; AC susceptibility

This work was supported by the National Science Foundation of China (grant No. 50372052, 50430137, 50588201), Specialized Research Fund for the Doctoral Program of Higher Education of China (grant No. 20040613027)

M2-B-04 Enhancement of Tc and orthorhombicity in argon preheated (Y1-xEux)(SrBa)Cu3O6+z

*B. Bouallal, **A. Nafidi**, A. El Kaaouachi, H. Chaib, H. Sahsah, GCMP University Ibn Zohr.*

We report here on the preparation, X-ray diffraction with Rietveld refinement and AC susceptibility measurements of (Y1-xEux)(SrBa)Cu3O6+z. We used two heat treatments: (i) the sintered sample were annealed in oxygen at 450°C for 3 days, this simple was denoted as [O] and (ii) the same sample were heated in argon at 850°C for 1 days, cooled and later annealed in oxygen at 450°C for 3 days [AO]. When x increase from 0 to 1, the orthorhombicity ort = (b-a)/(b+a) decreases with Tc[O]. However, Tc[AO] decreases with ort until x = 0.2 and after it increases by 7 K to 87 K for x=1 [AO]. Note that the parameter b is constant but a (and c) increase indicating an increase of the number of oxygen atoms by chain (NOC) along a leading to a decrease of ort(Tc) [O] toward a tetragonal structure. Some weak unidentified impurity peaks are eliminated in the samples [AO]. For each x, the [AO] treatment increases ort, Tc (for x sup 0.5) and the distance d[Cu(1)-O1] (decrease Tc) for x inf 0.5 and decrease it (increase Tc) for x sup 0.5. Remarkable correlations were observed. A combination of several factors such as decrease in d[Cu(1)-O(1)]; increase in cationic and chain oxygen ordering and in-phase purity for the [AO] samples may account for the observed data.

M2-C Novel Materials for Applications

M2-C-01 A Thermal Conduction Switch based on Low Hysteresis NiTiFe Shape Memory Alloy Helical Springs

***V.B. Krishnan**, C.N. Bewerse, R. Vaidyanathan, University of Central Florida; W.U. Notardonato, NASA Kennedy Space Center.*

Shape memory alloy (SMA) actuators have an inherent capability to sense a change in temperature and deliver significant force through a shape change against external loads as a result of a temperature induced phase transformation. The utilization of a cubic to trigonal (R) phase transformation in NiTiFe shape memory alloys helps reduce the transformation hysteresis. However, the shape recovery associated with the R-phase transformation is significantly lower than that of a monoclinic phase transformation. The use of helical NiTiFe SMA springs can solve this design constraint as they can produce significant stroke length when compared to straight elements, such as thin strips. This work reports on the development and implementation of NiTiFe helical springs in a low hysteresis thermal conduction switch. Such a low hysteresis thermal conduction switch can provide on-demand heat transfer between two reservoirs kept at different temperatures.

Support of NASA through grant NAG3-2751 is gratefully acknowledged.

M2-C-02 Superconducting and Conventional High Gradient Magnetic Separation of cellulignin

*J.P.B. Machado, M.L.G. Pereira, D.G. Pinatti, R.A. Conte, **D. Rodrigues Jr.**, Escola de Engenharia de Lorena-USP.*

In the BEM programme, cellulignin catalytic fuel can be generated by acidic prehydrolysis of biomass (wood, agricultural and forest residues, and the organic matter of municipal solid waste–MOL). In order to be used as a solid fuel in gas turbines with external combustor, the ash (inorganic) content of the cellulignin has to be as low as possible. The majority of particles containing inorganics in cellulignin have paramagnetic behavior. The superconducting HGMS system basically consists of a canister filled with 420 stainless steel wool (magnetic). The superconducting magnet was made with NbTi wire, with a maximum central magnetic field of 4 T. For the conventional HGMS tests it was used an INBRAS-ERIEZ magnetic separator that consists of: a canister filled with a matrix made of woven (mesh 4), with a maximum central magnetic field of 2 T. The cellulignin was prepared as suspension (5 wt. % in distilled water) for both systems. The HGMS systems reached almost the same reduction on cellulignin ash content. The woven matrix showed a better selectivity than the wool matrix.

The authors acknowledges support from: INBRAS-ERIEZ, CNPQ and FAPESP.

M2-C-03 Solderfilling of a CICC Cable for a Fusion Dipole

***P. Bauer**, A. Portone, E. Salpietro, A. Vostner, EFDA; P. Bruzzone, M. Vogel, CRPP; K. Weiss, , FZK.*

The first prototype Cable-In-Conduit-Conductor (CICC) cables for the superconducting EFDA dipole for future fusion conductor testing revealed an unexpected degradation of their critical current, Ic, in the SULTAN cable test facility. The degradation was clearly correlated with the electromagnetic loading and increased with each loading cycle. The strong Lorentz-forces during operation are thought to be sufficient to permanently degrade the brittle Nb3Sn superconductor from which the multi-strand CICC are made. In summer 2006 EFDA therefore launched a program to resolve the issue. One of the pursued solutions was to remedy the Ic degradation by solder filling the conductor in order to mechanically stabilize the stranded cable inside the conduit. This approach is considered unconventional, although it was previously applied with success in several cases. Some issues needed to be clarified before one could move ahead with this design. The most important among them were the choice of solder material, issues related to the solder filling, as well as the thermo-mechanical implications of a solder-filled, high-field, high-current cable. This work included not only extensive simulation but also experimental work, such as the mechanical testing of solder filled cables at cryogenic temperatures. This report summarizes the information gathered in the context of this effort and can be regarded as a useful resource for future projects facing similar issues.

M2-C-04 Influence of micro-damage on reliability of cryogenic bellows in the LHC interconnections

***C. Garion**, CERN; B. Skoczen, Krakow University of Technology.*

To achieve the maximum beam energy in the LHC the accumulated length dedicated to the interconnections between the main magnets, has been limited to around 3 % of the total magnetic length in the Arcs and Dispersion Suppressors. Such a low ratio leads to a very compact design of components located in the LHC interconnections. This implies development and evolution of high intensity plastic strain fields in the stainless steel expansion bellows subjected to thermo-mechanical loads at low temperatures. These components have been optimised to ensure high reliability standards required for the LHC. Nevertheless, initial imperfections such as local bulges, scratches or grooves can occur and lead to a premature fatigue failure. For structures in which plasticity is not confined to the crack tip region, standard failure mechanics, based classically on the stress intensity factor or the strain energy density release rate, can not be used. In the present paper, a constitutive model taking into account plastic strain induced martensitic phase transformation and orthotropic ductile damage is presented. The model is based on anisotropic plasticity and comprises both the constant anisotropy (texture effect), which can be classically taken into account by applying the Hill yield surface, and the plastic strain induced anisotropy. This local approach is used to predict the impact of initial imperfections on the fatigue life of thin-walled LHC bellows expansion joints.

M2-C-05 Modelling the Effect of Liquid Nitrogen and Mould Core Structure on the Heat Transfer in Heavy Hollow Ingot

*LuGui Chen, XiuHong Kang, LiJun Xia, DianZhong Li, **YiYi Li**, Institute of Metal Research, CAS.*

Based on the aerodynamics and thermodynamics, the effect of the proportion between liquid nitrogen and compressed air, the flux of gaseous mixture and the gas gap width of the pipeline on the heat transfer coefficient in 100 tons hollow ingot was determined. The heat transfer coefficient was calculated by inverse solution and matched the theoretical one. The parameters of the injector and the mould core were optimized by calculating the heat transfer and fluid flow of the gaseous mixture in the core. A mould core and a mixing injector were designed to increase the heat transfer coefficient between the inner sleeve and cooling medium. And the solidification process of a 100 tons hollow ingot was simulated, the results indicated that the end of solidification throughout the ingot located almost in the center of the wall thickness, and the A-segregation near sub-surfaces was avoided.
Keywords: mixing-injector; liquid nitrogen; modelling; hollow ingot

M2-C-06 Fiber Bragg grating as strain sensor for cryogenic applications

*R.J. Huang, S.F. Li, L.H. Gong, **L.F. Li**, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences; M. Xu, Z.H. Ni, Beijing Pi-Optics Co.Ltd..*

Fiber Bragg grating (FBG) strain sensor is a novel sensor which offers a series of advantages over conventional electric sensors. It has high strain sensibility, immunity to electromagnetic interference, long useable life, good linearity, small size and light weight. Therefore, it will have many promising potential applications in harsh environments such as strong electromagnetic fields, radiation and cryogenic atmosphere. In the past few years, FBG as room temperature strain sensor was widely investigated and got practical application, however, there are few reports on FBG strain sensor at cryogenic temperature.
In this paper, we studied the features of FBG strain sensor at cryogenic temperature. A novel of FBG strain sensor with rhombic encapsulation structure was designed. The wavelength and strain change of the FBG strain sensor at the liquid nitrogen (helium) temperature were measured. The relationship between wavelength and strain was analyzed. The strain coefficient of the FBG strain sensor is -0.7185με/pm, with excellent linearity up to 0.9998 at liquid nitrogen temperature. The results show that this FBG strain sensor exhibit excellent performance at cryogenic temperature.

Wednesday, 07/18/07 Oral 10:30am - 12:00pm

M2-G Radiation and Materials Evaluation - II

M2-G-01 Properties of Some Toughened, Radiation Stable Epoxy Resins

*H. Zhang, R.J. Huang, L.F. Li, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing, P.R. China; **D. Evans**, Advanced Cryogenic Materials, Abingdon, Oxon UK.*

Impregnating resins for use in fusion magnet technology are required to be radiation stable, have long useable and have some degree of toughness to minimise cracking during cool-down. Some multi-functional resins in combination with solid aromatic amines have, in the past, been shown to have lost little of their strength after a total absorbed dose of 200 MGy. However, these systems are known to lack ‘toughness’ and the solid hardener meant relatively high processing viscosities. Additives to increase ‘toughness’ work well but to date, such additives have not been radiation stable and could only be used at low concentrations. Recent advances in the chemistry of hardeners and resins means that there are now available liquid aromatic amine hardeners that offer low viscosity and attractive ‘useable lifetimes’. In addition, a ‘tough’ aromatic resin is now available that can be blended with existing resins to produce toughened systems, with predictably, no loss of radiation stability. This paper considers known radiation stable resins and optimises their processing characteristics for magnet impregnation, along with their mechanical properties with additions of the new toughened resin and liquid aromatic amine hardeners. Having developed and optimised these new toughened resin systems, a second phase of the work will be undertaken to confirm the predicted radiation stability.

M2-G-02 Mechanical behaviour of cyanate ester/epoxy blends after reactor irradiation to high neutron fluences

***R. Prokopec**, K. Humer, R.K. Maix, H. Fillunger, H.W. Weber, Atomic Institute of the Austrian Universities.*

The mechanical strength of conventional epoxy resins drops dramatically after irradiation to a fast neutron fluence of 1x10^22 m^-2 (E>0.1 MeV). Recent results demonstrated that cyanate ester/ epoxy blends were not affected at this fluence level. The aim of this study is to investigate the performance potential of these blends at higher fluence levels without significant degradation of their mechanical properties.
Short-beam shear as well as static tensile tests were carried out at 77 K prior to and after irradiation to fast neutron fluences of up to 4x10^22 m^-2 (E>0.1 MeV) in the TRIGA reactor at ambient temperature (340 K). In addition, load controlled tension-tension fatigue measurements were performed, in order to simulate the pulsed operation conditions of a tokamak.
Initial results show that only a small reduction of the mechanical strength under static and dynamic load is observed up to a fast neutron fluence of 2x10^22 m^-2 (E>0.1 MeV). The results at higher fluence levels will be presented.

M2-G-03 Dielectric properties of polyvinyl alcohol, poly(methyl methacrylate), and polyimide at low temperatures

***E. Tuncer**, D.R. James, I. Sauers, A.R. Ellis, ORNL.*

Performance of materials and their compatibility determine the size of the electrical insulation in power equipment. Dielectric properties of electrical insulation materials are needed for low temperature power applications. For instance, thin polymeric sheets can be utilized to electrically insulate contacts, wires and cables. Electrical properties such as dielectric permittivity, electrical conductivity and dielectric strength of a material are necessary parameters considered in power equipment design. Although the permittivity and conductivity of a material do not indicate significant correlation to defects in the material, the dielectric strength is a statistical quantity related to defects in the material, which can not be represented with a single number. In this work we report the dielectric properties of three polymers: polyvinyl alcohol, poly(methyl methacrylate) and polyimide. The dielectric measurements are performed with an electrical impedance analyzer in frequency domain in the frequency range 100-1MHz. The impedances are recorded in a cryocooler in the temperature range from 20K to 350K. The dielectric breakdown characteristics of the polymers are measured in a liquid nitrogen bath at atmospheric pressure. Results of the impedance measurements are analyzed with the distribution of relaxation times theory. The breakdown data are analyzed with a recently developed numerical method based on the Monte Carlo technique.
Research sponsored by the U.S. Department of Energy - Office of Electricity Delivery and Energy Reliability, Superconductivity Program for Electric Power Systems under contract DE-AC05-00OR22725 with Oak Ridge National Laboratory, managed and operated by UT-Battelle, LLC.

M2-G-05 Gap Filling Ceramic Insulating Putty for High Field Magnets

***J.A Rice**, H.M. Rice, MultiPhase Composites, LLC.*

Gaps between the A15 superconducting cable and its supports can sometimes occur causing expensive rework of the support or filling with a non-optimal material. Recently, a new ceramic putty has been developed that can fill these gaps to fully support the superconducting cable. This ceramic material can withstand the extreme temperatures between the high temperature heat treatment and the cryogenic operation. Significant performance improvements have been made that will enable the insulating putty to be used in some accelerator magnet systems. Processing methods will be discussed as well as strength and thermal data.
Supported by the U.S. Department of Energy under SBIR Grant # DE-FG02-04ER84014

M2-G-06 Neutron Diffraction Measurements of Internal Stress during Loading at Cryogenic Temperatures in Graphite/Epoxy Composites

***S. Qiu**, V.B. Krishnan, R. Vaidyanathan, , University of Central Florida; J. Carver, B.V. Sankar, University of Florida; D.W. Brown, B. Clausen, Los Alamos National Laboratory.*

One of the major issues in designing graphite/epoxy composites, especially for use at low temperatures, is the lack of knowledge of thermal stresses. Previously (e.g., Advances in Cryogenic Engineering, Vol 50 p. 83), we have reported on the design and implementation of an experimental setup for in situ neutron measurements of internal stresses during loading at cryogenic temperatures. This paper reports on internal stress measurements (both, externally applied and residual thermal stresses) in multi-layered [(0/90/90/0)4] graphite/epoxy composites. The strains in the graphite fibers were measured during selected combinations of cooling (to 140 K) and loading (to 265 MPa). A numerically implemented inverse algorithm is also presented that determines the stress and strain field from the neutron measurements and examines the load partitioning between the matrix and fibers. This study yields for the first time information about the internal residual stresses and load partitioning that develop in graphite/epoxy composites at cryogenic temperatures with implications for using such composites in cryogenic storage tanks.
Support of SRI is gratefully acknowledged.

M2-H Coated Conductor - II: Flux Pinning

M2-H-01 Flux-pinning enhancement in coated conductors via 3D self-assembly of insulating nanodots in REBCO films on technical substrates

***A. Goyal**, S.H. Wee, J. Li, P.M. Martin, M. Paranthaman, L. Heatherly, ORNL.*

Significant enhancement of in-field Jc was made possible via incorporation of 3D self-assembled insulating nanodots in thick REBCO films. It is found that in most cases the columns of nanodots nucleate at the buffer / superconductor interface and extend all the way through the thickness of the film. Both YBCO and NdBCO films with incorporation of such nanodots have been fabricated by pulsed laser ablation. Incorporation of various insulating nanodots have been studied and these include BaZrO3 (BZO), CaZrO3, YSZ, etc. The films were made by pulsed laser ablation from a single sintered target containing a mixture of insulating nanoparticles and YBCO or NdBCO. Since RABiTS and IBAD based technical substrates have very different microstructural characteristics, epitaxial superconductor films grown on these substrates with such columnar defects exhibit markedly different transport properties such as the angular dependence of Jc. Growth mechanisms leading to the 3D self-assembly of nanodots will be discussed. In order to understand the mechanism of self-assembly, controlled experiments with sequentially multilayered films will also be presented.
Research was sponsored by the U.S. Department of Energy under contract DE-AC05-00OR22725 with the Oak Ridge National Laboratory, managed by UT-Battelle, LLC.

