Accelerated Coated Conductor Initiative (ACCI)

Progress Report

OAK RIDGE NATIONAL LABORATORY

Presented at the
2001 Annual Peer Review
August 1–3, 2001
Washington, D.C.

Oak Ridge Team

- **Chemical & Analytical Sciences Division**
  - **D. B. Beach, M. Paranthaman, S. Sathyamurthy**
- **Metals & Ceramics Division**
  - **S. W. Cook, A. Goyal, L. Heatherly, H. Hsu, B. W. Kang, M. M. Kowalewski, D. M. Kroeger, D. F. Lee, K. J. Leonard, F. A. List, P. M. Martin, K. L. More, N. Rutter, E. D. Specht, R. K. Williams**
- **Solid State Division**
  - **T. Aytug, J. D. Budai, D. K. Christen, H. Christen, C. Cantoni, R. Feenstra, H. R. Kerchner, J. Thompson, H. Zhai**

Funding

- FY 2001 EE/RE Funding: $1700K

Industrial Collaborators

- **3M Company (3M)**
  - **Myles Brostrom, Dick Ericson, Dave O'Neill, Bill Robbins, Chris Shelton,Jonathan Storer, Sheryl Vanasse, Badri Veeraraghavan, Bruce Williams, Ed Yu**

- **American Superconductor Corporation (AMSC)**
  - **S. Annavarapu, Les Fritzemeier, Q. Li, Marty Rupich, Bart Riley, U. Schoop, C. Thieme, Z. Zhang**

- **MicroCoating Technologies (MCT)**
  - **Adam King, Totd Polley, Shara S. Shoup, Marvis White**

- **Oxford Superconducting Technology (OST)**
  - **Ken Marken**

National Laboratory Collaborators

- Los Alamos National Laboratory
  - Vladimir Matias, Paul Arendt, Steve Foltyn

FY 2001 Plans

- To identify and prepare suitable, high quality, laboratory space for use by DOE laboratories and partners.
- To begin staffing to support ACCI activities.
- To develop new equipment needed for more rapid preparation and characterization of coated conductors.

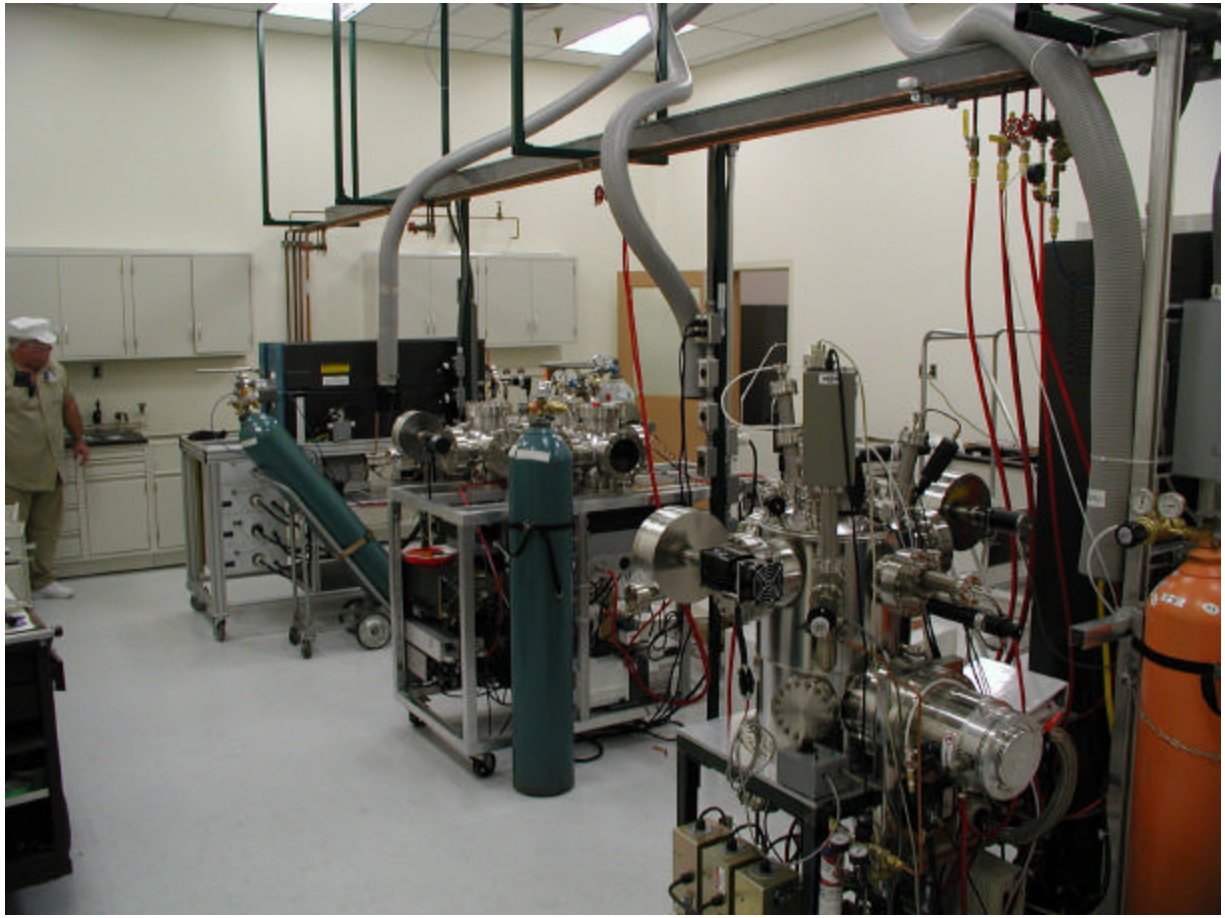
OUTLINE

- FY 2001 Results:
  - New laboratory space for ORNL ACCI
  - New equipment and staff for ORNL ACCI
- Summary of FY 2001 Results / FY 2002 Plans
- Research Integration

ACCI labs were created from 2,200 ft^2 of renovated space.

