RABiTS™

Wire Making Techniques

HTS Coated Conductors - Fact Sheet

Performance Characteristics

- RABiTS coated conductors have a simple architecture, low manufacturing cost and potential for high speed fabrication.
- All buffer-layer and YBCO-coating steps can be performed with non-vacuum processes.
- U.S. Companies have been successful in making long length RABiTS coated conductors.

Commercial Potential

There are many potential applications for coated conductors due to their ability to carry high currents in magnetic fields of 2 Tesla or greater at 77 K. Several prototypes are now being developed and field tested at real world conditions and will benefit from RABiTS coated conductors. Electric power applications include:

- power cables,
- motors,
- generators,
- current limiters, and
- transformers.

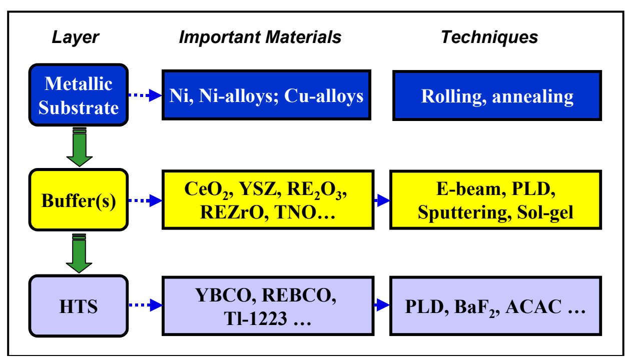
Rolling Assisted Biaxially Textured Substrates (RABiTS™) coated conductors, characterized by their low cost and simple architecture, promise to meet industry price and performance targets.

Introduction

Since the discovery of high-temperature superconductors (HTS), notably $YBa_2Cu_3O_7$ (YBCO), researchers at the U.S. Department of Energy's (DOE) national laboratories have searched for ways to manufacture affordable flexible wires with high current density. One of the chief obstacles to the manufacture of commercial lengths of YBCO wire has been the phenomenon of weak links, which exist where current crosses a non-superconducting region such as a grain boundary. By aligning grains carefully, low angle boundaries between superconducting grains are assured, which allows more current to flow. However, YBCO does not achieve the necessary grain alignment when subjected to the thermo-mechanical processes associated with the Oxide-Powder-In-Tube (OPIT) process of wire making, the technique that yields high quality $Bi_2Sr_2Ca_2Cu_3O_x$ (Bi-2223) wire. A technique developed at Oak Ridge National Laboratory may overcome these problems. Called "rolling assisted biaxially textured substrates," or RABiTS, the method produces near-perfect biaxial texture in a range of materials, including metals, and certain oxides deposited epitaxially on a textured metal strip. These textured substrates serve as structural templates for the final superconductor layer, which has substantially fewer weak links. Additionally, wires made by the OPIT process are characterized by high costs, due to the need to use pure silver. In the RABiTS process, silver is replaced by nickel or nickel alloys, which allows for fabrication of less expensive HTS wires. RABiTS represents one potential solution to the difficulties associated with the fabrication of practical long length YBCO wires suitable for practical electrical power applications.

RABiTS Process

The three main steps of the RABiTS process are: biaxially textured metal fabrication, buffer layer deposition, and superconductor deposition. In 1996, Oak Ridge National Laboratory (ORNL) demonstrated the production of RABiTS using pulsed laser deposition (PLD) to grow buffer layers. Later, using electron beam evaporation technology with RABiTS, ORNL produced a new industrially scalable template on which the superconductor may be deposited. First, pure nickel is roll-textured and heat-treated. Next, extremely thin layers of ceramic materials are rapidly deposited using an electron beam or sputtering system. The buffer layer is deposited between the nickel and the YBCO superconducting layer, which is later, deposited by several different processes. Nickel and YBCO are incompatible, so the buffer layer provides a chemical barrier between them while maintaining the texture, retarding NiO formation and aiding lattice matching between the substrate and YBCO.



RABiTS coated conductors are prepared by depositing buffer layers on a roll textured and heat-treated metallic substrate, such as nickel or nickel alloy to provide a chemical barrier between the substrate and the later deposited YBCO superconducting layer.