M2-H-02 Optimization of (M/YBa2Cu3O7-δ)xN Multilayer Films by Control of Layer Parameters

***T.J. Haugan**, P.N. Barnes, N.A. Pierce, F.J. Baca, M.F. Locke, T.A. Campbell, C.V. Varanasi, B.C. Harrison, A.D. Chaney, Air Force Research Laboratory; M. Sumption, The Ohio State University; H. Wang, Texas A.M. University.*

The superconducting properties of (Mn/YBa2Cu3O7-δ-m)N multilayer films were studied for variable M layer thickness n and variable superconducting layer thickness m. Different M phases were examined including green-phase Y2BaCuO5, Y2O3, BaZrO3, BaSnO3, CeO2, Sm123, brown-phase La211, and MgO, with lattice mismatch compare to Y123 varying from -12% to + 10% . Multilayer (Mn/123m)N films were grown by PLD onto single crystal substrates by ablation of separate 123 and M targets, at temperatures of 750-825 °C. The n layer thickness was varied from 0.1 nm to 4.5 nm, and the m 123 layer thickness was varied from 3 nm to 150 nm. Different M phase and n and m layer thickness caused strong variation of microstructural and superconducting properties. Strong flux pinning increase up to 2-4x was observed for M = Y2BaCuO5 and BaZrO3 phases and m = 4 to 25 nm, and for M = Y2O3 and m < 10 nm. Other phases and conditions studied thus far had worse flux pinning properties. To optimize flux pinning and Jc(77K,H=2T), the M pseudo-layer thickness had to be reduced below a critical value for each M phase, which correlated universally to pseudo-layer coverage < 15%. Unusual effects were observed for low lattice mismatch or poor pinning materials. The comparison and microstructural and superconducting properties of these different (Mn/YBa2Cu3O7-δ-m)N systems will be presented.

AFRL Propulsion Directorate and The Air Force Office Scientific Research

M2-H-03 Pinning mechanisms in YBCO films with nanoparticulates

***P.N. Barnes**, B.C. Harrison, J.W. Kell, T.J. Haugan, Air Force Research Laboratory; C.V. Varanasi, J.L. Burke, University of Dayton Research Institute.*

A theory espoused by Dew-Hughes provides one means of examining differences in the pinning force, F_p(h), curves caused by varying pinning centers In this theory, where h = H/H_irr is the normalized magnetic field, the type of interaction and geometries of the pins will result in different flux pinning functions which are reflected in different shapes for the F_p(h) curves. This theory is applied to YBCO pinning samples doped with different materials, including minute additions of deleterious rare earths, Y211 multilayered nanoparticles, and BSO nanoparticulate dispersions. Curve fitting was done to fit the equations of the form F_p = K . h^p . (1-h)^q where p, q are parameters that depend on the flux pinning mechanisms. Also, recently observed data of F_p vs h curves for YBCO pinned with BaSnO3 (BSO) nanoparticulates showed a double peak structure. A possible explanation for this phenomenon is given related to dual, distinct, pinning mechanisms. The various pinning mechanisms will be discussed.

M2-H-04 Flux Pinning Enhancement of YBCO Films by Elemental Doping at Minute Concentrations

***B.C. Harrison**, J.W. Kell, P.N. Barnes, T.J. Haugan, Air Force Research Laboratory; H Wang, Texas A & M / Dept of Electrical and Computer Engineering; M Rane, F Ramos, , University of Albany / SUNY.*

YBCO superconducting thin films maintain fairly high critical current densities in applied magnetic fields up to a few Tesla. Even so, this does not preclude the intentional addition of alternate flux pinning centers in the YBCO films to further improve upon the in-field Jc. However, this process can often cause additional steps or re-optimization of the deposition parameters for a given addition. Identifying potential additions that can optimize the performance of YBCO films without changing the deposition conditions would be ideal. The work presented here demonstrates that the incorporation of very minor additions (≤1%) of typically degrading rare earths into high quality YBCO thin films provides significant improvement to the film in-field current density. All of these dopants can typically degrade the performance of YBCO when used in the usual quantities of >10% for rare earth substitution of Y in the YBCO. All samples were deposited under identical conditions as pure YBCO. New dopants including both rare earth (Tm and Lu) and non-rare earth elements (Sc and Sr) will be discussed in addition to those previously presented (Tb, Pr, Ce, Nd, and La). Critical current density data will be presented for 65 K and 77 K in fields up to 9T in addition to new structural data obtained by secondary ion mass spectrometry and cross-sectional TEM.

M2-H-05 Modelling of HTS applications using EMTP with flux pinning scaling modules for practical HTS superconductors

***J.R. Cave**, V. Sood, IREQ Hydro-Quebec.*

The EMTP software (Electromagnetic Transient Programme) for modelling the behaviour of electric power systems is commonly used to obtain the transient response of system disturbances, for example caused by fault currents. We have developed specific modules describing practical HTS materials that can be used to describe new architectures involving superconducting power devices, for example fault current limiters. These modules include flux-pinning scaling models that vary smoothly in their parameterization of the J-T-B-E surfaces (current density, temperature, magnetic field and electric field). In addition, the non-linear low temperature materials properties, such as specific heat, are included for a more accurate description of device behaviour. The advantage of this approach is that the complex and non-linear flux-pinning and thermal characteristics of HTS devices can be integrated into power network models. The models and examples will be presented, with an emphasis on fault current limiters.

M2-H-06 Improved magnetic flux pinning in bulk (RE)-Ba-Cu-O superconductors

***D.A. Cardwell**, IRC in Superconductivity, University of Cambridge; N.H. Babu, IRC in Superconductivity, University of Cambridge; BCAST, Brunel University.*

(RE)-Ba-Cu-O bulk superconductors containing non-superconducting phase inclusions of composition RE2Ba4CuMOy [where M = W, Nb, Ag and Bi] and RE2BaCuO5 (RE-211) embedded in the REBa2Cu3O7-d (RE-123) superconducting matrix have been fabricated successfully. The RE2Ba4CuMOy phase has typical dimensions in the range 10 - 300 nm and forms effective flux pinning sites within the bulk superconducting matrix, since their size is comparable to that of the coherence length of RE-123. A direct correlation between the RE2Ba4CuMOy phase inclusion content in the RE-123 matrix and increased magnetic flux pinning has been observed. The critical current densities increase by an order of magnitude for the nano-composites compared to that of bulk RE-Ba-Cu-O melt processed without second phase inclusions, confirming their potential for improved current carrying performance.

M2-K Nb3Sn Conductor Fabrication and Processing

M2-K-01 Internal tin Nb_3Sn conductors for fusion and particle accelerator applications

***J.A. Parrell**, Y. Zhang, M.B. Field, M. Meinesz, S. Hong, Oxford Superconducting Technology.*

The past several years have seen a significant improvement in the maximum critical current density (J_c) in Nb_3Sn strand. However for many applications, high J_c alone is not sufficient. For fusion applications such as ITER, we have developed single-barrier internal tin strands having non-Cu J_c values over 1100 A/mm^2 (12 T, 4.2 K) with hysteresis losses less than 700 mJ/cm^3. Results will be presented for our latest designs, with the goal of maintaining the high J_c but further reducing the losses to meet ITER CS requirements. For high field magnet applications, higher J_c values are reached using a distributed barrier design. Results will be presented on a new high Jc Nb_3Sn strand that is made with Nb-Ti instead of Nb-Ta. This Nb-Ti strand maintains a J_c value of 3000 A/mm^2 (12 T, 4.2 K), but has improved higher field performance compared with our standard Nb-Ta material, reaching 1700 A/mm^2 at 15 T, with further optimizations still possible. To reduce the effective filament diameter in these high J_c strands, the number of subelement rods incorporated into the final restack billet needs to be increased from the 61 that is standard today. Results will be presented from manufacturing campaigns with 91 and 127 stack billet configurations.

M2-K-02 Structure and High-Field Performance of Jelly Roll Processed Nb3Sn Wires Using Sn-Ta and Sn-Ti Based Alloy Sheet

***K. Tachikawa**, T. Tsuyuki, Y. Hayashi, Tokai University; T. Takeuchi, National Institute for Materials Science.*

Sn-Ta based alloys with different Sn/Ta atomic ratio were prepared by the reaction of Sn+Ta mixed power at ~775 Ž. A small amound of Ti and Cu was added to the mixed power. The Sn-Ti based alloy was prepared by a melt and cast produce. 2wt%Ti and 5wt%Cu were added to Sn. Resulting alloys were fabricated into a sheet which was laminated with a Nb sheet, and then wound into a Jelly Roll composite. The composite was encased in a Nb-3.3at%Ta sheath, and fabricated into a wire which was finally heat treated at 700~775 Ž. The wires with Sn-Ta based alloy sheet showed a non-Cu Jc of 270A/mm2 at 20T and 4.2K for broad sheet composition range. The wire with Sn-Ti based alloy sheet showed a non-Cu Jc of 220A/mm2 at 20T and 4.2K. The thickness of Nb3Sn layer formed by the Sn-Ta based alloy is larger than that formed by the Sn-Ti based alloy. The origin of the enhancement of Nb3Sn layer formation by the Sn-Ta based alloy will be reported. Although the Sn-Ti based alloy yields somewhat lower non-Cu Jc than the Sn-Ta based alloy, it is attractive due to the easiness of mass production.

M2-K-03 Fabrication of Nb3Sn Conductors at Hyper Tech Research

***X. PENG**, J. Phillips, M. Rindfleisch, M Tomsic, hyper tech research Inc.; R Dhaka, M.D. Sumption, Ohio State University; E. Gregory, E.W. Collings, Supergenics LLC I.*

Standard Rod-in-Tube (RIT) conductors for High Energy Physics (HEP) and a newly developed Tube Type conductor are being developed at Hyper Tech Research Inc. for Hyper Tech and Supergenic LLC I. For HEP-RIT type conductors, 12 T, 4.2 K Non-Cu critical current density (Jc) of 3000 A/mm2 have been reached in HP31 subelement strands. In the new Tube type conductors, 127 filament arrays have been generated with 12 T non-Cu Jc values of about 2200 A/mm2, and 169 filament restack have been manufactured.

This work was supported by the U.S. Depart¬ment of Energy under Grant DE-FG02-03ER83674, DE-FG02-02ER83541, DE-FG02-05ER84191, DE-FG02-05ER84380.

M2-K-04 A Tubular Process for Making Niobium 3- Tin Conductors

***E. Gregory**, Supergenics I LLC; M. Tomsic, X, Peng, Hyper Tech Research Inc; R. Dhaka, M.D. Sumption, Ohio State University.*

It has been shown that subelements of niobium or niobium alloy tubes clad with copper and containing tin and tin alloy cores can be restacked in large numbers with few ductility problems. Critical current densities in the non-copper area of 61-subelement restacks as high as 2220 A/mm2 at 12 T have already been achieved. The process does not employ any electron beam welding, hot isostatic pressing or extrusion and, as a result, is more economical than the conventional internal-tin approach normally used for these materials. The multi-subelement restacks produced have been heat treated under a range of different heat treatment conditions, the aim being to produce materials with low a.c. losses and good intermediate field stability. The main efforts have been to determine how high a current carrying capability in the 12T to 16T range can be achieved reliably and reproducibility.

M2-K-05 Phase formation and Performance Limits in Tube type Nb3Sn

***M.D. Sumption**, R Dhaka, E.W Collings, LASM, MSE, The Ohio State University; E Gergory, Supergenics.*

Monofilamentary and multifilamentary “Tube”-type Nb3Sn conductors with up to 91 filaments have been studied in terms of their reactions and properties. Transport values of up to 2700 A/mm2 in the monofilaments and 2100 A/mm2 in the restacks have been demonstrated. During the reaction, the Cu/Sn reacts to form a liquid which then reacts with the tube wall to form NbSn2 (at very short times) followed by Nb6Sn5 and then A15. Samples were reacted for various times at 650°C-750°C and the formation of the various phases were quantified. 6:5 formation proceeds a certain distance into the Nb tube. Once the Sn composition in the Cu-Sn liquid phase is depleted sufficiently, A15 phase formation begins at the outer boundary of the 6:5. The 6:5 coverts to coarse A15 and the A15 formation beyond the previously existing 6:5 boundary is all fine grain. The density difference drives an inward motion of the fine-grain/coarse grain boundary. The radial position of the coarse grain/fine grain boundary can be calculated from the initial Cu/Sn ratio, and the final coarse/to fine grain A15 fraction (and resulting non-Cu Jc estimate) can be made by combining this with the Nb/Sn fraction and the density ratios of A15, Nb, Sn, and 6:5. The ultimate performance limits of these conductors can be estimated and compared with PIT and internal-Sn conductors.

This work was supported by U.S. Dept of Energy, Division of High Energy Physics, under Grant No. DE-FG02-95ER40900

M2-K-06 Highly Ductile Tantalum Sheet for Diffusion Barriers in Composite Nb3Sn Superconductors

***K.T. Hartwig**, S. Balachandran, R.B. Griffin, Texas A&M University; S.N. Mathaudhu, Army Reasearch Laboratory; T. Pyon, Luvata Waterbury, Inc.; R.E. Barber, Shear Form, Inc..*

Poor deformation behavior of commercial polycrystalline Ta sheet used for Sn diffusion barriers in Nb3Sn composite superconductors leads to the use of more Ta than is necessary in these conductors, and to premature strand fracture during wire drawing. These problems arise because the Ta layer deforms non-uniformly as it is reduced in thickness. The origin of the problem resides in the microstructure of the Ta and the co-deformation mechanics of relatively strong BCC Ta with surrounding weaker and more ductile FCC Cu. In an attempt to remedy this problem, 25mm square bars of Ta were processed by multi-axis severe plastic deformation (SPD) via equal channel angular extrusion (ECAE), then rolled to sheet and annealed. The processing is done to refine the microstructure and reduce non-uniformities in grain size and texture. Measurements of hardness, microstructural uniformity, Cu-Ta interface roughness and Cu-Ta co-deformation behavior are reported.

This work is supported by DOE SBIR contract DE-FG02-04ER84973.

M2-K-07 Influence of pre-Reaction HT on Sn distribution and final reaction properties of Nb3Sn Strands

***R. Dhaka**, M.D. Sumption, E.W Collings, LASM, MSE, The Ohio State University; E. Gregory, Supergenics; X. Peng, M Tomsic, Hyper Tech Research.*

The diffusion of Sn through the interfilamentary matrix within a subelement and the formation of the associated Cu-Sn phases was observed experimentally for several different Nb3Sn internal-Sn type strands with filament counts in the 61 and greater range. Two different pre-reaction heat treatment schedules were investigated, as well as several different reaction times and temperatures. Four different strands were measured, one without Ti, the others with Ti added either as NbTi rod replacements for selected Nb(Ta) filaments, or as wraps around each individual Nb(Ta) filament. In all but one case the majority of the filaments were a Nb-7.5wt%Ta. A simple model was used to determine the time and temperature dependence of Sn-diffusion through the Cu matrix of the subelements. The radial positions of η, ε, and α phases as a function of time during the pre-reaction heat treatment process were modeled and measured, and their influence on the subsequent Nb3Sn reactions was observed. The time required for complete reaction and final stoichiometry was compared for filaments at different radial positions under different experimental conditions was measured and modeled.

This work was supported by U.S. Dept of Energy, Division of High Energy Physics, under Grant No. DE-FG02-95ER40900.

M2-K-08 Progress of Niobium3-Tin Conductor Development for Higher Current Applications at Luvata

***T. Pyon**, H. Kanithi, Luvata Waterbury, Inc.; B. Karlemo, M. Holm, Luvata Pori Oy.*.

As the highest field performance is a primary goal of the conductor in the next generation of particle accelerators, emphasis has been focused mainly on the increase in current carrying capacity. The conductor needed for fusion application, however, requires much lower magnetization limit along with a critical current as high as possible. The strand specifications require further improvement of current density at little expense of ac loss or effective filament diameter. A conductor designed to meet such requirements has been fabricated. The effect of heat treatment schedule on its properties was investigated to develop the optimized reaction condition. An attempt was made to explore the selection of material and configuration of the diffusion barrier. Some efforts have also been made to determine the best strand design to ensure the minimum effective filament diameter and flux jumps of the wire. Some fabrication issues related with ductility of the wire components in the strand design are also discussed.

This work was partially supported by the NED program from CERN, and the US ITER-TF Prototype Superconductor Strand Procurement program under the contract from ORNL with the U.S. Department of Energy.

M2-L MgB2 Processing

M2-L-01 State of MgB2 wires development for magnet application

***G. Grasso**, R. Penco, D. Pietranera, C. D`Urzo, Columbus Superconductors SpA; D. Nardelli, R. Marabotto, M. Modica, , ASG Superconductors SpA.*

MgB2 superconducting wires have already achieved a remarkable development only six years after discovery of superconductivity. Multifilamentary wires and tapes are already produced at an industrial level in multi-Km length, with homogeneous transport properties along their length. Such conductors have been already employed in a number of full scale magnet demonstrators, as the 0.5 Tesla open MRI system by Paramed Medical Systems.