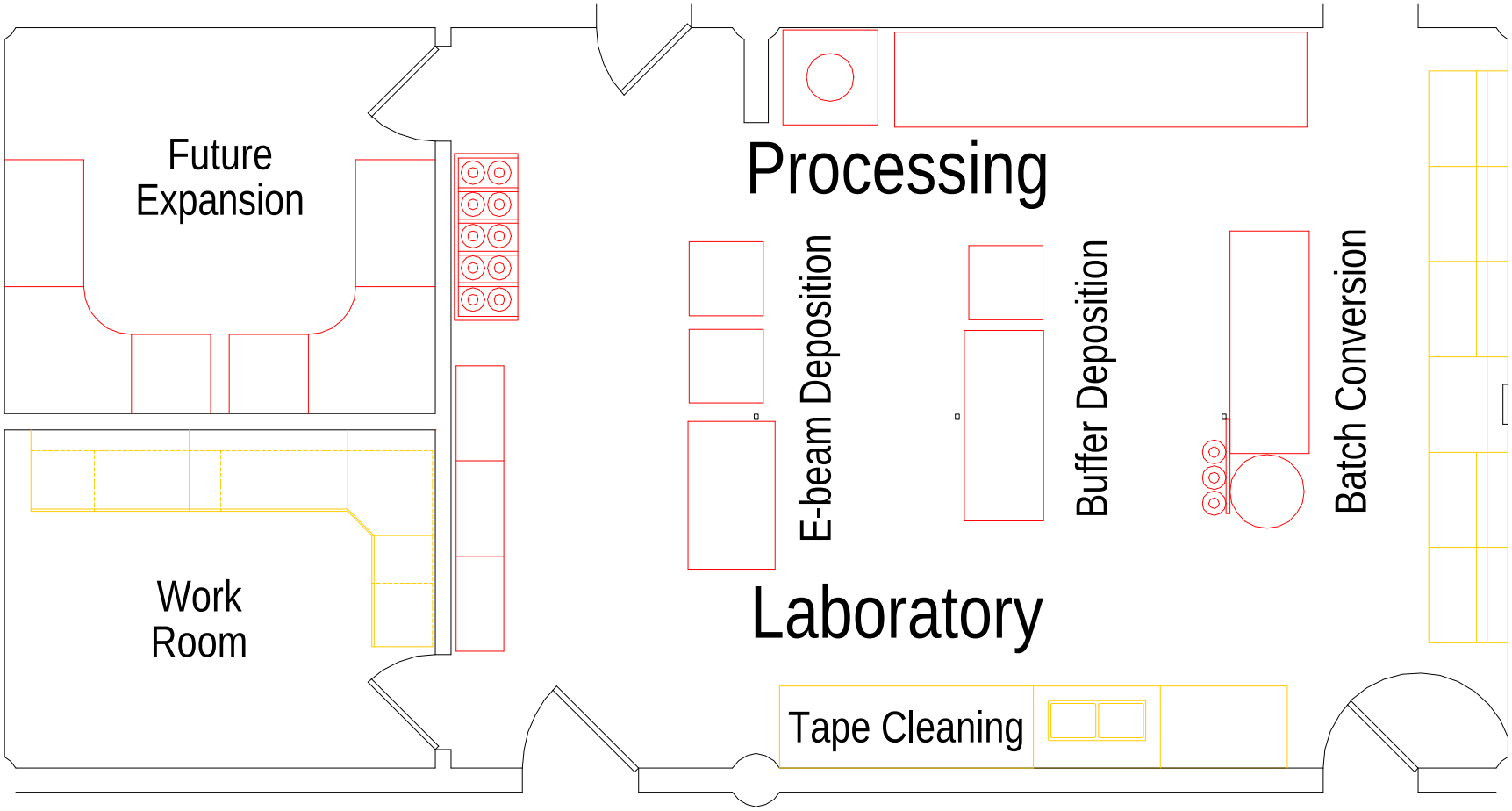
Before--December 2000

Reel-to-reel precursor deposition & buffer layer deposition; also large area precursor conversion

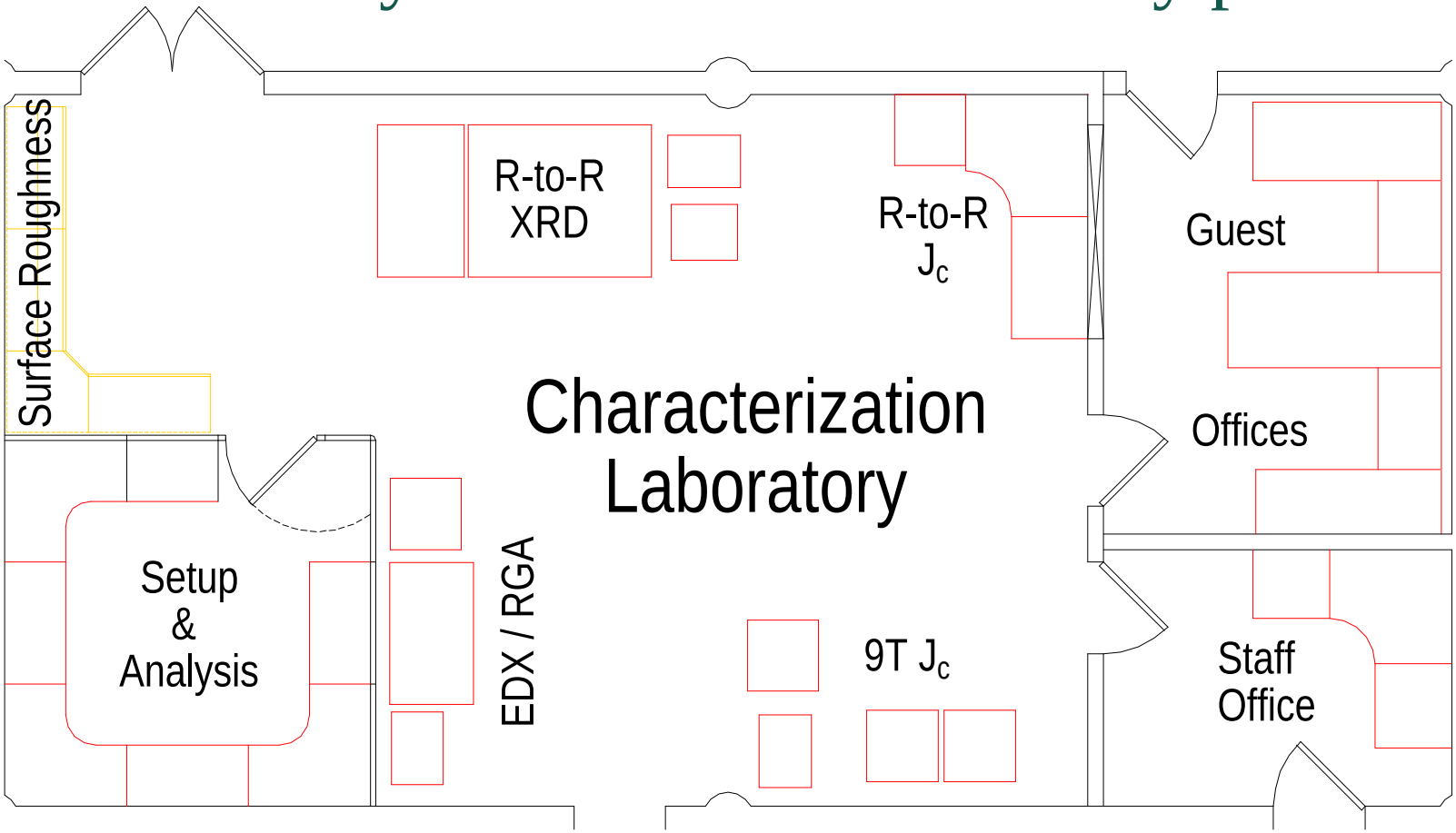


After--April 2001

The ACCI facility consists of two main labs—one for processing and one for characterization.