Industrial Partners

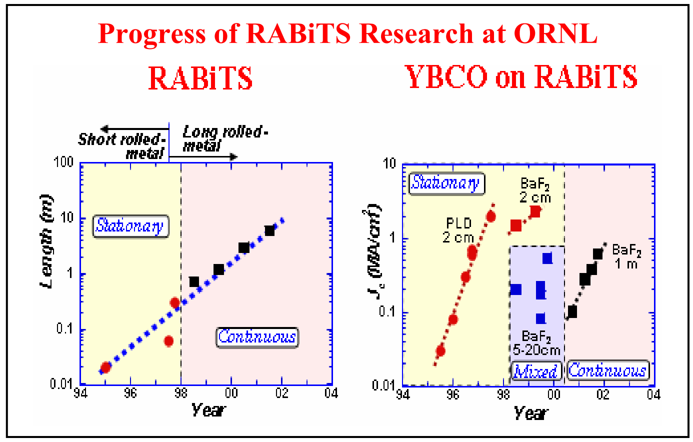
Five CRADA teams are working directly with Oak Ridge National Laboratory staff members to develop the industrial technology base to scale-up RABiTS coated conductors:

- **3M** - Jonathan Storer (651) 733-6462
- **American Superconductor -** John Scudiere (508) 836-4200
- **MicroCoating Technologies -** Shara Shoup (678) 287-2478
- **Neocera -** K.S. Harshavardhan (301) 210-1010
- **Oxford Instruments** – Kenneth Marken (732) 541-1300

Contact Information

- Robert Hawsey,
  Oak Ridge National Laboratory
  hawseyra@ornl.gov
- James Daley,
  U.S. Department of Energy
  james.daley@hq.doe.gov
- Marshall Reed,
  U.S. Department of Energy
  marshall.reed@hq.doe.gov
- Roland George,
  U.S. Department of Energy
  roland.george@hq.doe.gov

Current Status



ORNL demonstrated continuous processing of RABiTS and the attainable high critical current densities of RABiTS coated conductors.

Thick YBCO coatings prepared on short samples by the BaF_2 ex-situ process have yielded high critical currents greater than 150 A/cm-width. Strengthened nickel-based alloy substrates have been developed with excellent texture, as good as in the best pure nickel. Continuously processed tapes exceeding 1 meter lengths have been made with critical current densities greater than 1 MA/cm^2. ORNL's CRADAs with MicroCoating Technologies and Oxford Instruments demonstrated the production of long-length RABiTS using combustion chemical vapor deposited (CCVD) buffered Ni-(3%) tungsten substrates. ORNL obtained good results for a single buffer layer coating of $LaMnO_3$ (LMO) on short samples of RABiTS tape, with critical current densities of over 1 MA/cm^2 at 77K. LMO films are grown using RF-magnetron sputtering on biaxially textured Ni and Ni-W substrates, followed by pulsed laser deposition of the YBCO films. Successful application of a single-layer LMO can replace more complicated three-layer architectures of CeO_2/YSZ/CeO_2/Ni.

User Facilities Accelerate Technology Transfer: *ORNL's Accelerated Coated Conductor Laboratory provides industry access to the necessary facilities and equipment to produce continuous long length RABiTS coated conductors.*

Challenges Ahead

Critical current density has been found to decrease with increasing YBCO thickness. Thicker high-quality YBCO films with high critical currents need to be developed. HTS coated conductors with such films will be able to transport large amounts of current suitable for electric power applications. Strategic research will continue for the development of simpler and more robust buffer layers that will result in acceptable levels of AC losses, cost, texture, and thermal stability. Alternative nickel alloy substrates with increased strength and reduced magnetism need to be identified. Challenges remain in maintaining the outstanding HTS properties of coated conductors while increasing film deposition rates on longer tape lengths. Real time monitoring and control is needed to reduce grain boundaries, misorientations, and defects that can decrease the current carrying capabilities of coated conductors. The newly equipped Accelerated Coated Conductor Laboratory at ORNL provides the opportunity for industrial partners to work closely with the national laboratories and offers the necessary means to transfer expertise, from the laboratories to industry. This allows the scale-up of coated conductor fabrication into continuous reel-to-reel manufacturing processes that yield long length coated conductors with uniform properties.