MRS Superconductivity Workshop Explored Issues Related to Second-Generation YBCO-Coated Conductors

The Materials Research Society's International Workshop on Processing & Applications of Superconductors was held in Gatlinburg, Tennessee, July 31–August 2, 2002. Organized by M. Parans Paranthaman (chair), Amit Goyal, and Ron Feenstra of Oak Ridge National Laboratory, USA; Teruo Izumi of ISTEC, Japan; and Venkat Selvamanickam of IGC-SuperPower, USA, the international workshop presented research to 100 attendees from a group of 50 scientists from industry, national laboratories, and academia who are key players in the field of high-temperature superconductivity.

Major advances have been made in the last 15 years in high-temperature superconductor (HTS) research, resulting in increasing use of HTS materials in commercial and pre-commercial applications. HTSs are expected to be useful for numerous electric-power applications, including transmission cables, transformers, superconducting magnetic-energy storage (SMES), current limiters, motors, and generators. High efficiency, high power density, and improved materials utilization are some of the benefits expected from HTS materials. Much progress has already been made, from the near-term commercialization of the first-generation bismuth strontium calcium copper oxide (BSCCO) superconductor tapes to the continuing advancement in second-generation conductors coated with yttrium barium copper oxide (YBCO).

The goal of the workshop was to assess long- and short-term goals and needs, starting from an evaluation of the current status for each of the components of a typical YBCO-coated conductor, that is, the metallic substrate, buffer layers, and the YBCO coatings. An international panel of experts addressed recent advancements and developments of long-length YBCO-coated conductors and applications of HTSs. Eight sessions were held to focus on various YBCO processing techniques, substrate development, buffer-layer technology, characterization, and applications of coated conductors. In each session, 5–6 speakers addressed a number of issues formulated by the organizers. At the end of each session, a panel discussion was held. In the poster session, 16 papers were presented. In the "Rump Session," designed as an informal networking session, overviews were given on the status of second-generation YBCO-coated conductors in the United States, Japan, and Europe, followed by 10 presentations on late-breaking research and new directions. At the end of the workshop, a chair from each session contributed to the workshop summary.

J.B. Roberto (Associate Laboratory Director for Physical Sciences, Oak Ridge, and former MRS president) and J.G. Daley (Superconductivity Program Manager, U.S. Department of Energy) gave the welcome address. S. Tanaka (ISTEC, Japan) predicted the future of coated conductors in centimeter-wide 500-m lengths of tapes carrying critical currents of 300–350 A at 77 K and self-field. A. Malozemoff (American Superconductor Corp., USA) emphasized both the cost and ac loss advantages of YBCO-coated conductor composites over BSCCO multifilament composites. The development of second-generation coated conductors continues to show the steady improvement toward the long-length processing capabilities. Results were presented from studies of several meter-length YBCO-coated conductors based on ion-beam-assisted deposition (IBAD) and rolling-assisted biaxially textured substrate (RABiTS) approaches; some examples are shown in Figure 1. Y. Iijima (Fujikura Ltd., Japan) reported critical currents of 40 A

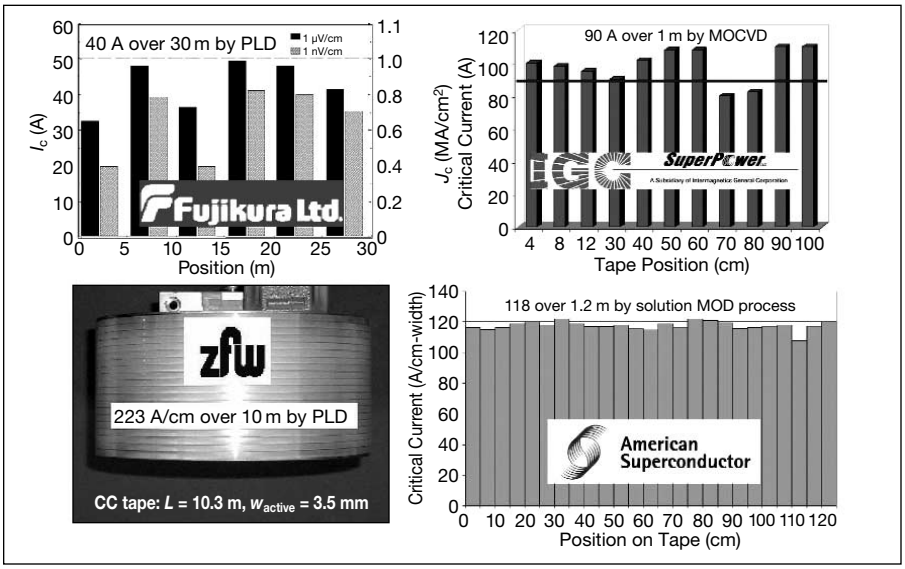

Figure 1. High-performance yttrium barium copper oxide (YBCO) superconducting tapes fabricated by various companies.