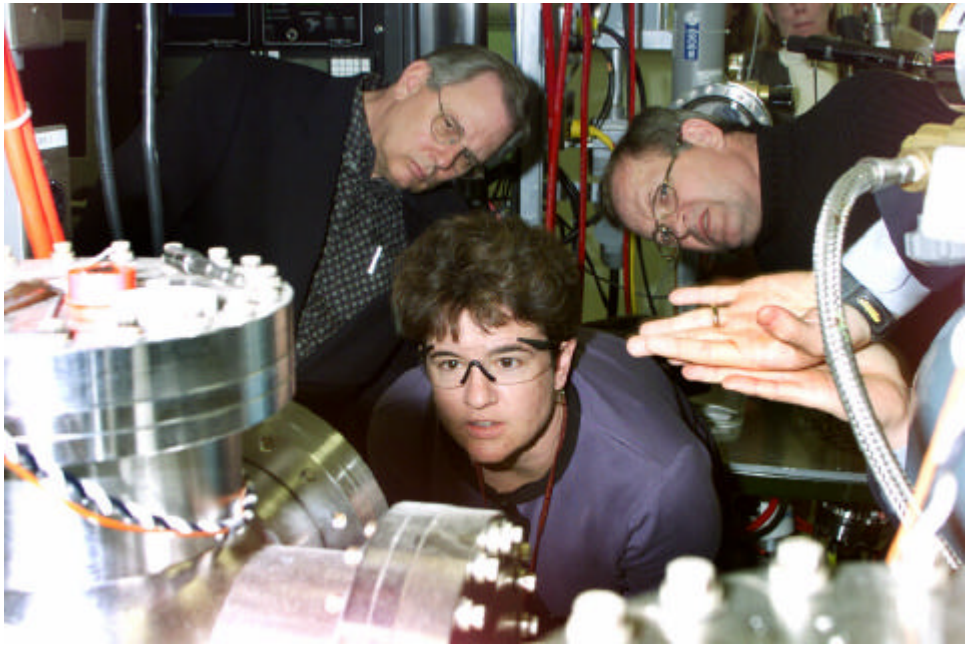
Guest offices have been provided for on-site visitations by industrial and university partners.



ORNL ACCI Dedication Event – April 19, 2001

"Studying the equipment are, from left, Charles Cook of the House Science Committee staff, and Debbie Haught and Roger Meyer of the Department of Energy's Office of Power Technologies."

From: The Oak Ridger, 4/20/2001



Ribbon Cutting:
Marshall Reed and Bill Madia

New equipment at ORNL will accelerate the development of RABiTS-based coated conductors.

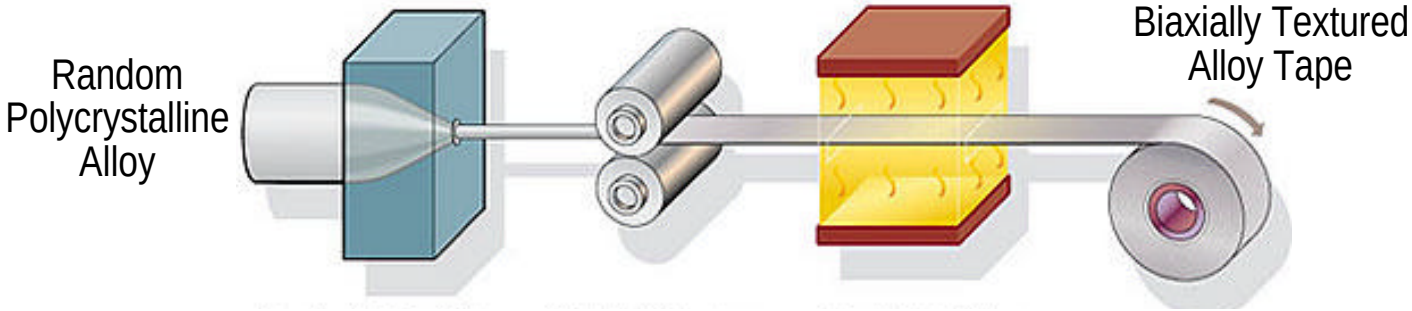
- Reel-to-reel systems for :
  - Deformation processing (rolling mill w/ clean room)
  - *In-situ* Auger characterization of annealed substrate *
  - Dip coating for solution based buffers & precursors
  - High-rate RF sputtering for buffer layer deposition
  - Effusion cell BaF_2 precursor deposition *
  - Four-circle XRD characterization
  - Surface roughness characterization
  - Transport and inductive J_c characterization

* - enhancement to existing equipment

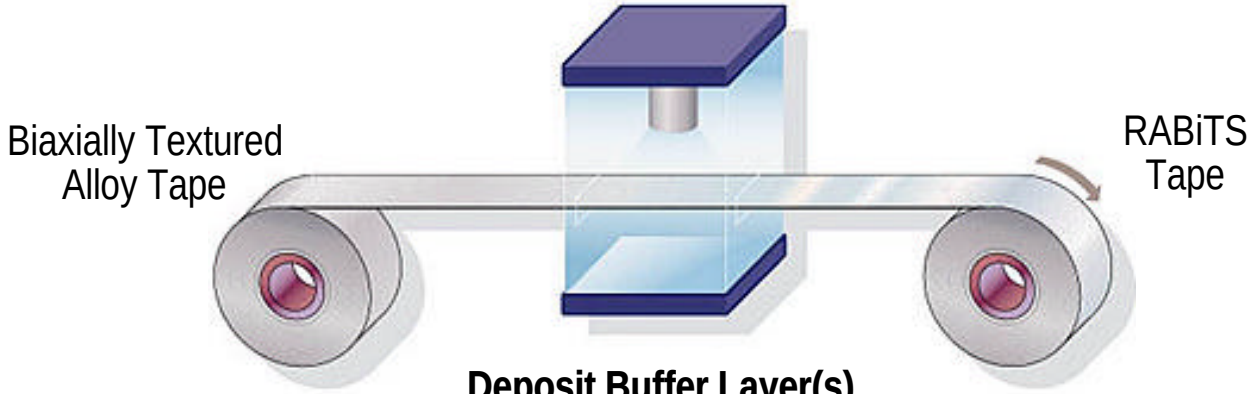
New equipment at ORNL will accelerate the development of RABiTS-based coated conductors.