In this work we present the latest development at Columbus Superconductors, comprising wires with 100+ filaments, length exceeding 1.6 km, and useful critical currents at 4.2 K, 8 Tesla, and 20 K, 3 Tesla, well exceeding in both cases 30 kA/cm2.

An overview of the different projects currently underway suing Columbus Superconductors wires will be also given.

M2-L-02 Development of ex-situ processed MgB2 wires and tapes and their improved behavior in magnetic field

*C. Bernini, V. Braccini, C. Ferdeghini, A. Malagoli, M. Putti, A.S. Siri, **A. Tumino**, M. Vignolo, CNR-INFM LAMIA; G. Grasso, Columbus Superconductors S.p.A.*.

Since the discovery of superconductivity in MgB2, a substantial improvement was soon achieved in their manufacture and use. The conductor processing is quite open to improvements that help in making it very attractive for DC and AC applications. Many km of conductor were already produced and it is now possible to start thinking about its systematic industrial production, as it is already possible to purchase it in remarkable lengths. These lengths of conductor were also wound in coils and their performance continuously improved. We synthesize MgB2 tapes through the ex-situ Powder-In-Tube method. This technique involves the cold working of metallic tubes previously filled by suitably reacted MgB2 powders, followed by proper heat treatments. We studied the influence of the starting powders on the properties of the conductors, trying to improve their behavior in magnetic field by mastering their grain size through ball milling and by inserting appropriate doping and nanoparticles. We also worked at the optimization of the geometry of the conductor, trying to improve the critical current performance in field by changing sheath material and increasing the superconducting fill factor, so as to make it useful in long lengths for applications also in high field regimes.

M2-L-03 Densification of MgB2 Superconducting Strands by Uniaxially Hot Pressing

*M. Bhatia, M. Susner, M.D. Sumption, **E.W. Collings**, The Ohio State University; M. Tomsic, M. Reindfleisch, Hypertech Research Inc.*.

In-Situ formed MgB2 strands can achieve much higher critical current densities, Jc, if high fill-factor in the strands can be achieved or if the strands can be densified during the in-situ formation reaction. In order to achieve the high density MgB2 strands and bulk samples and hence obtain much higher Jcs we have prepared both powder-in-tube MgB2 monofilament samples and powder compacted bulk samples and have subjected these to various temperature and pressure schedules. The monofilament strand samples were made with Nb-Cu/Monel sheath and had 15 mole % excess Mg with an outer diameter of 0.8mm while the bulk samples were made by compressing stoichiometric and excess Mg mixtures of Mg and B powders respectively in the H-13 steel die. The strand samples were divided into 4 sets. Set A was left as a round wire; Set B was cold-pressed while Set C was cold-rolled into tape form; Set D was uniaxially hot-pressed at a pressure of 100MPa and with peak soaking temperature and time of 700oC and 40 mins in flowing Ar. Sets A, B and C were also heat-treated at the same temperature schedule with no applied pressure. Similar uniaxial hot-pressing was also subjected to the bulk samples. The transport critical current, Jc, values of all the samples were compared to analyze the effect of various pressing conditions. Microstructural changes occurring due to different pressure and temperature schedules were also investigated using scanning electron microscopy.

This research work has been funded by DOE-HEP grant no. DE-FG02-05ER84363

M2-L-04 Boosting Jc through proper heat treatment in cold-worked MgB2

*B.J. Senkowicz, **E.E. Hellstrom**, D.C. Larbalestier, Applied Superconductivity Center.*

We cold worked pre-reacted MgB2 powder by high-energy ball milling for 20 hours, resulting in fine, disordered grains before heat treatment. We then made pellets from the milled powders and heat treated using a hot isostatic press (HIP) at ~30 kpsi for 24 hr at various temperatures. We found that increasing heat treatment temperature improves the connectivity but decreases flux pinning and electron scattering. Therefore, optimized Jc is the result of balancing connectivity against electron scattering properties such as Hc2. While our highest Jc(8 T, 4.2 K) ~ 2 x 10^4 A/cm^2 was obtained for a heat treatment temperature of 900 C, the optimum heat treatment temperature was higher for use at lower fields and higher temperatures where the connectivity is more important than electron scattering.

Support provided by NSF - Focused Research Group on MgB2 and by DOE - superconductors for fusion.

M2-L-05 Magnesium Diboride (MgB2) coil development at Hyper Tech Research

***M. Tomsic**, M. Rindfleisch, D. Doll, J. Yue, J. Phillips, Hyper Tech Research; M. D. Sumption, M. Bhatia, S. Bohnenstiehl, E. W. Collings, Ohio State University; Y. Hascicek, IEMM, Inc.; S. Shaheen, Y. Akin, T. Baldwin, Florida State University.*

Hyper Tech Research will discuss progress in developing MgB2 demonstration coils for several different applications. For a U.S. Navy sponsored project, five 4.2 cm solenoid coils were fabricated and assembled around an iron core to demonstrate a superconducting transformer. Both AC and DC test results will be discussed. For a NASA sponsored project MgB2 racetrack coils were fabricated for installation in a four-pole superconducting rotor as part of a 2 MW liquid-hydrogen cooled generator. MgB2 wire in piece lengths of one kilometer was fabricated for these coils. The MgB2 wire wound on these demostration coils consisted of 19 filaments, niobium-barriers, copper stabilization and outer Monel sheaths. The coils were fabricated using the wind and react approach. The coils were characterized for transport properties initially in liquid helium, and then at higher temperatures up to 30 K.

U.S Navy contract N00014-05-C-0015; NASA contract NNC05CA04C

M2-L-06 Wind and React MgB2 Rotor Coils

M.D. Sumption, *S.D. Bohnenstiehl, M. Majoros, Materials Science and Engineering - The Ohio State University; M. Tomsic, M. Rindfleisch, J. Phillips, J. Yue, E.W. Collings, Hyper Tech Research.*

Five rotor coils intended for a prototype 2 MW generator were fabricated and tested. The coils were wound with stabilized multi-filamentary MgB2 strand in a wind and react mode with S-glass insulation followed by vacuum epoxy impregnation. The overall dimensions were 26.7 cm x 13.1 cm x 5.4 cm and each coil had typically 550 m of MgB2 strand. The coils were then measured separately for Ic and magnetic field in the bore with temperatures ranging from 4.2-35 K. The bore field as a function of depth was also determined near the critical current at 4.2 K. In addition, the magnetic field profile outside of the bore was measured by attaching several hall probe sensors to the winding at various locations. This data was compared to a calculated magnetic field map based on the coil geometry and critical current density. The load lines of the coils were also compared to short sample Jc values. The coils typically reached 186 A at 4.2 K generating a 1.7 T field, and 116 A at 20 K generating a 1.0 T field, which is reasonably consistent with the expectation from short samples.

This work was supported by NASA under Contract NNC06CA55C.

M2-L-07 Superconducting properties of MgB2 films with alternately layered nanostructures

H. Kitaguchi, *H. Kumakura, National Institute for Materials Science; T. Doi, Kagoshima University; T. Yoshidome, S. Hata, N. Kuwano, Kyushu University.*

We prepared MgB2/Ni and MgB2/B alternately-layered films on Si (100) single crystal substrates. Multi-layer nanostructure was achieved through an alternate growth of MgB2 (42, 24, or 15 nm, using an electron beam evaporation) and Ni (~1 nm, using a coaxial vacuum arc evaporation) or B(~5 nm) layers. XRD and STEM (scanning transmission electron microscope) analyses revealed that the designed nanostructure was successfully obtained. The critical temperature, Tc, decreased as the MgB2 layer became thinner, for both MgB2/Ni and MgB2/B films. Moreover, the Tc was affected by only the MgB2 layer thickness, and was independent of the inserted layer materials. The alternately-layered structure enhanced the critical current density, Jc, in the magnetic fields, B, parallel to the inserted layer(s). For example, Jc-B curve of MgB2(15nm)/Ni(1nm) film had a plateau in the parallel fields ranging 1~5 T and Jc exceeds 1 MA/cm2 even in 6 T (at 4.2 K.) These Jc values were five times higher than that for the film without the layered nanostructure. The results indicate that the alternately-layered nanostructure is effective to enhance flux-pinning performance.

This work was supported in part by Research Promotion Bureau, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan, under the contracts: Nos.17-212, 17-213 and 18-191. STEM observations and analyses were carried in "Nanotechnology Support Project" of the MEXT, Japan.

M2-L-08 Levitation forces between Permanent Magnets and MgB2 cylinders

E. Perini, *Edison SpA; G. Ripamonti, G. Giunchi, Edison Spa; T. Cavallin, CNR-IENI.*

The behavior of the bulk superconductors as levitators of Permanent Magnets (PM) has been studied for the textured YBCO HTS material, in the temperature range lower than 77K, obtaining extremely high trapped fields but also experiencing limitations on the mechanical characteristics of the material and on the possibility to produce large objects. Alternatively the bulk MgB2, even if it is superconducting at lower temperatures, has less mechanical problems, when fully densified, and presents stable magnetization in the temperature range between 10 and 30 K. [1]. With the Reactive Infiltration technique we have produced dense MgB2 bulk cylinders up to 60 mm diameter and 100 mm height. This kind of cylinders can be considered as prototypes of passive magnetic bearing for flywheels or other rotating electrical machines. We have conductively cooled these superconducting cylinder inside an ad hoc constructed cryostat and their levitation forces and stiffness, respect to various arrangements of the PM, have been measured as a function of the temperature below Tc. The very stable characteristics of the induced magnetization have been also recorded and a model of the superconducting behavior of the cylinders will be presented.

[1] M. Zeisberger et al. ,J. Appl. Phys. 98, 023905 (2005)

M2-M AC Loss and Stability - I

M2-M-01 AC loss characteristics of HTS coated conductors with copper stabilization layers

O. Tsukamoto, *Z. Li, Yokohama National University.*

AC loss characteristics of HTS coated conductors with copper stabilization layers are investigated. Generally, HTS conductors are hard to be quenched because of high temperature margin and high heat capacity of the conductor. However, the conductors still have possibilities of quenches due to local defects in the conductors or over load operation. HTS coated conductors that are made by deposition of thin HTS film on high resistance Ni based alloy substrates such as Hastelloy tapes are highly resistive when they are quenched. Therefore, stabilization and quench protection are more important for HTS conductors than for Bi/Ag sheathed tapes which have low resistive silver matrices.

It is common to attach copper layers to the conductors by soldering or plating to stabilize and protect the conductors from the burning due to quenches. However, the copper stabilization may affect the AC losses of the conductors. In this work, the AC losses (transport magnetization and total losses) in HTS coated conductors with copper layers were measured and influence of the copper layers on the AC loss.

M2-M-02 Temperature dependence of the total AC loss in high temperature superconducting tapes

D.N. Nguyen, *Center for Advanced Power Systems and Department of Physics, FSU; D.C. Knoll, P.V. P. S. S. Sastry, Center for Advanced Power Systems, FSU; J. Schwartz, College of Engineering, National High Magnetic Field Laboratory and Center for Advanced Power Systems, FSU.*

AC loss characteristics of YBa2Cu3O7 coated conductors and (Bi1.8Pb0.3)Sr2Ca2Cu3O10 tapes were measured at temperatures ranging from 30 K to 100 K using a novel experimental setup. The sample temperature was monitored by differential thermocouples mounted along the length. Two heaters, one on each current lead, were controlled to achieve the uniform temperature along the sample. The cryostat was evacuated and backfilled helium gas which helps the system to stabilize faster and reduces the temperature rise on the sample during the AC loss measurements. Temperature dependences of the AC losses were fitted with analytical models.

M2-M-03 Low-Frequency "Stator-Like" HTS Coils

R.L Holtz, *J.H. Claassen, D.U. Gubser, Naval Research Laboratory.*

One of the most promising prospective applications of HTS is ship propulsion motors. The current generation of HTS motor demonstrations, for example the 36.5 MW American Superconductor motor, utilize HTS rotors with copper stators. Future machines could employ HTS stators, as well. Since marine propulsion motors are low-speed motors, around 100-200 rpm top speed, the AC current in the stators is low-frequency, only a few Hz. While AC losses at such low frequencies are not negligible, they may be more manageable than at, say, 60 Hz. Additionally, stator coils would require more complex topologies than are used for rotors. We present here some exploratory studies of the fabrication and testing of small scale "stator-like" HTS coils using YBCO based wire obtained from American Superconductor and SuperPower Inc. We discuss the mechanical stability and thermal management challenges of such coils. Results of tests performed at 77K at various frequencies and currents are described. We use these exploratory results to discuss the feasibility of integration of low-frequency AC coils with cryogenic power electronics components, and discuss the key issue of AC loss and refrigeration requirements on the feasibility of all-superconducting marine propulsion motors.

M2-M-04 Superconductor-stabilizer interfacial resistance and normal zone propagation in coated conductors.
***G.A. Levin**, P.N. Barnes, Air Force research laboratory.*
We will discuss the normal zone propagation in YBCO-coated conductors. An emphasis will be on the role of the interfacial resistance between the stabilizer and superconducting film. This resistance determines the current-exchange length between the superconductor and stabilizer, and the speed of propagation of the normal zone. A novel method of measurement of the interfacial resistance will be discussed as well.

M2-M-05 Stability in copper-stabilized YBCO coated conductors
***R.C. Duckworth**, J.A. Demko, M.J. Gouge, Oak Ridge National Laboratory; V. Selvamanickam , Y.Y. Xie, SuperPower; C.L.H. Thieme, American Superconductor.*
A series of transient and steady state dc currents were applied to 20-cm and 1-m long YBCO coated conductors with different amounts and methods of copper stabilization. With samples mounted onto an insulated G10 former in a liquid nitrogen bath, voltage and temperature profiles were monitored during testing to track normal zone development and degradation of the conductor. Experimental results and numerical simulations show that the maximum amount of current a conductor could take before degradation was directly related to the amount of copper stabilization and not on the superconducting properties. For operation at constant currents, localized development of normal zones along the conductor length without propagation indicated the superconductor properties were more important. For each case, the significance of current transfer between the copper and YBCO in the context of the numerical simulations will be presented.
Research sponsored by the U.S. Department of Energy - Office of Electricity Delivery and Energy Reliability, Superconductivity Program for Electric Power Systems under contract DE-AC05-00OR22725 with Oak Ridge National Laboratory, managed and operated by UT-Battelle, LLC.

Wednesday, 07/18/07 Poster 3:30pm - 5:00pm

M2-O Properties of YBCO Thin Films and Coated Conductors

M2-O-01 Spin-polarized Top Injection from LCMO to YBCO along the a-b Direction
***X. Deng**, M. Chakalova, M. S. Colclough, C. M. Muirhead, School of Physics and Astronomy, University of Birmingham,UK; Y. Tse, Electronic, Electrical and Computer Engineering, University of Birmingham,UK.*
There have been many experiments on the injection of spin-polarised electrons from LCMO into YBCO. All experiments so far reported have involved injection which is intended to be in the crystallographic c-direction. Those experiments which claim to show gain have a geometry which may also permit edgeways injection along the a-b plane. Here we report experiments on YBCO/LCMO layers where the YBCO is grown with the c-axis in-plane and the a and b axes at 45 degrees to the film normal, in order to deliberately inject into the a-b directions. Uniform injection is ensured by an overlayer of gold on the LCMO track. The gold film eliminated the heating effect from the resistance of LCMO. It also provides equipotential injection.
The V-I characteristics of the YBCO were measured at a number of temperatures below Tc under various injection current. The effect due to the presence of an external magnetic field is also investigated. Early results show no sign of gain in this geometry, although high resolution TEM is showing distortion of the LCMO layer within a few nanometers of the interface. Development is in hand to improve the epitaxy at the interface.

M2-O-02 Evanescent Microscopy Characterization of YBCO Thin Films with Nanosize Pinning Centers
*R.A. Kleismit, **G. Kozlowski**, Wright State University; I. Maartense, A.L. Campbell, T.L. Peterson, Air Force Research Laboratory.*
YBCO superconducting thin films were deposited on LAO single crystal substrate by using pulsed laser ablation technique. Critical current densities of the films were optimized by depositing a critical amount of ultra thin layer (10 pulses at the rate of 1 Hz – elixir) from different targets (CeO2 , CuO, Y2O3, SRO, LMO,…) as a source of pinning centers. Our previous studies show that elixir (CeO2) deposited on 150 nm thick YBCO film followed by another YBCO layer (100 nm thick) produces films with the highest critical current density (ΔTc = 0.6 K).
A near-field evanescent microwave microscope based on a coaxial transmission line resonator with an end-wall aperture is used to map local dielectric properties of the surface of these films by measuring a change in quality factor (ΔQ) and frequency shift (Δfo). Correlation between the local dielectric and superconducting properties of the films will be established and discussed.