Organizers of the MRS International Workshop on Processing & Applications of Superconductors (left to right): Venkat Selvamanickam (IGC-SuperPower), Ron Feenstra (Oak Ridge National Laboratory), M. Parans Paranthaman, chair (Oak Ridge National Laboratory), Amit Goyal (Oak Ridge National Laboratory), and Teruo Izumi (ISTEC, Japan).

https://doi.org/10.1557/mrs2002.254

At the MRS International Workshop on Processing & Applications of Superconductors, held in Gatlinburg, Tennessee, July 31–August 2, 2002, researchers had many opportunities to discuss their ideas during the oral and poster sessions and informally during coffee breaks and at panel discussions.

over a 30-m length of centimeter-wide IBAD-$Gd_2Zr_2O_7$-based tape. V. Selvamanickam reported critical currents of 90 A over a 1-m length of centimeter-wide IBAD tape using metal-organic chemical vapor deposition (MOCVD). H.C. Freyhardt (University of Goettingen, Germany) reported critical currents of 223 A/cm over a 10-m length of IBAD-yttria stabilized zirconia (YSZ) tape. D. Verebelyi (American Superconductor Corp., USA) reported critical currents of 118 A with a standard deviation of less than 3% over a 1-m length of centimeter-wide RABiTS tape using solution-based metalorganic decomposition (MOD). He also showed a histogram of the average critical current of 100 A from each of 10 consecutively processed 1-m tapes. All of the reported critical currents were measured at liquid-nitrogen temperatures of 77 K and self-field.

For the RABiTS approach, in-plane grain alignment of 4° for the textured metal substrate was reported to be extremely important in achieving high critical currents (I_c) in second-generation coated conductors. A percolative current flow model predicted that the reduction in J_c in going from a short sample to a kilometer is only 10–15% for a typical RABiTS conductor 1-cm wide having a grain size of 50 μm. Inclined substrate deposition (ISD) and ion-beam nano-texturing (ITEX) processes to produce biaxially textured buffer layers were also covered. YBCO films of over 3-μm thickness were produced with dense microstructure and high critical currents using pulsed-laser deposition at Oak Ridge and ZFW, Goettingen. Controlling the substrate temperature during film growth is critical in obtaining these results. D. Peterson (Los Alamos National Laboratory, USA) reported I_c values of over 600 A/cm-width on short-length samples of multilayered structures of SmBCO/YBCO on IBAD-YSZ substrates. In the *ex situ* BaF_2/MOD process, low-pressure conversion resulted in an enhanced YBCO film-growth rate. M. Strikoviski (Neocera Inc., USA) reported a novel pulsed-electron-beam deposition process for YBCO film growth. Y. Shiohara (ISTEC, Japan) reported the use of liquid-phase epitaxy (LPE) for persistent current switches and current-lead applications. Due to the reaction of metal substrates and the LPE solution, this

https://doi.org/10.1557/mrs2002.254

process is, however, not suitable for coated conductors. N. Kashima (Chubu Electric Power, Japan) reported the successful deposition of 100-m lengths of YBCO on rolled, non-textured Ag tape using a six-stage MOCVD system. S. Sambasivan (Applied Thin Films, USA) reported a method for preparing YSZ buffer layers by the oxidation of YZN (yttria-stabilized zirconium nitride) films deposited directly on both textured Ni and Ni-Cr tapes by reactive sputtering in N_2 atmospheres. RABiTS tapes of more than 10 m in length are being produced at Oak Ridge and at 3M. The presence of a sulfur c 2 × 2 superstructure is key to growing the oxide seed layers on textured Ni/Ni-alloy substrates. S. Sathyamurthy and T. Aytug from Oak Ridge reported the development of simplified buffer architectures using lanthanum zirconium oxide ($La_2Zr_2O_7$) and lanthanum manganese oxide ($LaMnO_3$). D. Peterson from Los Alamos reported the development of strontium ruthenium oxide ($SrRuO_3$) for IBAD-MgO substrates.

In the session on applications, several speakers discussed the requirements of coated conductors for devices such as transmission cables, generators, motors, fault current limiters, and magnetic-levitation systems. Coated conductors are attractive for these devices because of the potential for lower cost, low ac loss, operation at a higher temperature and higher critical current, and reduced component size. Most speakers projected that a cost of $50/kA m has to be achieved in order for coated conductors to be used in electric-power device applications. Nondestructive quality control for *in situ* process monitoring using Raman spectroscopy, Auger, and x-ray techniques were presented by V. Maroni (Argonne National Laboratory, USA) and L. Heatherly (Oak Ridge) in the characterization session. Use of magneto-optical imaging of the J_c distribution, coupled with reel-to-reel I_c measurements, will be ideal for the determination of bad spots in long tapes (M. Feldmann, University of Wisconsin, USA).

Transmission electron microscopy revealed several interfacial reactions in the tape. Controlling the grain-boundary chemistry is also important. M. Suenaga (Brookhaven National Laboratory, USA) said that as the critical currents of the tapes become increasingly large, the so-far neglected investigation of the cryostability of the coated conductors will also become an important issue. Y. Shiohara predicted the availability of long lengths of YBCO-coated conductors by 2006. He also predicted that there would be a crossover from BSCCO conductors to YBCO-coated conductors later in this decade.

The workshop was supported by Argonne National Laboratory, IGC-SuperPower, Los Alamos National Laboratory, MicroCoating Technologies (USA), Oak Ridge National Laboratory, and the University of Wisconsin.

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