- Batch systems for :
  - 6-meter batch reactor for BaF_2 precursor conversion
  - Low pressure batch conversion (w/ EDX and RGA)
  - Variable gas-flow conversion
  - Warm-bore, 9T magnet for J_c characterization

Rolling-Assisted, Biaxially Textured Substrate (RABiTS™) Process



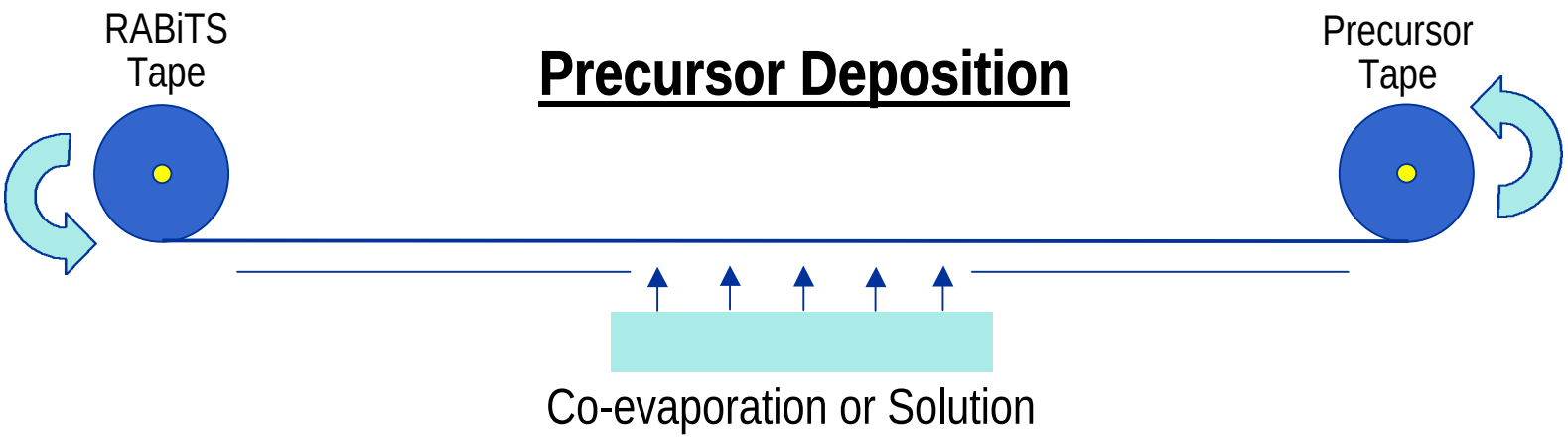
Fabricate a textured metal template by rolling and heat-treating nickel alloy

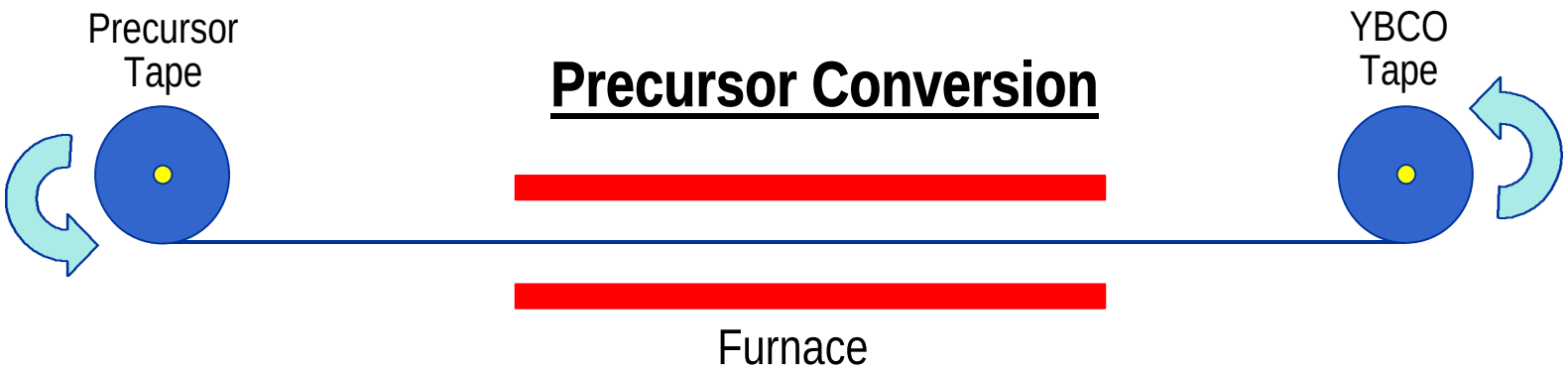


Deposit Buffer Layer(s)

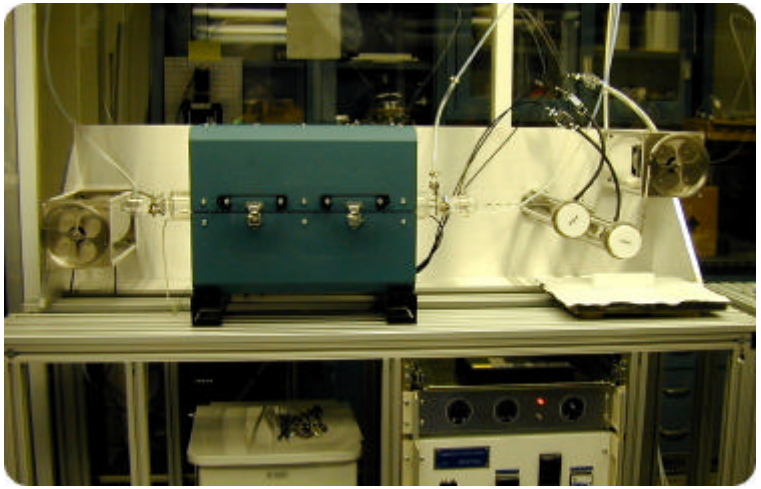
Drawings courtesy American Superconductor Corp.

YBCO on RABiTS™ by a precursor approach requires additional processing steps.