M2-O-03 Mapping of the Jc distribution in YBCO coated conductors using a magnetic knife
***J. Hänisch**, S.P. Ashworth, F.F. Mueller, J.Y. Coulter, V. Matias, Los Alamos National Laboratory.*
We have investigated the spatial Jc distribution in YBa2Cu3O7-x coated-conductor tapes using a magnetic knife [1] consisting of several Nd2Fe14B permanent magnets in close proximity to the sample. Thus, our device is very compact, independent of an external power source and affords a very high field gradient. A zone, less than 200 µm wide, of low and eventually zero magnetic field is embedded in a background field of about 600 mT. This region is scanned across the sample perpendicular to the current flow in the tape. Ic is measured for each position with a low-level four-point technique at 75 K. The raw data are deconvoluted with a Fourier inversion method. By scanning the device in the current direction as well, 2D mappings of the current flow are obtained. Current-density distributions of different coated-conductor samples and the effect of certain defects on this distribution are investigated. Application possibilities for post- or in-production line homogeneity assurance will be discussed. Special attention will be given to the effect of tape striation because of its importance for AC loss minimization.
[1] ten Haken et al., Physica C 334, 163 (2000)
This work is supported by the Department of Energy Office of Electricity Delivery & Energy Reliability.

M2-O-04 Pulsed Laser Deposition LaMnO3 Cap Layers and YBa2Cu3O7-x Coatings on IBAD -MgO buffered Flexible YSZ Ceramic (Ceraflex) Substrates
***C.V. Varanasi**, J. Burke, I. Maartense, University of Dayton Research Institute (UDRI), Dayton, OH ; P.N. Barnes, Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH; R. Lu, J. Wu, Univ. of Kansas.*
In ac applications, the resistivity of the substrate used in coated conductors can contribute towards the losses due to the eddy currents. So there is a need for developing coated conductors using non-conducting or highly resistive substrates. Commercially available Ceraflex substrates (flexible Yttria Stabilized Zirconia) are presently being explored if they can be used as substrates for coated conductors. However, proper buffer layers with required bi-axial texture and suitable cap layers need to be grown on them to deposit high quality YBCO coatings. Initial work indicated that highly textured IBAD-MgO and YSZ can be grown on the Ceraflex substrates. In this work, we studied if Lanthanum Manganate (LMO) can be deposited as a cap layer on top of IBAD- MgO buffer layer to process high quality YBCO coatings. Different processing conditions were used to deposit highly textured Lanthanum Manganate layer by pulsed laser ablation on IBAD-MgO buffered Ceraflex substrates. On top of these cap layers, YBCO coatings were deposited by PLD. Highly textured YBa2Cu3O7-x coatings with Tc > 88K were grown on top of these LMO layers. The data on transport critical current density, texture and micro-structural details of YBCO/LMO/IBAD-MgO/Ceraflex architecture will be presented.

M2-O-05 Comparison of quench behaviour of different coated conductors

***Chr. Schacherer**, M. Noe, A. Kudymow, M. Schwarz, Forschungszentrum Karlsruhe .*

This paper presents experimental results of quench studies at short samples of YBCO coated conductors cooled in liquid nitrogen at 77K by varying the current amplitudes. Available coated conductors from several HTS manufacturer with different cap layer and stabilisation are used for these studies. Samples without any stabilisation, except the original silver layer as well as composite samples with an additional stabilisation of hastelloy or copper are systematically investigated for the use in fault current limiters. The variation of the sinusoidal current amplitudes covers a wide range starting from currents below Ic up to currents of more than 10 times Ic. The test results show that the stabilisation of the coated conductor has a great influence on the homogenous quench behaviour of the coated conductor. Furthermore, basic calculations are made to estimate the temperature in the coated conductors.

M2-O-06 Effect of lateral critical current distribution on AC loss components of YBa2Cu3O7 coated conductors

***D.N. Nguyen**, Center for Advanced Power Systems and Department of Physics, FSU; D.C. Knoll, P.V. P. S. S. Sastry, Center for Advanced Power Systems, FSU; J. Schwartz, College of Engineering, National High Magnetic Field Laboratory and Center for Advanced Power Systems, FSU.*

AC loss in the superconducting layer (superconducting loss) and eddy current loss in the stabilizer (eddy current loss) were calculated numerically for YBa2Cu3O7 coated conductors with different critical current density distributions when an AC transport current and/or an AC background magnetic field are applied. The calculation is based on solving the two-dimensional Poisson's equation for vector potential. The transport current flows along the conductors (z-direction) and external magnetic field is applied perpendicular to the wide surface of the tape (x-direction). In the calculations, the superconducting property of the samples is assumed to follow power-law characteristics. The calculated results are presented and compared for three types of critical current density: (A) uniform, (B) convex and (C) concave distributions.

M2-O-07 Origin of the plateau in the temperature dependence of the normalized magnetization relaxation rate in disordered high-temperature superconductors in remnant state

***L. Miu**, National Institute of Materials Physics, Bucharest-Magurele, Romania; D. Miu, National Institute for Plasma, Laser, and Radiation Physics, Bucharest-Magurele, Romania; G. Jakob, H. Adrian, Institute of Physics, University of Mainz, Germany.*

The relaxation of the remnant magnetization in optimally doped disk-shaped YBa_2Cu_3O_(7-delta) films was measured for a large temperature interval T using the SQUID magnetometry. The initially applied magnetic field was oriented along the c axis. The T dependence of the normalized relaxation rate exhibit three distinct regions: a low-T region and a high-T domain, where S(T) increases with increasing T, separated by the well known plateau in the S(T) variation at intermediated T. The S(T) behavior at high T can be explained in terms of plastic vortex creep, whereas the plateau appears to be caused by collective (elastic creep), in a dynamically ordered vortex system. The ordering is generated by the macroscopic currents induced in the sample. For the investigated specimens, the time decrease of the remnant magnetization below approximately 20 K is mainly due to the occurrence of micro flux jumps, which generate a peculiar S(T) at low T.

Wednesday, 07/18/07 Oral 5:00pm - 6:00pm

M2-R AC Loss and Stability - II

M2-R-01 Measurement of AC Losses in Second-Generation HTS Conductors

***M. S. Osofsky**, Naval research Laboratory; R. J. Soulen, Jr., SFA, Inc.; D. U. Gubser, Naval Research Laboratory; T. Datta, University of South Carolina.*

The successful application of superconductivity to motors and power system components depends in part on minimization of the ac loss in the superconductor used for fabrication of the component. We report on measurements of transport ac losses and critical currents of normal conductors coated with YBaCuO. The measurements were performed with the samples immersed in liquid nitrogen at 77K and 65K in zero applied magnetic field. We studied the ac loss as a function of frequency of the applied current. We will also present results of measurements performed with the samples in dc magnetic fields parallel and perpendicular to the conductor.

M2-R-03 AC Applied Magnetic Field Loss and Transport AC Loss measurements in YBCO Coated Conductors with Different Substrates at 50-200 Hz

***M. Majoros**, M. D. Sumption, E. W. Collings, The Ohio State University; S. Kawabata, Kagoshima University.*

AC applied magnetic field loss as well as transport ac loss measurements have been made on different kinds of YBCO coated conductors with different substrates. Various arrangements of YBCO coated conductor have been measured in applied magnetic field at frequencies ranging from 50 Hz to 200 Hz, with amplitudes up to 140 mT using the pick-up coil method. Different sets of YBCO coated conductor were measured – 12 mm wide conductors with Cu added either on one side only, or on both sides (as well as the edges) and 4 mm wide conductors. Transport ac loss of samples with ferromagnetic substrates show higher losses compared with the theoretical values obtained from the critical state mode at currents lower than the critical current. An influence of a ferromagnetic substrate on transport ac loss increase was calculated numerically by finite element method. It was determined numerically that the presence of a ferromagnetic substrate affects transport ac losses in YBCO film. This means that the two loss contributions – transport ac loss in YBCO film and ferromagnetic loss in the substrate cannot be considered as mutually independent. The power loss in W/m was compared for conductors of various width and stabilizer and put in the context of applications.

M2-R-04 AC Loss Measurement of HTS Coils Using Nitrogen Boil-off Method

***D.C. Knoll**, D.N. Nguyen, J. Mulder, S.V. Pamidi, FSU Center for Advanced Power Systems.*

An ac loss measurement facility using the calorimetric method for high temperature superconducting coils is described. The facility uses the nitrogen boil off method to measure ac loss and is suitable for coils up to 12 cm in diameter and 10 cm in height. The measurement chamber consists of a thick walled glass-fiber reinforced plastic tube sealed at each end. The HTS coil is suspended from the top plate with a G10 support structure allowing the coil to be immersed in a bath of liquid nitrogen. The entire measurement chamber is sealed and immersed in a bath of liquid nitrogen to minimize heat transfer into the measurement chamber from the surrounding environment. As heat is generated inside the chamber during calibration or ac loss measurement, liquid nitrogen is boiled off at a proportional rate. The boiled off nitrogen gas flows through digital flow meter to measure volume flow rate. Before each measurement, the setup is calibrated using a resistance heater sealed inside the chamber with the sample coil. Data of ac loss measurements on Bi-2223 and YBCO coils will be presented.

This work was supported by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, under Award no. DE-FG02-05CH11292.

Thursday, 07/19/07 Plenary 8:00am - 9:00am

M3-A Thursday Plenary Session

M3-A-01 Cryogenic Structural Materials for the ITER Superconducting Magnets

K. Okuno, *H. Nakajima, K. Hamada, K. Kawano, K. Takano, F. Tsutsumi, Japan Atomic Energy Agency.*

The ITER superconducting magnet system consists of 18 Toroidal Field (TF) coils, one Central Solenoid (CS) and six Poloidal Field (PF) coils. The TF coil has a D-shape with a height of 14 m, a width of 9 m and a weight of 310 tons. In order to sustain large electromagnetic forces, the TF coil has a massive coil case that contains a winding pack and integrated with a set of inter-coil structures which will be connected to a neighboring coil to provide a main structure of the magnet system. The coil case uses several kinds of materials depending on the requirement of the mechanical strength. The maximum thickness of the case is more than 200 mm and forged blocks and hot rolled plates will be used. The total weight of stainless steel required for the 18 TF coils amounts to 3,800 tons in finished shape, which corresponds to more than 10,000 tons in raw materials. At the highest stress area, forged JJ1(12Cr- 12Ni- 10Mn- 5Mo- 0.2N) will be used and its yield strength (YS) is more than 1,000 MPa at 4 K. At the second highest stress area, ST316LN (strengthened 316LN with nitrogen content of more than 0.17%) will be used and its YS is more than 850 MPa. At relatively low stress area, 316LN hot rolled plates will be used. Trial fabrications of these structures are underway at full scale in extensive collaboration with industries. Complete database on mechanical properties of these materials is being established. Technologies for the machining and welding of these materials into coil case segments are also under development and successful results have so-far been obtained.

Thursday, 07/19/07 Poster 9:00am - 10:30am

M3-B Advances in MgB2

M3-B-01 Effect of Boron Form on Reactions and Transport Jc in MgB2 Strands

S.D. Bohnenstiehl, *M.D. Sumption, E.W. Collings, Materials Science and Engineering - The Ohio State University.*

The effect of amorphous, alpha-rhombohedral, and beta-rhombohedral boron powders on MgB2 formation was analyzed by Differential Thermal Analysis (DTA). The activation energies for MgB2 formation from different boron forms was estimated by using five different heating rates and the Kissinger analysis on each magnesium and boron mixture. A series of magnesium and boron pellets were then reacted to form MgB2 using the various forms of boron and confirmed by X-ray Diffraction. DC susceptibility was used to identify the superconducting fraction for the series of pellets. Grain size was also measured for these various Mg-B variants to determine the influence of B type on this parameter, the effect of starting particle size, and its potential influence on Jc. The above results were then used to interpret the transport results for MgB2 strands made with different B powder sources.

This work was supported by U.S. Dept of Energy, Division of High Energy Physics, under Grant No. DE-FG02-95ER40900.

M3-B-02 Analysis of excess Mg, grain size, and pinning in MgB2 strands

M.A. Susner, *MSE, The Ohio State University ; M.D. Sumption, E.W. Collings, MSE, The Ohio State University; M.A. Rindfleisch, M. Tomsic, Hyper-Tech Research.*

The effect of adding Mg in excess to the strict stoichiometric ratio of MgB2 was quantified in terms of the resulting microstructure and grain size of the superconducting material. In addition, pinning centers were introduced into the strands in the form of the nano-oxides MgO and La2O3 to determine the effect on critical current density. These nano-oxides were purchased from a commercial source at an average particle size of ~10nm and were suspended in isopropyl alcohol to prevent agglomeration and introduced to mixed powders of Mg+B, which were then Planetary milled and then mixed, after which the alcohol was evaporated off. Monofilamentary wires were fabricated in Nb-lined monel sheaths for both the excess Mg and the nano-oxide strands. . Transport Jc measurements were performed on the samples under a variety of magnetic fields and temperatures. Pinning force density curves were generated at different temperatures, and compared to the expectation from various pinning mechanisms. The influence of anisotropy, connectivity, and inhomogeneity were considered.

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This work was funded by DOE grant No. DEFG02-05ER84363

M3-B-03 Low resistance normal metal junction semi-persistent joints in MgB2 Strands

M.A. Susner, *MSE, The Ohio State University ; M.D. Sumption, P.F. Cleary, MSE, The Ohio State University; M.A. Rindfleisch, J. Yue, M. Tomsic, Hyper-Tech Research; E.W. Collings, , MSE,The Ohio State University.*

NMR and MRI magnets, because of the need for field stability, require operation in persistent mode. This requires both persistent joints and persistent switches. The operative definition of a persistent joint is that its resistance be between 10^-10 and 10^-15 W. This can be attempted either by a direct SC-SC connection, or by a very low resistance normal metal connection. Following this latter route, it is essential to utilize a sheath material with low resistivity such as 101 Cu or ODS Cu. In the present work, 19-filament 101 Cu or ODS Cu-clad MgB2 strands soldered together over approximately 0.5 m lengths (using Indium or 40Pb-60Sn solder. A test rig was designed to measure the resistivity of the joint using the field decay technique. This measurement system makes use of a single strand ~1 m in total length. The ends of the strand are used for the joint itself, the rest is wound into a coil with a 0.5 in. bore. An FeNdB magnet, present during the initial cool-down to below Tc, generated the loop-current whose persistence was measured magnetically. Resistance values extracted from these measurements are presented and discussed.

Funded by NIH Grant No. 1R44EB006652-01

M3-B-04 High magnetic field properties of MgB2/Fe tape fabricated by in-situ-PIT method

***A. Matsumoto**, H. Uematsu, H. Kitaguchi, H. Kumakura, NIMS; H. Yamada, N. Uchiyama, Central Japan Railway Co..*

One of most interesting method to improve Jc is the C substitution for B sites for MgB2 tapes and wires. This C substitution for B can be obtained by the impurity additions such as SiC and hydrocarbons. In this report, the critical current density (Jc), irreversibility field (Birr) and upper critical field (Bc2) have been investigated for MgB2/Fe tapes doped with nano-size SiC and hydrocarbons. We tried to add high density of nano-size SiC powders and various hydrocarbons to the mixture of MgH2 + amorphous B. Jc measurements in high magnetic fields up to 30 T and resistivity measurements up to 7 T in various temperatures were carried out for these tapes. Both Bc2 and Birr increased with increasing SiC doping level, and Birr and Bc2 value of 25.5 T and 28.2 T was obtained at 20at%SiC doped tape. Jc at 10 T of 20%SiC doped tape is 13700 A/cm2, which is comparable to those of 10at%SiC doped tape. We reported that the values of Jc in the low magnetic fields were higher than SiC doped tapes. However, the Jc values of high fields over 12 T were smaller than those of 10at%SiC doped tapes. From the resistivity measurements, the Bc2(Birr) values of 15.7(10.5), 14.3(10.1), and 13.7(9.6) T at 20 K were obtained at non-doped, 10at%SiC doped, 10at%C6H6 doped tapes, respectively. The lower values of Jc in high magnetic field for hydrocarbon-doped tapes were due to the lower values of Bc2 and Birr. The relationship between the resistivity and various impurities will be discussed.