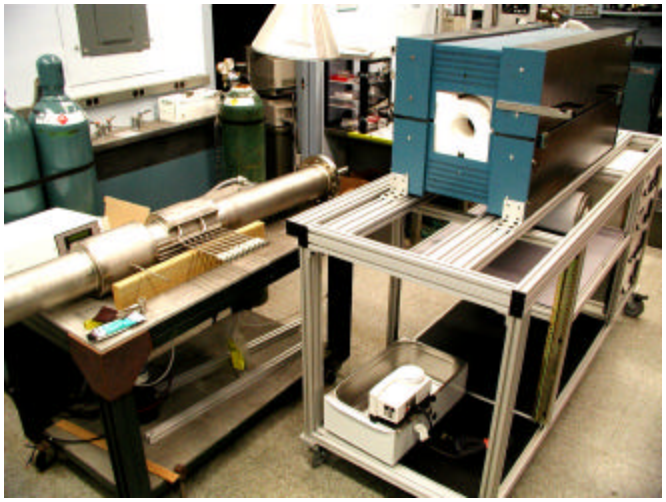




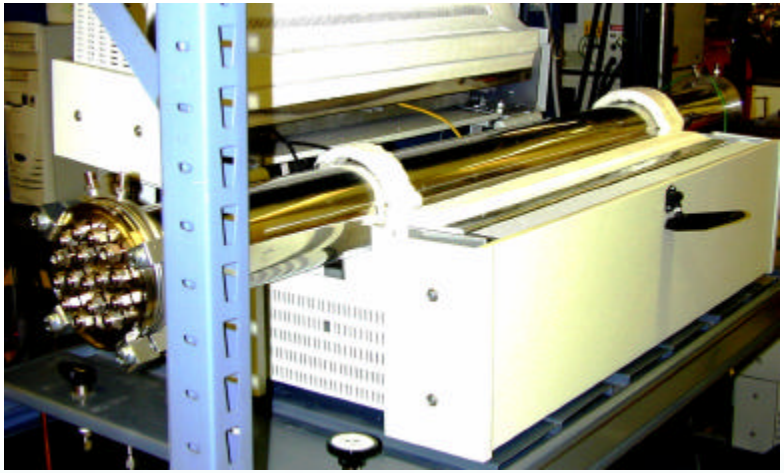
ACCI New Equipment Available in 2001 for Coated Conductor Research



Reel-to-reel Dip Coater/Reactor

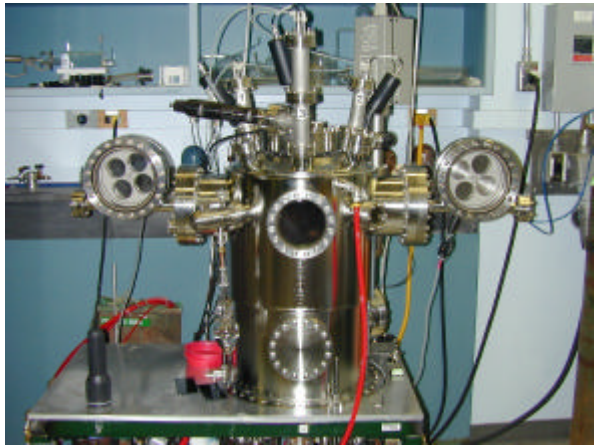


6-meter Batch Conversion Reactor

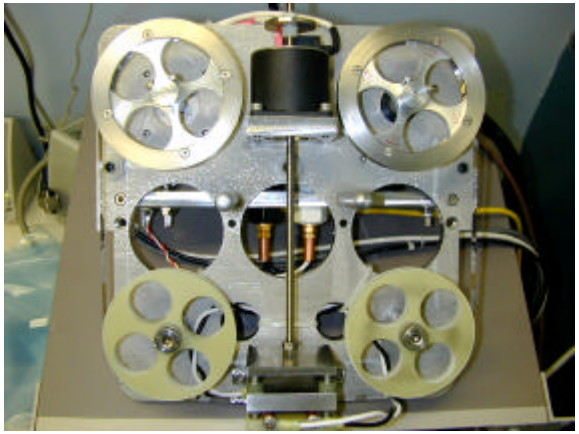


Variable Gas-flow Conversion Reactor

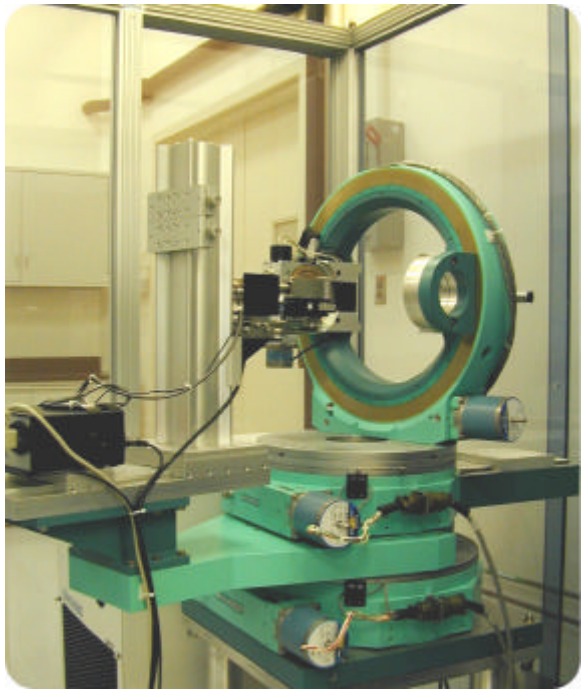
ACCI New Equipment Available in 2001 for Coated Conductor Research



Effusion Cell Precursor Deposition System

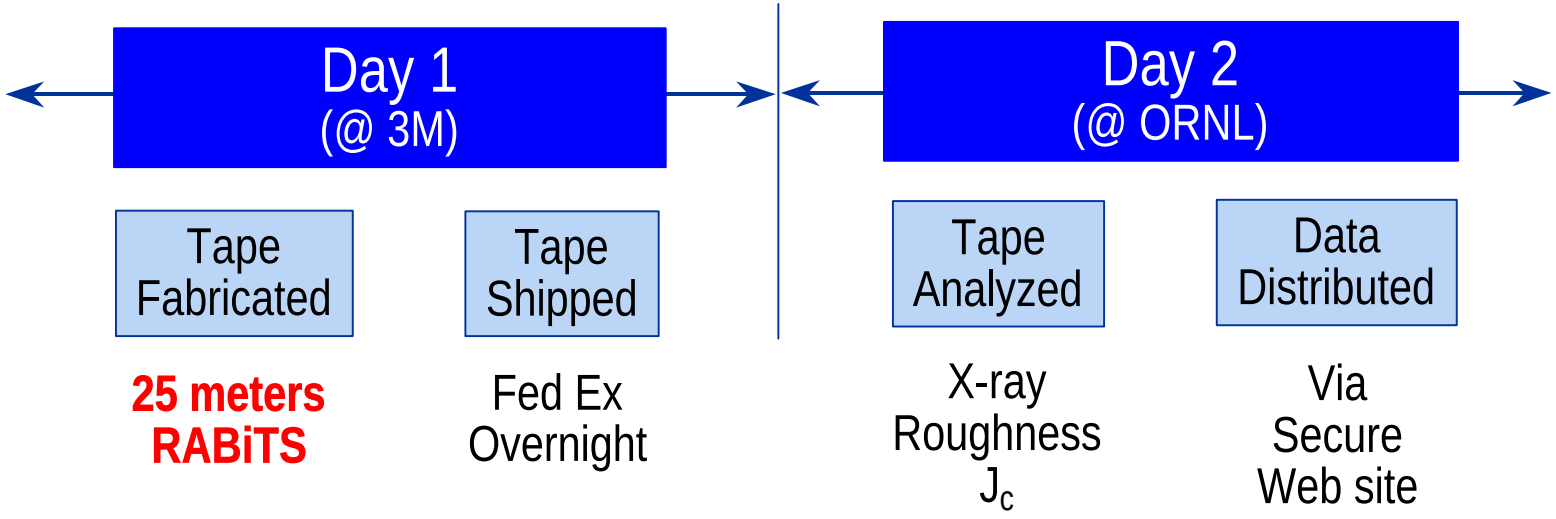


Reel-to-reel J_c Apparatus



New Reel-to-reel X-ray Equipment

ORNL has provided CRADA partners with "Same Day Service" for tape characterization.



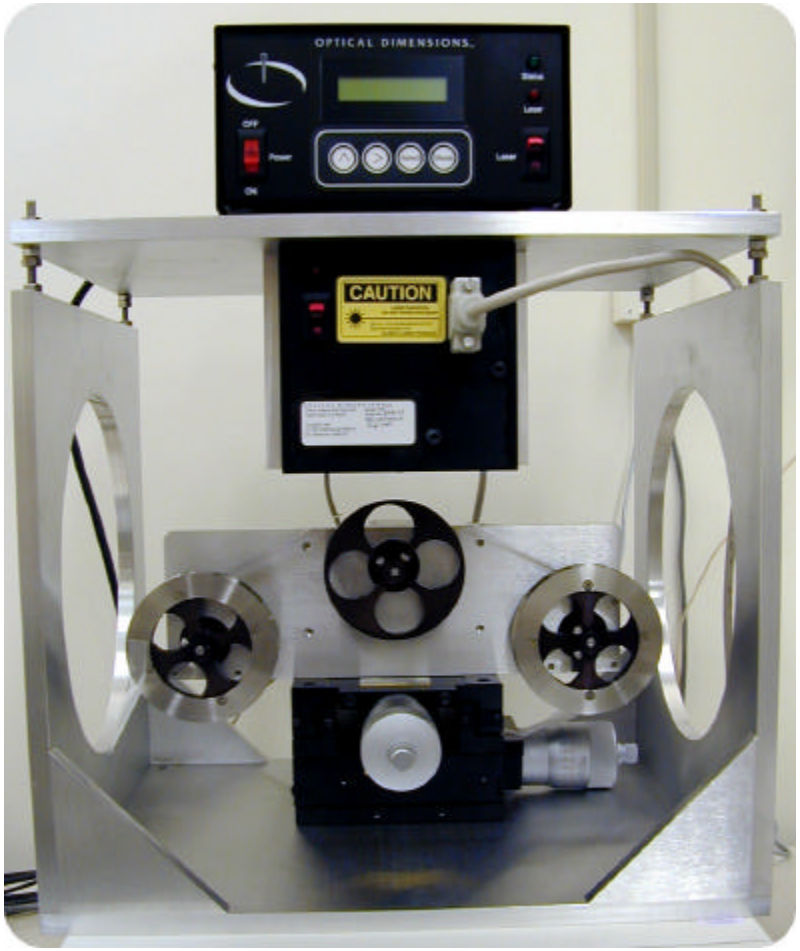
- Accelerated coated conductor development requires accelerated information exchange.

Surface roughness to 25Å can be determined rapidly on 40 meter lengths of tape.

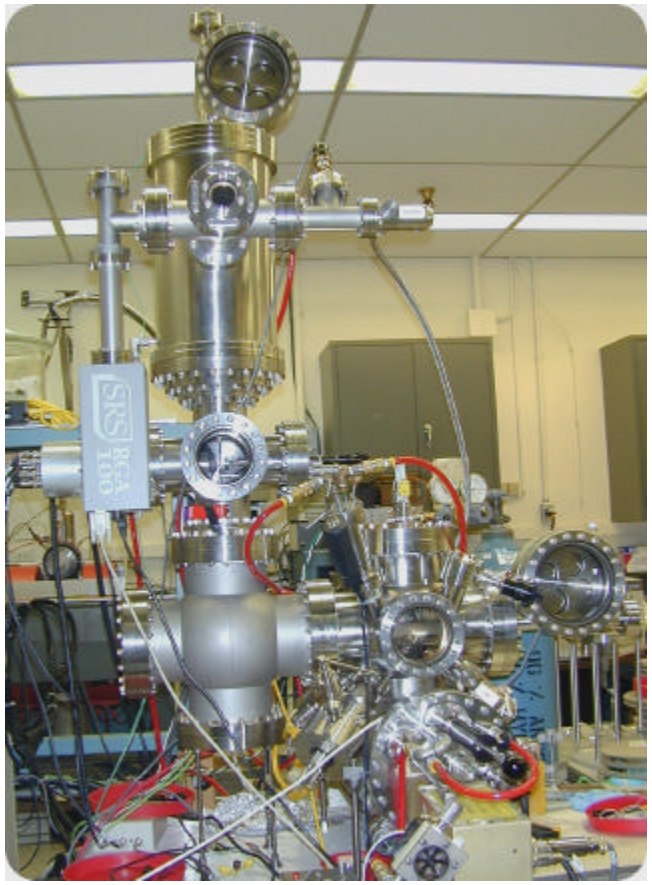
Performance:

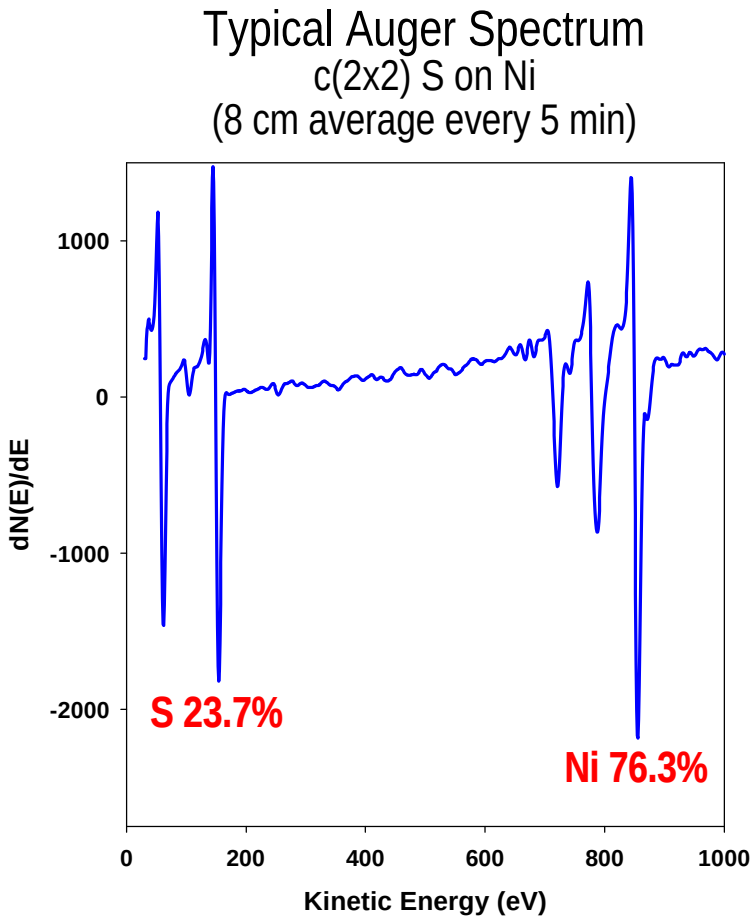
- Method – Laser reflectance & scattering
- Measurement speed – 30 readings/sec
- Measurement range – 25 –12500Å Ra
- Measurement size – 1 x 5 mm
- Tape speed – **100 meters/hr** (approx.)
- Capacity – 40 m of 0.002” thick tape

  -- (100 m with reel change)

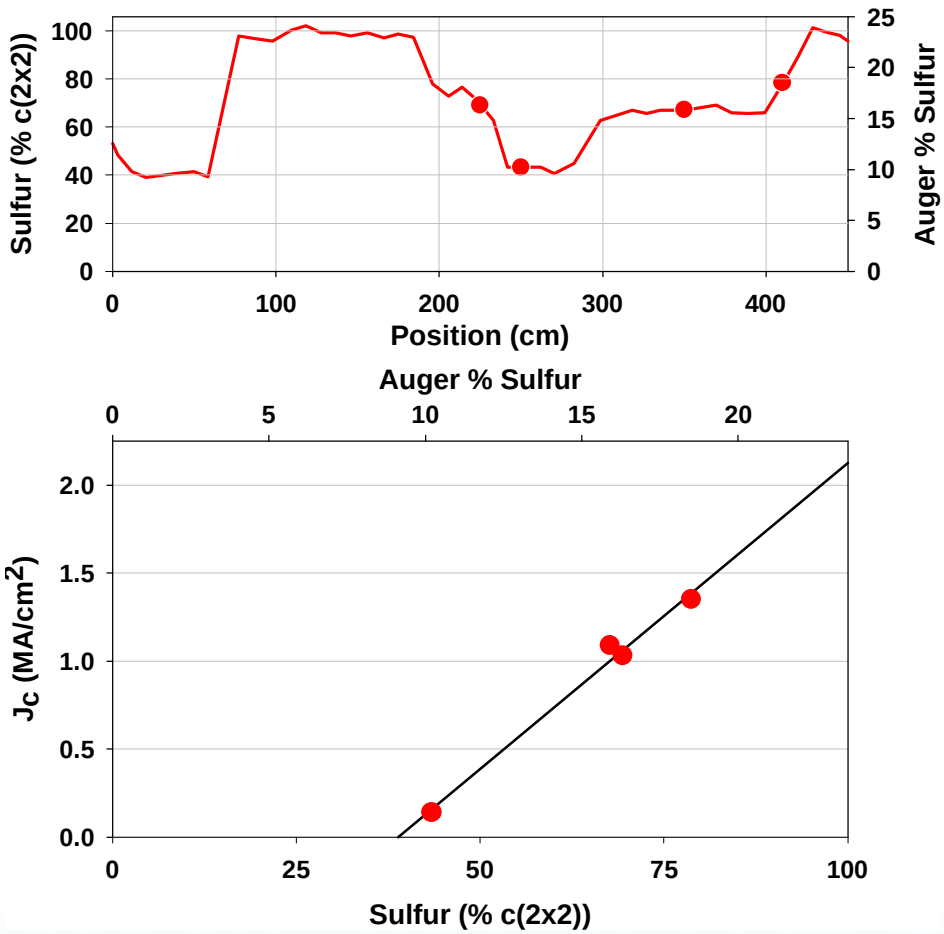


In situ Auger characterization of moving tape facilitates epitaxial buffer layer development.





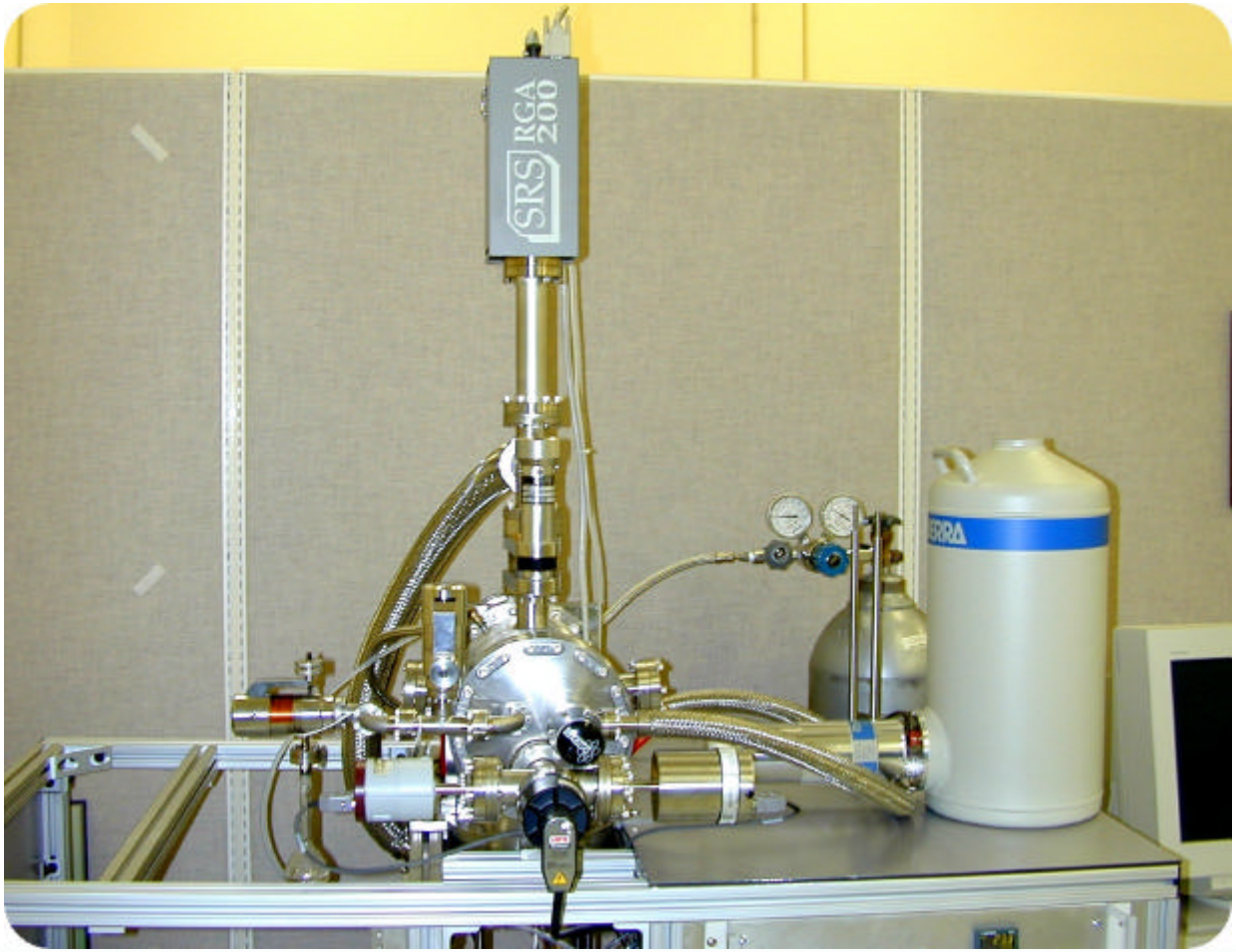
In-line diagnostics can lead to rapid improvements in processing.