M3-B-05 High Jc performance of MgO-dispersed MgB2 thin film in high magnetic fields

***T. Doi**, K. Fukuyama, K. Masuda, Y. Hakuraku, Kagoshima University; M. Haruta, T. Fujiyoshi, Kumamoto University; H. Kitaguchi, S. Hata, National Institute for Materials Science; N. Kuwano, Kyushu University.*

We prepared as-grown MgB2 thin films by an electron beam evaporation method on Al2O3 (0001) and Si (100) single crystal substrates under the controlled oxygen atmosphere. The substrate was set in the deposition chamber with the base pressure of <5×10-7 Pa and heated at 250-300C, then the oxygen was introduced into the deposition chamber. After the oxygen partial pressure became stable, Mg and B were started to deposit. Very fine magnesium oxide particles were confirmed to exist at the grain boundaries and in the grains of MgB2 by TEM observations. Very high critical current density, Jc, was obtained for the film prepared under P(O2)=10-6 Pa. Jc measured at 10K in 5, 10T (B perpendicular to the film surface) reached 500,000 , 60,000 A/cm2. The results indicate that the nano-sized magnesium oxide particles are very effective to enhance flux-pinning performance.

This work was supported in part by Research Promotion Bureau, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan, under the contracts: Nos.17-212, 17-213 and 18-191. STEM observations and analyses were carried in "Nanotechnology Support Project" of the MEXT, Japan.

M3-B-06 Hot Extrusion of MgB2

***W.T. Nachtrab**, M.K. Rudziak, Supercon, Inc; T. Wong, Supercon, Inc..*

Considerable progress has been made in the development of MgB2 superconductors, particularly with regard to improvement in basic properties such as Birr and Jc. For commercial conductor, the technology needs further development to produce round multifilament wire with higher fill factors. Supercon has been exploring the potential of producing multifilament round wire via a combination of hot extrusion and wire drawing. This paper will discuss Supercon`s experience with hot extruding ex-situ MgB2 powder and the production of multifilament conductor. The effects of factors such as billet design, barrier material and extrusion conditions on monofilament production and multifilament conductor fabrication will be covered.

This work is supported by DOE Phase I SBIR grant DE-FG02-06ER84480

M3-B-07 High-energy ball milling of MgB2 with AlB2-type compounds: microstructural and superconducting characterization

***D. Rodrigues Jr.**, Departamentro de Engenharia de Materiais, Escola de Engenharia de Lorena, Universidade de São Paulo, Lorena, SP, Brazil; B. J. Senkowicz, D. C. Larbalestier, Applied Superconductivity Center and National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL, USA; J. M. Hanson, Materials Science and Engineering Department, University of Wisconsin-Madison, WI, USA; E. E. Hellstrom, Applied Superconductivity Center, University of Wisconsin-Madison, WI, USA.*

MgB2 is considered to be the high field conductor of the future due to its high values of critical field (≈40T) and critical temperature (≈35-40K), low raw materials costs, and the possibility of operating with cryogenic refrigerators.

Optimizing flux pinning in these conductors is important to improve their critical currents. Introducing doping can influence the flux pinning efficiency and grain connectivity, and also affecting the resistivity, upper critical field and critical temperature.

High-energy ball milling was used to homogenously mix MgB2 with AlB2-type compounds. The MgB2 samples were prepared using WC jars and balls with a Spex 8000M mill in a nitrogen-filled glove-box. The MgB2 doping concentration (Mg1-xM'x)B2 was up to x = 0.15 for AlB2, TaB2, TiB2, VB2, and ZrB2. Samples were removed from the WC jars after several milling times up to 4000 minutes and formed into pellets using cold isostatic pressing. The pellets were placed in stainless steel tubes, evacuated, welded on both ends, and heat treated in a hot isostatic press (HIP) at 1000ºC under a pressure of 30 kpsi for 24 hours.

The samples were characterized using XRD and SEM just after milling and after the HIP heat treatment. Superconducting properties were characterized using a PPMS to analyze the influence of doping.

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M3-B-08 The inclusions of Mg-B (MgB12?) as feasible pinning centers in high pressure-high temperature manufactured magnesium diboride

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Systematic study of structure and superconductive characteristics of high-pressure-high temperature synthesized and sintered MgB2 from different types of initial materials (different types of amorphous boron and magnesium diboride) with and without additions of Ti, Ta, Zr, SiC gives us grounds to conclude that Mg-B inclusions with a stoichiometry that is very close to MgB12 can be feasible pinning centers in the magnesium diboride and influence the critical current density. For example, if the area that is occupied by the inclusions in the SEM composition image of 1600 power magnification increased from 2 to 10 %, the critical current density, jc, may increase by a factor of more than 10 at 20 K in 1 T field. The X-ray examinations have shown that the average grain sizes in the materials produced under a pressure of 2 GPa and high temperature having high jc were 15-37 nm. The highest jc in zero field was 1300 kA/cm2 at 10 K, 780 kA/cm2 at 20 K and 62 kA/cm2 at 35 K for high-pressure synthesized magnesium diboride without additions, while for the material with 10% of Zr added the jc at 20 K in zero field was 1800 kA/cm2 and at 7 T field jc about 1 kA/cm2. The high-pressure synthesized MgB2 with additions of Ti demonstrated jc higher than 100 kA/cm2 at 10 K up to 4.5 T field and at 20 K up to 3 T.

M3-B-09 Effect of pulsed Magnetic Field Processing on the superconductivities of Carbon Nanotubes Doped MgB2

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The undoped and carbon nanotubes (CNTs) doped MgB2 wires were sintered in the 5T pulsed magnetic field at 800 Ž for 30min. The critical temperature (Tc) is 36.3K, a little higher than that of the bulks sintered without magnetic field, 35.7K. The Jc(H) increased by a factor of 2-3 in low filed and more than an order of magnitude in high field after processing in magnetic field. The anisotropy of Jc(H) is explained by the CNTs orientation during the magnetic field processing. The alignment of CNTs along the processing field direction was observed by SEM detection.

Keywords: MgB2; Carbon nanotube (CNTs); superconductor; pulsed magnetic field

Thursday, 07/19/07 Oral 10:30am - 12:00pm

M3-G Mechanical Properties of Metals and Alloys

M3-G-01 Comparison of Strength and Serration at Cryogenic Temperatures among 304L, 316L and 310S Steels

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Tensile tests of 304L, 316L and 310S steels were performed at cryogenic temperatures and their yield strengths and serrated plastic deformation behavior were compared. Computer simulations were also carried out to draw stress-strain curves and to discuss the effects of certain alloying elements and martensitic transformation induced during deformation on the strength and the serration. Conditions of tensile tests and procedures of computer simulation were almost same as those in our previous papers. Tensile tests exhibited that yield strength of 310S steel is highest and that the appearance of serration was delayed and the density of the load drop in the serration was lowest in this steel. The highest yield strength of 310S steel can be explained by the highest stability against martensitic transformation and the largest solid solution strengthening in this steel. As for the serrated deformation behavior, it was clarified that the effect of the transformation was large.

M3-G-02 Bi-axial strain response of structural materials and superconducting Nb3Sn wires at 295 K, 7 K, and 4 K

A. NYILAS, CEME; ***K. P. WEISS****, Forschungszentrum Karlsruhe.*

A new extensometer capable to measure diametral strains during axial loading of structural materials and superconducting composite wires has been developed. Using this new transducer it is possible to determine both the averaged axial strain and the transverse strain. The diametral extensometer with a mass of around 1 g is foreseen to be clamped onto the wire inside the double extensometer averaging sensing device system. The sensitivity of this new diametral extensometer is high, nearly a factor of ten higher than the axial extensometer system.

In addition, for structural materials and for composite materials an adjustable diametral extensometer enabling to test specimens between 5 mm and 15 mm diameters has been also developed and tested successfully at 4 K. For materials 304L, Inconel 718, and modified Type 316LN stainless steel cast alloy the Poisson's coefficients could be determined at 295 K. Material 310S type stainless steel has been investigated at 7 K and at 4 K using the adjustable extensometer to determine the Poisson's coefficient, too. After comprehensive calibration different type of superconducting A15 phase composite wires with diameters between 0.8 and 1.3 mm's were characterized in axial and diametral orientation. The tested superconducting materials were in majority Nb3Sn type, however, Nb3Al type wires are also tested under the same condition.

This work is partly supported by the New Energy and Industrial Technology Organization (NEDO) as collaboration research and development of fundamental technologies for superconductivity research.

M3-G-03 Hydrogen embrittlement evaluation in tensile properties of stainless steels at cryogenic temperatures

T. Ogata*, T. Yuri, Y. Ono, National Institute for Materials Science.*

In fuel-cell car system, recently, mechanical properties data of structural materials in high pressure hydrogen environments at low temperatures have been required. Authors have developed a very simple and safe procedure to evaluate hydrogen embrittlement of up to 13 MPa hydrogen environments in mechanical properties tests at cryogenic temperatures and carried out tensile tests for stainless steels, SUS 304, 304L, and 316L. The tensile properties by this simple method gave good agreement with the previous data obtained by using a high-pressure vessel and an effect of hydrogen on reduction of area of SUS 304 and 304L increased remarkably around 200 K, where fractured surfaces of the specimens showed brittle fracture. At 77 K, the fractured surfaces showed dimple and ductile fracture. The effect of hydrogen was changed also with the amount of strain-induced martensitic transformation in those steels at low temperatures. Effects of high pressure hydrogen environments on the tensile properties from 293 K to around 20 K will be presented.

This work was supported by the New Energy and Industrial Technology Development Organization project, development for safe utilization and infrastructure of hydrogen.

M3-G-04 Phase Diagram Calculation and Experiment for Fe-Mn-Al System at Different Temperature

YuTuo Zhang, ***DianZhong Li****, YiYi Li, Institute of Metal Research, CAS.*

Fe-Mn-Al alloys have been developed for different applications from cryogenic temperatures up to 873 K. The phase equilibrium of the Fe-Mn-Al ternary system plays an important role in development of cryogenic alloys and heat-resistant steels. In this paper, the isothermal sections of Fe-Mn-Al system were calculated at different temperatures from 1777 K to 4 K. The calculated results indicate that there is a three-phase region at 873K and this region moves to the Mn-rich corner with the temperature increasing and it disappears above 1273K. Besides, the relative experiments also processed by use of optical microscopy and electron probe after heat treatment at different temperature for equilibrium condition. At 77K, although it is a non equilibrium condition but some phase transformation from austenite to martensite can be obtained.

M3-G-05 High-Cycle Fatigue Properties and Fatigue Crack Initiation Behavior of Ti-5%Al-2.5%Sn ELI Alloy at Cryogenic Temperatures

***Y. Ono**, M. Demura, T. Yuri, T. Ogata, National Institute for Materials Science; S. Matsuoka, Kyushu University; S. Hori, Japan Aerospace Exploration Agency.*

Tensile tests and uni-axial loading fatigue tests were performed at 4 K, 77 K and 293 K for Ti-5%Al-2.5%Sn Extra Low Interstitial (ELI) alloy with a mean alpha grain size of 80 µm. The 0.2% proof stress and the tensile strength of this alloy increased with decreasing temperature. Fatigue strength in the longer-life region did not increase in response to increments in tensile strength at cryogenic temperatures. In the specimens fatigue-tested at cryogenic temperatures, the fatigue cracks initiated and formed faceted structures around crack initiation sites. In the specimens fatigue-tested at 293 K, however, there was no facet that can be clearly identified around the crack initiation sites. This difference in the aspects of the fatigue crack initiation sites represents that the fatigue crack initiation behavior changes depending on the test temperatures. On the facets formed at cryogenic temperatures, orientation analyses by electron backscatter diffraction (EBSD) method were carried out to clarify the fatigue crack initiation mechanism at cryogenic temperatures. The EBSD analyses revealed that the facet plane corresponds to {11-21} twin plane. Based on these results, the fatigue crack initiation with twin deformation is supposed to cause the low fatigue strength at cryogenic temperatures.

M3-G-06 Role of Fe in Low Temperature NiTiFe Shape Memory Alloys

***R.M. Manjeri**, M. Mistretta, R. Vaidyanathan, University of Central Florida.*

NiTi shape memory alloys are of engineering interest due to their ability to undergo a reversible temperature/stress induced martensitic transformation. Addition of Fe to NiTi introduces an intermediate trigonal R-phase and further suppresses the monoclinic B19` martensitic transformation to lower temperatures, among others. The R-phase transformation in NiTiFe offers a useful window for actuator operation as it exhibits reduced hysteresis with a favorable fatigue response. However, not much is known about the R-phase transformation. This study establishes correlations between compositional and thermo-mechanical processing parameters and the formation of the R-phase. Selected compositions of both Ni-rich and Ti-rich alloys were arc-melted and subsequently thermo-mechanically processed. In addition to the effect of Fe, the influence of precipitates and dislocations on the R-phase formation was studied using differential scanning calorimetry (DSC), in situ transmission electron microscopy (TEM) and dynamic mechanical analysis (DMA). The alloys fabricated as part of this work have potential application in cryogenic switches, valves and seals.

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M3-H LTS and HTS Cables

M3-H-01 Critical Currents in ROEBEL assembled Coated Conductors (RACC)

***W. Goldacker**, A. Frank, R. Heller, S.I. Schlachter, C. Schmidt, A. Kling, Forschungszentrum Karlsruhe.*

Roebel-type assembling of coated conductors (CC) has already been introduced as a practicable method to prepare high current flat cables from CC in a low AC loss structure with the feature of fully transposed strands. Up to now we have prepared and analyzed three RACC cables with 16 strands from different industrial CC-tapes: SuperPower MOCVD-CC and THEVA TCE-CC. Compared to the sum of single-strand Ic values all cables show a current degradation of about 30% or more. The main contribution comes from the quite inhomogeneous self field, which initiates a strong current redistribution across the strands. The quality of the CC, in particular the homogeneity of the superconducting layer and the critical currents, determines the maximum achievable transport currents and consequently the AC losses. We present detailed investigations of conductor homogeneity and self-field effects in the specific cables and correlate the results with modelled self field distributions in the cable cross sections. First methods to achieve a moderate interstrand coupling were applied and found to have a strong effect on current redistribution and maximum Ic.

M3-H-02 Case studies of AC losses in multi-layer power transmission cables composed of coated conductors

***N. Amemiya**, Z. Jiang, Yokohama National University.*

Very thin cross sectional shape of coated conductors is a potential advantage for AC loss reduction, when they are used for superconducting power transmission cables where magnetic field liens are mostly circular and parallel to thin layers of superconductor. The AC loss due to the magnetic field component parallel to the wide face of coated conductors is so small that the AC loss generated by a small but finite perpendicular magnetic field component dominates the AC loss in coated conductors which compose a cable. In case of mono-layer cables, it is produced by not-completely-circular but polygonal cross-sectional shape of cables and finites gap between conductors. The situation in multi-layer cables is much more complicated: for example, a coated conductor in an outer layer is exposed to the magnetic field produced by the current in inner layers. In this study, numerical electromagnetic field analyses of multi-layer cables are made to calculate their AC losses. We use the one-dimensional model of coated conductor where only the perpendicular magnetic field component is taken into account. The reduced computation time by neglecting the two-dimensional effect enables us to perform case studies of AC losses in multi-layer power transmission cables: various parameters including cable dimensions, conductor width, critical current, etc. are varied to study their influence of AC loss characteristics.

This work was supported by NEDO as Collaborative Research and Development of Fundamental Technologies for Superconductivity Applications.

M3-H-03 Effect of cores on magnetization and AC losses of Nb3Sn Rutherford cables

***E.W. Collings**, M.D. Sumption, LASM, MSE, The Ohio State University; E. Barzi, D. Turrioni, R. Yamada, A.V. Zlobin, Fermilab, Batavia IL.*

A metallic core in Rutherford cables is known to reduce the eddy current component of cable magnetization and, if made of ferromagnetic material, also to correct the cable persistent current magnetization. Both effects are important for achieving a required field quality in accelerator magnets. Nb3Sn cables with thin, ferromagnetic, full-width cores, as well as stainless steel cores of a number of widths and thicknesses were fabricated. The former cables were chosen in an attempt to reduce both cable loss and persistent magnetization, the latter to enable more control of the value of contact resistance. Losses were determined using calorimetric and magnetic AC-loss measurement techniques in face-on and edge-on applied AC fields. In preparation the cables, fabricated at Fermilab from RRP-type strand were wrapped with S-glass tape impregnated in most cases with a ceramic binder (applied before reaction HT). The HT/pressurization sequence of the cables was made to mimic as closely as possible the expected (LARP) accelerator magnet-fabrication schedules. Contact resistance values were extracted from known loss expressions. Short segments of the cables were also measured by vibrating sample magnetometry to examine the values of magnetization at the expected injection field ranges.

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M3-H-04 Measurements of RRR variation in strands extracted from Nb3Sn-type Rutherford cables

***M.D. Sumption**, E.W. Collings, LASM, MSE, The Ohio State University; E Barzi, D Turrioni, R Yamada, A.V Zlobin, Fermilab, Batavia IL.*

Modern high-Jc Nb3Sn strands and cables used in high field accelerator magnet models suffer from flux jump-related instabilities at low magnetic fields. These instabilities are determined by the values of Jc, deff, and RRR. It has been postulated that local RRR is a more relevant parameter than average RRR for these considerations, but the range of RRR values present in a cable has not yet been quantified. Thus, longitudinal variations of matrix resistivity were estimated from multiple-tap measurements of RRR along the length of strands extracted from representative (reacted) cables. The associated cables, some of which were made with RRP strand, and some from PIT strand, were subjected to various levels of deformation (and HT before strand extraction). Average and local RRR values so obtained were compared to values for virgin (uncabled but reacted) strands reacted in the same cycles. Selected regions of the strand with locally depressed RRR were examined by SEM and EDS to check for Sn leakage and examine the type of strand failure present.

This work was supported by the U.S. Dept. of Energy, Division of High Energy Physics, under Grant No. DE-FG02-95ER40900.

M3-H-05 Transport AC Losses in MgB2 Multifilamentary Strands with Magnetic and non-Magnetic Sheath Materials

***M. Majoros**, M. D. Sumption, E. W. Collings, The Ohio State University; S. Kawabata, Kagoshima University.*

Transport AC loss measurements have been made on two different kinds of MgB2 superconducting strands. Seven filament strands made via an in-situ route with Nb chemical barriers, a Cu-interfilamentary matrix, and either Monel or ODS Cu outer sheaths were used. Strands were untwisted, and measured in self-field at temperatures from 4.2 K to Tc. AC losses of samples with no ferromagnetic elements present in their matrix agreed reasonably well with theoretical predictions for a wire of round cross-section. The samples containing a weakly ferromagnetic matrix showed significantly higher losses compared with the theoretical values obtained from the critical state model. In some amplitude regimes the difference was an order of magnitude. Thus, from a transport loss point of view, even weakly ferromagnetic elements are to be avoided in strands under the given geometries.

M3-I Properties of HTS

M3-I-01 Jc – Tc correlations in long-length coated conductors

***J.O. Willis**, J.Y. Coulter, J. Haenisch, Los Alamos National Laboratory.*

Production of high temperature superconductor (HTS) coated conductor (CC) tape requires tight control of many variables to achieve high performance (critical current density, Jc) and high homogeneity as a function of position x along many 100s of meters of conductor. Jc(x) itself is one of the most important and commonly used parameters to characterize a CC, but it depends largely on extrinsic properties of the superconductor, such as defect structures, impurities, etc. In contrast, the superconducting critical temperature (Tc) is an intrinsic property, and variations in Tc(x) indicate process variations that may be detrimental to performance. To assess this possibility, we measured Jc (0.6 T H||c) at 75 K and 85 K and the inductive Tc value at the same positions in long (1 meter +) tape samples and then analyzed those values for correlations. We found that strong positive correlations with Jc are seen for those tape samples with degraded Tc values. On the contrary, for tape samples with optimized Tc values (optimized process chemistry), Jc is only weakly correlated and depends primarily on other (extrinsic) factors. Details of the measurements and results and application to CC processing will be presented.

M3-I-02 Inter- and intra-grain dissipation at low angle [001]-tilt YBCO bicrystalline films under the influence of external magnetic field

***T. Kiss**, A. Matsekh, D. Mitsui, M. Inoue, Kyushu University; Y. Shiohara, Superconductivity Research Laboratory.*

Flux flow dissipation at low angle [001]-tilt grain boundaries in YBCO bicrystalline films has been visualized by the low temperature scanning laser microscopy under external magnetic field (B) up to 5 T. Transport current-voltage (I-V) characteristics have also been measured simultaneously by the four-probe method. While the critical current (Ic) is limited at the grain boundary in low magnetic field region, inter-grain Ic merged with intra-grain Ic when the external field is increased larger than a cross-over field (Bcross). Spatially resolved dissipation images show good agreement with the transport measurements. In the grain-boundary limiting region: B < Bcross, dissipation is localized at the grain boundary. However, the dissipation is distributed non-uniformly also along the grain boundary with a typical spacing of around 50 um. This suggests that the grain connectivity is not uniform across the grain boundary but it is influenced by a long range micro-structural disorder such as faceting and defects. Flux flow at the grain boundary is followed by intra-grain flux flow as the bias current is increased. This is consistent with a kink structure in the transport I-V curves. Under a high enough external field: B > Bcross, grain boundary dissipation merged with intra-grain dissipation, and no trace of grain boundary has been seen.

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M3-I-03 A method to twist subdivided HTS coated conductors without twisting conductors -quasi- twisted conductors

*O. Tsukamoto, **A. K. M. Alamgir**, S. Sekizawa, Yokohama National University.*

To reduce magnetization losses in HTS coated conductors, HTS layers are to be subdivided into multiple filaments. In those multifilamentary conductors, the electromagnetic coupling between the filaments should be suppressed to reduce the coupling losses by twisting the conductor somehow. However, mechanical twists of the conductors cause serious problems, deteriorating the mechanical strength, critical currents of the conductors and packing factor of coil windings. A quasi-twisted conductor configuration was proposed to obtain the same decoupling effect of the twist without twisting the conductors themselves at a sacrifice of slight increase of the transport current losses. The proposed method is that HTS layers on substrates of coated conductors are subdivided into multiple filaments by slanted striations and that a quasi-twisted conductor is composed by electrical connection of a pair of those striated tapes. The effect of the twisting is obtained by this composition.

Short models of the quasi-twisted conductor were fabricated by making the electric contacts between the HTS filaments using diffusion joint process of silver layers on the HTS layers. The AC losses in the model quasi-twisted conductors and the resistance at the contacts between the HTS filaments were measured. In the paper, the effectiveness of the quasi-twisted conductor is estimated based on the measurement results.

M3-I-04 Position Dependent Critical Current Magnetic Field Anisotropy Characterization of Multi-Meter Coated Conductors

***J.Y. Coulter**, J. Haenisch, T.G. Holesinger, J.O. Willis, L. Civale, Los Alamos National Laboratory.*

As Rare Earth Barium Copper Oxide (REBCO) coated conductor production technology has evolved, critical current (Ic) anisotropy measurements made as a function of angle at constant magnetic field (H) and temperature on short samples have been used to identify the behavior of the microstructures necessary to produce good conductor performance. However, Ic characterization of long length REBCO coated conductors usually consists of position dependent self-field Ic measurements to determine the homogeneity. Position dependent Ic anisotropy characterization is needed to verify the in-field Ic homogeneity, the successful reproduction of the microstructural properties in long lengths, and to demonstrate conductor performance for applications. In the past year we have developed the capability to make these measurements in the liquid cryogens nitrogen and argon. We present results from characterization of multi-meter coated conductors. We will show how the positional dependence of Ic anisotropy can be used to obtain information for tape processing optimization.

M3-I-05 Study of HTS Conductors for High Field Solenoids

***E. Barzi**, M. Lamm, V. Lombardo, D. Turrioni, A.V. Zlobin, Fermilab; C. Thieme, AMSC.*

An experiment is in the works at Fermilab to confirm that ionization cooling is an efficient way to shrink the size of a muon beam. This would pave the way for Muon Collider machines, which require in their last stages of acceleration very high field solenoids. The use of high temperature superconducting materials (HTS) is being considered for these magnets using Helium refrigeration. A test stand was set up at Fermilab to perform critical current (Ic) measurements of HTS conductors under externally applied magnetic fields at zero to 90 degree with respect to the sample face. This was performed in an ample range of temperatures. A description of the test setup and results on BSCCO-2223 tapes, and second generation (2G) 348 coated conductor are presented. In addition, small pancake coils made of 2G-HTS were built and tested in the bore of a 16 T solenoid.

M3-I-06 High-pressure oxygenation of MT-YBCO: the way to reduce the oxygenation time, to prevent macrocracking, and to obtain materials with high critical currents

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The oxygenation under the controllable isostatic oxygen pressure (from 5 mbar to 160 bar) at high temperature (900-700 oC) allowed us to reduce the time of oxygenation of bulk and thin-walled (with artificially drilled wholes) MT-YBCO from 270 to 80-80 hours, practically prevent macrocracking and to get high critical current density, jc, (at 77 Ê the jc in ab plane was 85 kA/ñm2 in 0 Ò field and was higher than 10 kA/ñm2 in the fields up to 5 Ò, the field of irreversibility was 9,8 T, and in the ñ- direction jc was 34 kA/ñm2 0 Ò field and higher than 2,5 kA/ñm2 in 10 Ò field).
The Young modulus and nanohardness estimated under a low load (30 mN) are approximately similar for both the types of studied MT-YBCO; for all types of ceramics, the Young modulus in the ab-plane (186-185 GPa) is lower than in the perpendicular direction (203 - 232 GPa); on the contrary, the nanohardness in the ab-planes (12.2-12.6 GPa) is higher (9.3-10.9 GPa). The microhardness estimated under a higher load, from which we may judge about mechanical characteristics of the material as a whole, for both bulk and thin-walled ceramics was higher after oxygenation under the controllable isostatic oxygen pressure, but in general the thin-walled ceramics demonstrates higher microhardness and fracture toughness.
The influence of twin density on jc is discussed.

M3-K Nb3Sn and Other A-15 Compound Superconductors

M3-K-01 Tensile properties of Nb3Sn bronze route wires between 300 K and 4 K

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Outer stabilized Nb3Sn bronze route wires have been investigated at room temperature, at 7 K and at 4.2 K with respect to their stress strain behavior using the recommendations of the draft foreseen for a new tensile measurement IEC standard.
A significant decrease of the yield strength has been observed partly at wires with a Nb diffusion barrier compared to wires with a Ta barrier if cooling down from room temperature to 4.2 K. The reaction heat treatment at four different temperatures (943 K, 973 K, 993 K and 1023 K) shows also a clear influence on the yield strength decrease. The highest decrease of yield strength is related with the 1023 K reaction heat treatment while the heat treatment at 943 K shows the expected increase. Detailed investigations with selected wires are initiated to confirm that a part of this phenomenon maybe attributed to the differential thermal expansion of the different materials embedded inside the composite wires.

M3-K-02 Performance of Nb3Sn RRP Strands and Cables Based on an Improved 108/127 Stack Design*

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The high performance Nb3Sn strand produced by Oxford Superconducting Technology (OST) with the Restack Rod Process (RRP) in a 108/127 stack design is the present baseline conductor for the Fermilab's accelerator magnet R&D program. This strand was further improved in stability by increasing the Cu thickness between subelements after proving the effectiveness of this method in a 60/61 stack design. The strand cross section was optimized to reduce subelement strain by removing the corner subelements of the hexagonal array. The performance of this new strand was extensively studied using virgin and deformed strand samples, and compared with that of the previous 108/127 and 60/61 stack designs. Rutherford cable made of 1 mm strand was also tested using a superconducting transformer and small racetrack coil. This paper presents the RRP strand and cable parameters, and reports the results of strand, cable and racetrack coil testing.

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M3-K-03 Longitudinal and transversal strain sensitivities of high Jc Nb3Sn

***J Lu**, K Han, R.P. Walsh, S.T. Bole, NHMFL.*

The strain sensitivity of high Jc Nb3Sn has important impact on the design of large superconducting magnets using cable-in-conduit conductors (CICC) such as the series-connected-hybrid magnet at the NHMFL. Although the behavior of the Ic vs. longitudinal strain for low Jc strands is well documented, the database for advanced high Jc conductors is far from complete. Furthermore, the influence of the compressive transverse strain which can be large in a large CICC is yet to be formulated. In this work, the Jc dependence on both longitudinal and transverse strains of high Jc Nb3Sn conductors is investigated using an apparatus designed and constructed at the NHMFL. We will also discuss the effect of strand design and heat treatment temperatures on its strain sensitivity.

Financial support of the National Science Foundation under grant of DMR-0084173 is gratefully acknowledged.

M3-K-04 Magneto Optical and Electromagnetic Study of Deformation in Brittle Superconductors.

***A.A. Polyanskii**, P.J. Lee, D.C. Larbalestier, NHMFL, FSU; E. Barzi, D. Turrioni, FNAL.*

We have used Magneto Optical (MO) imaging, magnetization and transport measurements, to study the effect of mechanical deformation on Powder-in-Tube (PIT) and Restack Rod Process (RRP) Nb3Sn strands so as to help understand the effect of cabling on different strands. Rolling was chosen as the deformation method, as it produces a homogenous, reproducible deformation along the length of the strand. The amount of rolling deformation was varied according to the range of deformation expected during cabling. MO imaging was used to observe superconducting property changes produced by mechanical and heat treatments as it this technique provides us with the capability to observe and quantify local changes and inhomogeneities in the superconducing properties in strand cross-sections down to a spatial resolution of ~5 µm . At each stage of deformation we identify various types of defects, filament size distribution, high and low field superconducting properties and compare strands of both PIT and RRP designs. We also examine the effect of annealing RRP material before cabling, to measure the effect of increased Cu thickness between subelements in a novel design produced by OST, and finally to verify how much damage is already present before reaction and how much occurs during reaction.

M3-K-05 Effect of Rutherford Cable Parameters on Nb3Sn Strand Deformation and Subelement Damage*

***E. Barzi**, D. Turrioni, R. Yamada, A.V. Zlobin, Fermilab; T. Collings, M. Sumptions, Ohio State University.*

In order to optimize the parameter space for Rutherford cables used in accelerator magnets and their technology, experimental studies of effect of Rutherford cable parameters on Nb3Sn strand deformation and subelement damage were performed. A number of cables were fabricated with different keystone angles, packing factors and number of strands. RRP strands with regular and increased Cu spacing between sub-elements were used. For several cables and conditions, the overall strand deformation was measured as a function of its location across the cable cross section. Studies of internal strand damage in the cabled strand include measurement of sub-element size distributions, and identification and counting of defects across the cable cross section before and after heat treatment. To correlate damage with performance, high and low field SC properties were also measured for the extracted strands.

** This work was supported by the U.S. Department of Energy*

M3-K-06 Investigation on the Correlation between Composition and Upper Critical Field of Nb3Sn Conductors

***X. Peng**, Ohio State University & Hyper Tech Research Inc.; M.D. Sumption, R. Dhaka, E.W. Collings, Ohio State University; M. Tomsic, Hyper Tech Research Inc.; E. Gregory, Supergenics LLC I.*

A few Nb3Sn conductors made by internal-Sn method were investigated. Different heat-treatments with varying temperature and duration time were performed in this study. High resolution scanning electron microscopy (SEM) with attached Energy Dispersive Spectroscopy (EDS) and Scanning Transmission Electron Microscopy (STEM) were used to observe the microstructure of the strands and measure the composition profile along the radial direction of the strands. Bc2 values were estimated via Kramer plot extrapolation and by resistive transitions at high magnetic fields, and the difference between them was explained. The Bc2 value was correlated to strand composition.

This work was supported by the U.S. Depart¬ment of Energy under Grant DE-FG02-03ER83674, DE-FG02-02ER83541, DE-FG02-05ER84191, DE-FG02-05ER84380.

M3-K-07 Microstructure Examination of Al2O3 Strengthened Nb3Sn Wire

***J. Chen**, NHMFL.*

Nb3Sn conductors are strain/stress sensitive and degradation may occur if the net strain in Nb3Sn reaches a critical value. If the strength is increased, Nb3Sn can sustain large stress with less strain than conventional Nb3Sn. We demonstrated that the strength of the Nb3Sn composites can be strengthened by Al2O3 nanoparticles embedded in Cu-Sn. In addition, the critical current is improved. The microstructure examinations of the strengthened and regular wire reveal the insight of the improvement of the properties.

M3-L BSCCO Wires and Tapes

M3-L-01 Progress of high performance DI-BSCCO wire

***M. Kikuchi**, N. Ayai, J. Fujikami, S. Kobayashi, K. Yamazaki, S. Yamade, T. Ishida, T. Kato, K. Hayashi, K. Sato, Sumitomo Electric Industries, LTD..*

Due to the recent dynamic technological innovations, such as the introduction of ConTrolled Over Pressure (CT-OP) process and total optimizations of whole processes, Ic has reached 201 A which is equivalent to 493 A per 10 mm width. The engineering current density has been 21 kA/cm2, while the critical current density has been 56 kA/cm2. Present unit length has reached over 1600m with homogeneous Ic. We plan to produce over 2 km long wire with 200 A-class Ic. The new wire, which is named Dynamically Innovative BSCCO (DI-BSCCO) wire, shows excellent properties in a magnetic field. It is expected that DI-BSCCO wire will be used in a wide variety of cryogenic applications. We produce 3 types of DI-BSCCO wires, Type H (High Ic), Type S (Slim) and Type AC which feature a high Ic, a lower AC loss and a lower operation current with the half cross section of Type H, and a much lower AC loss with twisting filaments or electric insulation layers, respectively. We also produce the DI-BSCCO wires which have more excellent mechanical properties by reinforcement with stainless steel tapes or Cu tapes.

M3-L-02 Microstructure and Jc improvements in multifilamentary Bi-2212/Ag wires for high field magnet applications

***H. Miao**, M. Meinesz, B. Czabaj, J. Parrell, S. Hong, Oxford Superconducting Technology.*

Bi-2212/Ag conductor is one of the most promising materials for expanding superconducting magnet applications to higher fields than present LTS systems. From the view point of practical application, Bi-2212/Ag round wires have significant advantages over more typical HTS tape conductors, such as no anisotropy, and easier handling and coil winding, which allows considerable flexibility in the magnet design. Recent development efforts at Oxford Superconducting Technology (OST) have recently been aimed at manufacturing high quality multifilamentary Bi-2212/Ag round wires to fabricate HTS insert coils for high field magnet applications. However, further improvement of critical current density (Jc) and engineering current density (JE) in long length conductors is desirable for practical applications. Recent results show a strong dependence of the wire JE and Jc performance on its microstructure, in particularly, the interface of Bi-2212/Ag. In this paper the progress on the development of this conductor will be reported.

M3-L-03 Correlation between Critical Current, Critical Temperature and Irreversibility Field in Bi2212 conductors

***J. Jiang**, F. Kametani, F. L. Hunte, D. C. Larbalestier, Applied Superconductivity Center-NHMFL; M. Rikel, J. Bock, Nexans SuperConductors; H. Miao, K. Marken, E. E. Hellstrom, Oxford Superconducting Technology.*

Bi2212 conductor is one of the most promising superconducting materials for high field magnet applications. Significant improvement in critical current in round Bi2212 wire has been achieved recently by optimizing the precursor powder and the melt-processing. Bi2201 intergrowth layers within the Bi2212 grains are believed to deteriorate critical current density (Jc) in Bi2212 conductors. Significant effect of overall precursor composition on the critical current density Jc(4.2K, sf) and the Jc- maximum processing temperature window was found. In order to clarify the reasons for such an effect, we performed a thorough characterization of critical temperature (Tc), irreversibility field (Hk) and microstructure of dip-coated tape samples prepared from precursor powders of different stoichiometries. A strong correlation between Jc, Tc and Hk(20K) was found, suggesting that changes in Jc(4.2 K) are greatly affected by the changes in overall Tc of the Bi2212 phase. These findings are discussed in connection with the results of microstructural studies of the density of Bi2201 intergrowths determined by X-ray diffraction and changes in phase composition determined by scanning electron microscopy and transmission electron microscopy.

M3-L-04 Radiation Damage to BSCCI-2223 from 50 MeV Protons

***A.F. Zeller**, R.M. Ronningen, NSCL/MSU; A. Godeke, L.H. Heilbronn, P. McMahan-Norris, LBNL; R. Gupta, BNL.*

Neutron interactions in the coils of superconducting magnets that will be used in high-intensity heavy ion accelerators are a major problem, both in the short and long term. Heating in the cold mass causes high loads on the refrigeration system and damage to the coils and insulation causes failure of the magnet. One proposed solution is to use HTS conductors, like BSCCO. Operating the coils at 20 – 30 K, reduces the refrigeration load. By using stainless steel as the insulation, the long-term damage to the insulation in the coil package will be reduced. The uncertainty is the radiation sensitivity of the superconductor. There have been some irradiation studies of HTS conductor with low-energy neutrons and low doses, but the results are inconclusive. Because high-energy neutrons and protons have similar damage profiles, we have irradiated samples of BSCCO-2223 from two different manufacturers with 50 MeV protons at the LBNL 88.
Works supported in part by grants from DOE

M3-L-05 BSCCO-2212 Wire and Cable Studies*

***E. Barzi**, M. Lamm, V. Lombardo, D. Turrioni, R. Yamada, A.V. Zlobin, Fermilab; S. Hong, M. Hanping, OST.*

BSCCO-2212 round wires are being studied at Fermilab for possible use in accelerator magnets. Several billets were produced by OST with various fill factors in a diameter range between 0.7 and 1 mm. To allow for cabling, a modified process was implemented as opposed to the regular process with oxygen anneal. Rutherford-type cables were fabricated and the performance of extracted strands was compared with that of virgin samples. Cables were also tested using a superconducting transformer.
** This work was supported by the U.S. Department of Energy*

M3-L-06 Bi-2212 Coil Technology Development

***J. Byeon**, A.D. McInturff, P. McIntyre, A. Sattarov, C. English, Texas A&M University.*

Initial results are reported on experiments to optimize coil technology utilizing Bi-2212/Ag round-strand multi-filament superconducting wire. Two configurations are being developed: ten-stack studies of windings utilizing Rutherford cables, and 6-on-1 structured cable-in-conduit. In each case heat treatments are being evaluated using iso-pO2 thermal cycle and iso-thermal pO2 cycle. Short-sample current is obtained by preparing the cable containing a single strand of high-performance conductor and the balance of dummy strands in which the cores are loaded with non-superconducting powder. Implications for high-field hybrid dipoles and for high-field solenoid inserts are discussed.

M3-L-07 Design of a Toroidal Magnetic Shield for Project Orion

***P. McIntyre**, A. Sattarov, Texas A&M University; S. Ting, V. Choutko, Massachusetts Institute of Technology.*

Initial results are reported on experiments to optimize coil technology utilizing Bi-2212/Ag round-strand multi-filament superconducting wire. Two configurations are being developed: ten-stack studies of windings utilizing Rutherford cables, and 6-on-1 structured cable-in-conduit. In each case heat treatments are being evaluated using iso-pO2 thermal cycle and iso-thermal pO2 cycle. In each configuration two routes for thermal processing are being investigated: an iso-thermal heat treatment in which the transition to partial melt is controlled by modulating the partial of O2 (pO2), and the conventional iso-pO2 temperature programming. Optimization utilizes both strand short-sample measurements and evaluation of microstructure within the cores. Subsequent studies will further optimize processing for stacks of cable elements that simulate coil cross-sections.
For those studies we plan to measure short-sample current by preparing cables containing a single strand of high-performance conductor and the balance of dummy strands in which the cores are loaded with non-superconducting powder. Implications for high-field hybrid dipoles and for high-field solenoid inserts are discussed.
This research is funded by the U.S. Dept. of Energy, grant DE-FG02-06ER41405.

M3-O Materials Evaluation and Testing

M3-O-01 Cryogenic NOL Ring Tests of Composite Materials

***T. DeLay**, NASA/MSFC; J. Patterson, HyPerComp Engineering; J. Schneider, Mississippi State University.*

A cryogenic COPV research effort has been expanded to performance at liquid hydrogen temperatures (-420F). Candidate COPVs are being burst tested by using liquid helium as the pressurization fluid; however, this type of testing consumes considerable resources. NOL ring tests(ASTM 2290) are being used to help screen the suitability of composite materials for the over-wrap of COPVs. NASA/MSFC has a unique tensile tester that allows precise tests at ambient, LN2 and LH2 conditions. Previous research has demonstrated that the matrix resin can make a considerable contribution to COPVs at cryogenic temperatures. The NOL tests demonstrate the ultimate strength of the fiber/resin systems but it also allows for the cryogenic controlled loading of additional samples(at 10,000 microstrain) that are inspected for damage(resin micro-cracks, fiber breaks). The data from the cryogenic NOL ring tests may also help the understanding of other materials test at cryogenic conditions such as: short beam shear of the composite laminate, tensile test of neat resins , impact test etc..

M3-O-02 Cryogenic Design and Predicted Performance of the James Webb Space Telescope Beryllium Aft Optics Subsystem Optical Bench

***K. Martinez**, J. Sullivan, A. Barto, J. Lewis, R. Franck, T. Dreher, B. Shogrin, J. Sokol, Ball Aerospace and Technologies Corp.*

With a planned launch of 2013, NASA's James Webb Space Telescope (JWST) will be the premier space observatory for astronomers worldwide. This infrared space telescope will be passively cooled to cryogenic temperatures in its L2 orbit. The JWST Optical Telescope Element (OTE) features a 6.5 meter, segmented Primary Mirror which focuses light onto a Secondary Mirror and finally redirected into and through the Aft Optics Subsystem (AOS). The AOS consists of an optical bench which aligns and supports the telescope's Tertiary Mirror and Fine Steering Mirror Assemblies. This paper reviews the unique cryogenic requirements and design of the JWST Beryllium AOS optical bench. Key performance requirements are discussed including: launch environment, the cryogenic operating environment (nominally 39K), and optical alignment stability at cryogenic temperatures. The mechanical design approach utilizing Beryllium as the structural material for the AOS Bench is described relative to meeting the driving requirements. Material property verification, low and predictable material variability, and low thermal gradients across the structure are also discussed.

M3-O-03 Neutron Diffraction Measurements during Loading at Cryogenic Temperatures in NiTiFe Shape Memory Alloys

***V.B. Krishnan**, S.B. Shmalo, R. Vaidyanathan, University of Central Florida; B. Clausen, D.W. Brown, M.A.M. Bourke, Los Alamos National Laboratory.*

Shape memory alloys are incorporated as actuator elements due to their inherent ability to sense a change in temperature and actuate against external loads by undergoing a shape change as a result of a temperature-induced phase transformation. The cubic austenite to trigonal R-phase transformation in NiTiFe shape memory alloys offers a practical temperature range for actuator operation at low temperatures. A cryogenic loading capability, to temperatures as low as 90 K, for in situ neutron diffraction measurements was implemented on the Spectrometer for Materials Research at Temperature and Stress (SMARTS) at Los Alamos National Laboratory. Experiments were performed on NiTiFe samples during compressive loading at 92 K and heating under a constant load of 50 MPa, in the presence of stress-induced and temperature-induced phase transformations, respectively. Neutron diffraction spectra were recorded at appropriate intervals during these experiments, facilitating the monitoring of the phase-specific strain, texture and phase fraction evolution. Implications of these measurements for cryogenic actuator design are presented.

This work was supported by grants from SRI, NASA (NAG3-2751) and NSF (CAREER DMR-0239512) to UCF.

M3-O-04 Effect of retained austenite on the cryogenic mechanical properties of 13Cr4NiMo martensitic steel

*X. Li, Y. Song, **YY Li**, Institute of Metal Research,CAS.*

Low-carbon 13Cr4NiMo martensitic stainless steels have high strength and good corrosion resistance and superior low temperature toughness, and are good candidates for cryogenic applications. Since their mechanical properties are mainly resulted from dispersive retained austenites, 13Cr4NiMo steels with different amount of retained austenite were obtained by controlling heat treatment in present work, and the cryogenic mechanical stability of the retained austenite particles was accessed by controlling tensile tests with different elongation in a temperature range from 293K to 77K. Corresponding cryogenic treatment of the sample at the same temperatures without deformation were conducted as comparison. X-ray diffraction, transmission and scanning electron microscopy were used to study the retained austenites and their interactions during tensile testing and cryogenic treatment. It is shown that the higher the amount of austenite is, the higher the cryogenic ductility is. An explanation is proposed in this study, based on the mechanical stability of the retained austenite at cryogenic temperature.

M3-O-05 Fracture Toughness Measurement of Cryogenically Treated M2 Tool Steel by Charpy Instrumented Impact Test

***S. Angel Darshini**, Anna University; S. Venkateswaran, A. Bensely, D. Mohan Lal, A. Rajadurai, Anna Unievrsity; A. Gyongyever Lenkey, Bay Zoltan Foundation for Apllied Research.*

Fine blanking is an important precision stamping process practised presently. To improve the performances, the fracture toughness and hardness of the AISI M2 steel has to be improved. Earlier studies on the wear resistance of cryogenically treated tool steel revealed an improvement of 110%. A set of three samples which are conventionally heat treated (CHT), shallow cryogenically treated (SCT) at 193 K and deep cryogenically treated (DCT) at 77 K are then subjected to three stages of tempering. The effects of the treatments on properties like hardness, fracture toughness of AISI M2 have been studied. The Vickers hardness test reveals that the hardness values decreases marginally in double and triple tempering. DCT followed by tempering improves hardness by 4% and SCT followed by tempering improves hardness by 2.5% when compared with CHT. Charpy instrumented impact test reveals that average impact energy is higher in CHT samples than in DCT and SCT samples. The static fracture toughness (KIc) is 4.25% and 7.2% lesser in DCT and SCT samples respectively than in CHT samples when single tempered. Similarly, the dynamic fracture toughness (KId) is 1.61% and 2.76% lesser in DCT and SCT samples respectively than in CHT samples when subjected to a single tempering. KIc and KId increases with a higher order tempering by 7.5% and 3% in DCT and 12% and 4.5% for SCT respectively. Microstructural analysis using optical microscope is also carried out at every stage of AISI M2 steel.

The authors are indebted to thank M/s.Sharp Tools, Coimbatore for machining the V- notches exactly as per ASTM standards. Also the authors gratefully acknowledge M/s.Chennai Metco Private Limited for extending the metallurgical facilities for the successful completion of the work.

M3-P Coated Conductor - III: Processing

M3-P-01 Enhanced Current Transport Across Grain Boundaries of YBCO by Novel Methods

***T.J. Haugan**, P.N. Barnes, N.A. Pierce, F.J. Baca, T.A. Campbell, M.F. Locke, I. Maartense, T.L. Peterson, The Air Force Research Laboratory; C. Kwon, M. Yamamoto, R.G. James, J.L. Young, Cal State Univ at Long Beach.*

Recent experiments using novel methods to enhance transport currents across grain boundaries (GB) of YBa2Cu3O7-z (YBCO or 123) coated conductors will be presented. Multilayer (Mn/Y123m)N films were deposited onto SrTiO3 single crystals with grain boundaries from 4° to 36°, and with layer thickness n = 0.5-1.0 nm and m = 5-10 nm. The M phase addition studied was (Y1-xCax)2BaCuO5, with x ranging from 0.0 to 0.10 and overall Ca concentrations of the film varying from 0.0% to 0.5%. Deposition temperatures from 775 °C to 850 °C were tested, to study the effect of varying diffusion and deposition conditions. Results show that 2-100 times improvements of GB transport currents at 77K can be achieved, varying depending on the film parameters, process conditions, and bi-crystal angle. The microstructures and mechanisms that correlate with the increase of critical currents were studied with SEM, scanning laser and microwave microscopy, and Raman stress mapping. These studies indicate the microstructures of the film are strongly changed both in a macroscopic regions around the grain boundary, as well as right at the grain boundary. The results and significance of these experiments will be discussed.

AFRL Propulsion Directorate and the Air Force Office Scientific Research

M3-P-02 Development of a Metal-Organic Decomposition Process for Growth of Lanthanum Manganate Buffer Layers for Coated Conductors

*K. Venkataraman, **E.E. Hellstrom**, University of Wisconsin-Madison; M. Rupich, American Superconductor Corporation.*

Based on the diffusion barrier properties and close lattice match with YBa2Cu3O7-x, LaMnO3 (LMO) had been previously identified as a suitable material to replace Y2O3 and yttria-stabilized zirconia buffer layer materials in the coated conductor architecture employed by American Superconductor Corp. (AMSC). The growth of LMO on various metal and oxide substrates via a metal-organic decomposition (MOD) process, which is a rapid and economic alternative to physical vapor deposition (PVD) processes, was investigated to evaluate MOD process-properties relationships. Multi-layer epitaxial films of LMO were successfully grown via MOD on single crystal STO under T-pO2 conditions that do not oxidize the Ni-5%W substrates. Growing epitaxial LMO on bare or buffer-coated Ni-5%W substrates has proven challenging due to the incongruent overlapping requirements of Ni-5%W stability, thermodynamics of LMO formation, and kinetic characteristics of the MOD process. The main problem appears to be tungstate formation due to tungsten in the substrate and the cations in the overlying film reacting when processing in the T-pO2 window required to obtain epitaxial LMO films via MOD. This presentation will delineate the process-property relationships evaluated for MOD of LMO films on Ni and Ni-W substrates, and will propose alternative strategies to obtain epitaxial MOD LMO buffer layers compatible with a RaBiTs CC architecture.

This work was supported by DOE-OETD.

M3-P-03 YBa2Cu3O7-x Films With BaSnO3 Nanoparticles Prepared by Pulsed Laser Ablation Method Using Different Processing Approaches

***C.V. Varanasi**, J. Burke, I Maartense, University of Dayton Research Institute (UDRI), Dayton, OH ; T.J. Haugan, P.N. Barnes, Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH.*

Nanoparticles of BaSnO3 were introduced into YBa2Cu3O7-x (YBCO) films by pulsed laser deposition (PLD) method using three different processing approaches viz. 1) using a single PLD target consisting of distinctive dual sectors of BaSnO3 and YBCO 2) A target made with premixed powders of BaSnO3 (2 to 10 wt%) with YBCO 3) Two distinct targets of BaSnO3 and YBCO that are alternated to deposit films in multilayer fashion. Initial results using a dual sector target approach showed that high field critical current density (Jc) can be significantly improved in YBCO+BaSnO3 films. The number density of nanoparticles in YBCO+BaSnO3 films was found to vary considerably depending upon the processing parameters and the methods used. Depending upon the number density of the particles, variations in the Jc data were observed. Microstructural details and magnetization critical current density (Jc) of the films processed by these three processing methods will be presented. The position of the maximum of the bulk pinning force curve, Fp,max, occurred at more than half of Hirr in quality YBCO+BaSnO3 films as opposed to the typical ~0.3 Hirr. Further, a distinguishable dual peak structure in Fp vs. H curves was also observed in the data taken from these films. Some of the possible flux pinning mechanisms responsible for such dual peaks will be discussed.

M3-P-04 Effect of Holmium Additions on Microstructure in YBa2Cu3O7-δ

***R Goswami**, SAIC/NRL; R Holtz, G Spanos, NRL; M.W Rupich, American Superconductors; W Zhang, American superconductors.*

The microstructure of Y-Ho-Ba-Cu-O samples with two different levels of Ho, Ho/Y = 0.5 and 1.0, processed by the trifluoroacetate metalorganic deposition process, have been studied by Transmission Electron Microscopy techniques including High Resolution TEM (HRTEM), conventional TEM, Z-contrast imaging, and fine probe Energy Dispersive Spectroscopy (EDS). Oxide nanoparticles with varying levels of Ho have been characterized in detail, and related to other microstructural features.

At a lower level of Ho, segregation of Ho at (110) twin boundaries has been observed by Z-contrast imaging and EDS analysis. Further increase in Ho content considerably reduces the number of twins, and stabilizes a tweed-like structure. Ho additions increase the critical current for the magnetic field parallel to the c-axis, and decrease it for the field parallel to the a-b plane, resulting in a decreased anisotropy of critical current with field angle. These trends are discussed in terms of the detailed microstructural observations.

This work was supported by the Office of Naval Research, in connection with the DARPA program on Superconducting Hybrid Power Electronics.

Friday, 07/20/07 Oral 9:15am - 10:45am

M4-B Novel Materials and Processes

M4-B-01 A Comprehensive Review on Cryogenic Treatment

***A Bensely**, G Nagarajan, D Mohan Lal, Anna University; F Randall Barron, Louisiana Tech University.*

Engineers are always looking for ways to improve the mechanical properties of materials. Deep Cryogenic Treatment (DCT) is a process in which the material is cooled to an extremely low temperature (77 K). It is an inexpensive, one time, supplementary process for conventional heat treatment to improve mechanical properties of materials. Much time has been spent by many investigators and the results of such investigations have been widely published relative to cryogenic treatment, but it appears that the information has not reached where it can be most advantageously applied. Despite the numerous practical successes of cryogenic treatment and research projects undertaken worldwide, no conclusive metallurgical understanding of this treatment has been established. The benefits of cryogenic treatment on steel and other materials have been debated for many years. Even today, many metallurgical professionals worldwide have serious reservations about its mechanism. The purpose of this work is to condense the information available concerning the effects of cryogenic treatment on metal structure, as well as an overview of the actual process involved in treating materials.

M4-B-02 Effect of control of precursor powder size upon short-sample performance for PIT multi-filament superconductors

*A. McFarlane, **P. McIntyre**, Texas A&M University; S. Seshadri, Accelerator Technology Corp..*

A process for inert-gas-buffered milling and particle size separation has been commissioned into practice. It has been used to process the precursor powders for PIT superconductors of Nb3Sn, MgB2, and Bi-2212. Powders processed in this manner were fabricated into multi-filament strand, and the short-sample performance was compared with that of strand prepared with otherwise-identical powder.

This work is supported by the U.S. Dept. of Energy, grant DE-FG02-05ER84344.

M4-B-03 New Insulation Application Process for Wind-and-React Magnet Fabrication

***K.S. Kano**, M.W. Stewart, M.W. Hooker, Composite Technology Development.*

Wind-and-react processes offer a cost-effective means of fabricating large-scale Nb3Sn magnets while also eliminating the need to manipulate the brittle superconductor after the high-temperature reaction process. In this work, a new process is demonstrated for applying a thin, ceramic-based insulation that is compatible with wind-and-react processing. The insulation was applied to Rutherford cables using a continuous manufacturing process, and cable assemblies (i.e., 10-stacks) were fabricated. The electrical and mechanical performance of the cable assemblies will be presented.

M4-B-04 The LHC cryomagnet supports in glass-fiber reinforced epoxy: a large scale industrial production of high reproducibity in performance

***V. Parma**, A. Poncet, M. Struik, CERN; J. Trigo, EADS CASA Espacio.*

The about 1700 LHC main ring super-conducting magnets are supported within their cryostats on 4700 low heat in leak column-type supports. The supports were designed to ensure a precise and stable positioning of the heavy dipole magnets while keeping thermal conduction heat loads within budget. A trade-off between mechanical and thermal properties led to the choice of glass fiber reinforced epoxy (GFRE), also based on cost considerations. To ensure the reproducibility of the supports performance throughout the large production, Resin Transfer Moulding (RTM), featuring a high level of automation and control, was the manufacturing process retained. The Spanish aerospace company EADS-CASA Espacio developed the specific RTM process, and produced the total quantity of supports between 2001 and 2004.
This paper describes the development and the production of the supports, and presents the production experience and the achieved performance.

M4-B-05 Measurements of Cu-Ta Interface Roughness in Composite Nb3Sn Superconductor Wires

***S. Balachandran**, R.B. Griffin, K.T. Hartwig, Dept. of Mechancial Engineering, Texas A&M University.*

A common problem with manufacture of composite Nb3Sn superconductor wire which contains a tantalum diffusion barrier is an increasing roughness of the interface between the Cu and Ta regions as the wire is drawn down. As the Ta layer thins, the scale of this interface roughening can become large relative to the Ta layer thickness. When this happens, the chances of layer fracture increases. Breaches in the Ta layer lead to contamination and a dramatic local decrease in the RRR of the Cu stabilizer material outside of the Ta layer by diffusing Sn during the long term heat treatment needed to form Nb3Sn. Another consequence of Ta layer fracture can be wire breakage. This occurrence limits the maximum continuous length of wire that can be made, increases wire manufacturing costs, and leads to lower efficiency magnets wound from shorter lengths of wire which requires a larger number of resistive joints. The authors have developed a method for measuring the surface roughness of the Ta diffusion barrier in Nb3Sn superconducting wires. Several examples of Cu-Ta interface roughness will be presented including cases which quantify how the relative roughness increases as the Ta layer thins during wire drawing. Considerations of the rate of increase of interface roughening should enable prediction of when a Ta layer fracture will occur during the layer thinning process (wire drawing). A discussion of related issues will be presented.

M4-B-06 Experimental Analysis of Freezing Time of Shrimp

***R.M Khadatkar**, G.H.Raisoni College of Engineering; S.C. Pattanayak, Indian Institute of Technology, Kharagpur.*

Fast freezing arrests the deterioration of quality of food very effectively. The metabolic changes that are due to microbial, enzymatic and chemical reactions, are retarded and even eliminated if fast cooling rate is maintained and the required temperature is brought down with particular time period. Cryofreezing has been a crying need for IQF (Individual Quick Freezing) foods, particularly for marine products in view of WTO regulations. It is an established truth that metabolic changes due to microbial, enzymatic and chemical reaction are retarded abruptly and even eliminated by cryofreezing. In order to improve the quality of frozen shrimp and reduce the cost of production , the freezing time should be at its optimum. In this paper, the freezing times calculated from the simplified analytical models were compared with the experimental values. This study is extended to different masses of shrimp and to develop co-relations to predict the freezing time required with respects to volume of food frozen.
This investigation also includes the studies on the effect of precooling chamber on the total performances of the cryofreezer and the optimum consumption of LN2 for a certain amount of loading.
Keywords: cryofreezing, LN2, quality, metabolism.

M4-C Material Evaluation and Testing: HTS and LTS - II

M4-C-01 Critical Current and Mechanical behaviors of Sub-Sized Nb3Sn Superconducting Cables under Transverse Load.

***L. Chiesa**, M. Takayasu, J.V. Minervini, MIT.*

The inherent load caused by the Lorentz force in a cable-in-conduit conductor has drawn attention of the fusion community following unexpected degradation of cables designed for the International Thermonuclear Experimental Reactor magnet. Efforts in measuring and modeling strain effects on single strands and cables have increased over the past decade. In particular, pure and periodic bending and transverse load effects have been the main focuses. We have built an apparatus to study the effect of transverse load on a sub-sized cable under various mechanical loads that simulates the stress condition in the ITER Central Solenoid conductor. A typical test sample is a single turn circular cable composed of 36 superconducting strands. The mechanical load is applied in subsequent steps aimed to measure the critical current behavior under loading-unloading processes. Various cables fabricated with different Nb3Sn wires have been tested using a 20 T, 190 mm bore Bitter magnet at NHMFL. The average Lorentz load for a typical ITER cable is up to 20 MPa but locally the strands could experience a much higher load. In the experiments transverse loads as high as 110 MPa have been applied. This paper presents critical current and mechanical behaviors as a function of applied load. The newly developed high performance, internal tin type wires seem to be very sensitive to strain, bending and transverse load. The paper will discuss possible causes for the observed transverse load effects.
This work was supported by the U.S. Department of Energy, Grant No. DE-FC02-93ER54186. A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by NSF Cooperative Agreement No. DMR-0084173, by the State of Florida, and by the DOE.

M4-C-02 Determination of irreversible strain limits of ITER Nb3Sn strands

***N. Cheggour**, J.W. Ekin, L.F. Goodrich, NIST.*

More aggressive (higher temperatures and/or longer times) heat treatments of Nb3Sn wires may be required to meet the critical-current density specifications for the International Thermonuclear Experimental Reactor (ITER) project. This can cause the Nb3Sn filaments grow together, which effects the electro-mechanical properties of the strand. In particular, it affects the irreversible strain limit that is a key characteristic of when irreversible strand damage will occur. The filament design and spacing in the strand will also affect the sensitivity of the irreversible strain limit to the heat treatment parameters. The dependence of transport critical current (Ic) on axial strain (ε) was measured on developmental Nb3Sn strands that were reacted with various heat-treatment schedules. Measurements were made as a function of tensile strain up to 1 % at 4.0 K and 12 T. The strain was loaded and unloaded to determine whether or not the critical current was still a reversible function of strain. The lowest strain where the function is no longer reversible is the irreversible strain limit (εirr). The hypothesis that more aggressive heat treatment reduces the irreversible strain limit of the strand is verified.
This work supported in part by the U.S. Department of Energy, Office of Fusion Energy Sciences.

M4-C-03 Metallographic Examination of Irreversible Damage in Nb3Sn
Composite Wires Under Bending Strain at 77 K
***M.C. Jewell**, P.J. Lee, D.C. Larbalestier, Applied Superconductivity Ctr., NHMFL, Florida State Univ..*
Filamentary Nb3Sn composites combine a classic brittle intermetallic, Nb3Sn, with classical ductile metals like Cu, Sn and Nb. However, the differential thermal contractions in typical commercial composite geometries have the beneficial effect of applying substantial compressive prestrain to the Nb3Sn filaments, which greatly enhances the conductor strain to fracture well beyond the canonical 0.2% typically expected for brittle filaments. Indeed well supported Nb3Sn conductors seldom show signs of filament fracture, but there are strong indications of gradual degradations in performance in some cable in conduit magnet tests that can only be accounted for by filament fracture under cyclic loading. Also, increasing demands for high critical current density strand has led to new strand geometries that should be expected to have enhanced fracture sensitivity. In previous studies of a wide range of Nb3Sn strand designs, we have found that the initiation of cracking was more likely in proximity to large areas of relatively soft Cu and that interfilamentary Cu and Nb can be effective crack-arrestors. However, those bend strain studies were performed at room temperature, so to more closely approximate the conditions experienced by the strand during magnet operation, we have extended the study to bending at 77 K. We discuss the impact of strand design on the results from our tests and also evaluate recent fracture results on a representative Nb3Sn cable-in-conduit conductor.

M4-C-04 Novel model for understanding the effect of cabling, void fraction and strand stiffness on Lorentz forces response and conductor degradation in Nb3Sn Cable In Conduit Conductors
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We present the latest results of our novel model for transverse electro-magnetic load optimization (TEMLOP) especially developed for ITER type of cable-in-conduit conductors. The most important feature of the model computations is that the severe degradation in large CICCs can be drastically and straightforwardly improved by increasing the pitch length in subsequent cabling stages and by reducing the void fraction. These corrective measures give more support to the strands and reduces the effect damage at strand cross-over points in the cables. It is the first time that an increase of the cable twist pitches has been proposed and a SULTAN test on the European TFPRO-II /OST-II conductor adapted according this new insight is scheduled for spring 2007 and should experimentally validate the predictions.
As input, the model uses data describing the behaviour of single strands under periodic bending and contact loads, measured with the TARSIS set-up. The model gives an accurate description for the mechanical response of strands to a transverse load, from layer to layer in the cable, in agreement with mechanical experiments performed on cables. The model substantiates that strand bending is the dominant mechanism causing degradation.
The twist pitch scheme and void fraction of the present conductor layout unfortunately turns out to be practically a worst-case scenario. The ITER conductor operation margin can be improved significantly by the proposed changes.
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M4-C-05 Large intrinsic effect of axial strain on the critical current of high-temperature superconductors for electric power applications
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A remarkably large reversible reduction in the critical current of "second generation" high-temperature superconductors for electric power applications has been measured with a new technique over a wide range of mechanical strain. The effect amounts to a 40 % reduction in critical current at 1 % compressive strain in self magnetic field, and is symmetric for compressive and tensile strains. The intrinsic effect is measured in highly aligned multigranular YBa2Ca3O7-d coated conductors made by different processes, including superconductors with nanoscale pinning centers. This effect and its magnitude are expected to have a significant impact on power applications and provide a useful new parameter for probing the fundamental nature of current transport in high-temperature superconductors.

M4-C-06 Mechanical Properties of YBaCuO high temperature superconductor ceramics doped with Au and Ga
*E.E. Sanaia, **E.R. Kutelia**, G.Sh. Darsavelidze, Georgian Technical University.*
Physico-mechanical properties of YBCO high temperature superconductor ceramics doped with Ga and Au has been investigated using the complex method of low frequency internal friction, shear modulus and dillatometry in the temperature range 20-700 0C.
Near 200 0C relaxation maximum of internal friction and anomaly of shear modulus were found, caused by movement of twin boundary, interacted with the oxygen atoms. It was established that activation energy of the relaxation peak is equal to ~ 0.9eV and the frequency factor. Doping by significantly raised activation characteristics of relaxation processes, and values of shear modulus and elastic limit, which are estimated at first.
Influence of doping with Ga and Au of YBCO ceramics on thermal expansion has been investigated. Two interval of hysteresis of internal friction and thermal expansion in 500-400 0C and 350-200 0C temperature range are observed in Ga doped ceramics.

M4-C-07 A SC Transformer for SC Cable Tests in a Magnetic Field*
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To meet the need in the applied superconductivity community of a cable test facility at high magnetic fields, a superconducting current transformer that can deliver more than 30 kA of DC current in Rutherford cables was designed and fabricated for operation in a 14T/16T solenoid of 77 mm bore. The existing infrastructure of the Short Sample Test Facility at Fermilab, including one of its cryostats, a 1000A power supply for the primary circuit, and a fast data acquisition system, was used for housing and operating the transformer. Its design, assembly and commissioning are described, as well as sample preparation and test procedure.
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M4-C-08 Radiation damage of HTSC films: new perspectives on radiation hard sensors.
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The sensor safety under particle irradiation either in space or in large facilities such as novel accelerators or fusion machines presents a challenge putting into play new materials and new technological solutions.
Sensors based on HTSC superconductors play an interesting role in this framework, due to their ability to swallow huge defect quantities without breaking their superconductive response to external excitations.
In this paper we report about “in-situ” and “ex-situ” radiation damage properties of YBCO films under proton irradiation at 3.5 MeV. The samples are either as grown films or films with confined nanostructuring by high energy heavy ions.(E. Mezzetti et al., Advances In Cryogenic Engineering Materials 52, (2006) 786). The “in-situ” measurements are directly performed under beam: the magneto resistive behavior of the targets is monitored in real-time for different temperatures and magnetic fields in order to evaluate transient damage, damage thresholds and, if reachable, shut down thresholds. The ex-situ measurements imply nanostructure changes investigation as well as transport characterization up to 6T.
The results are discussed in the framework of established damage standards.