- Greater Jc for greater surface sulfur.

- <u>Results are shared with CRADA partners</u>

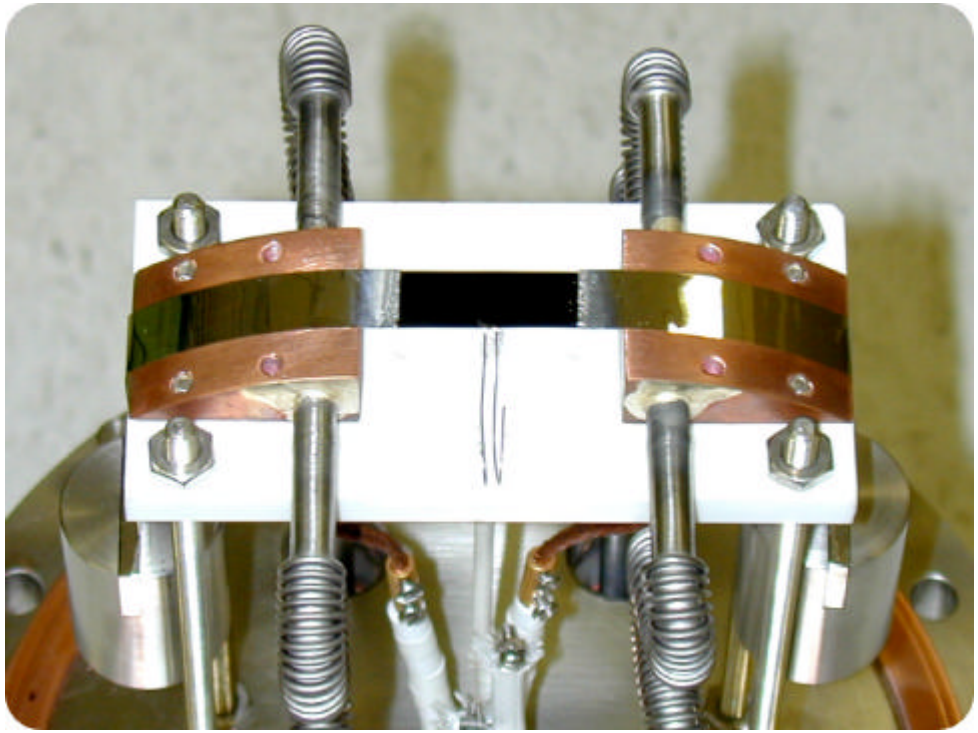
Lower pressure precursor conversion may result in more rapid and more efficient conversion.



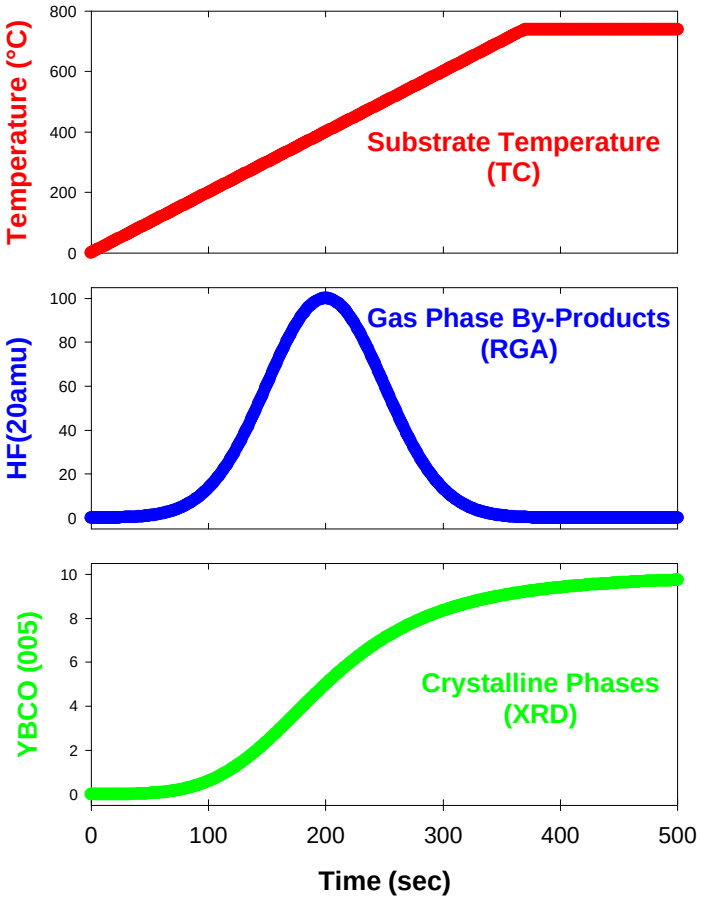
Features:

- Energy dispersive X-ray diffraction (EDX).
- Residual Gas Analysis (RGA).

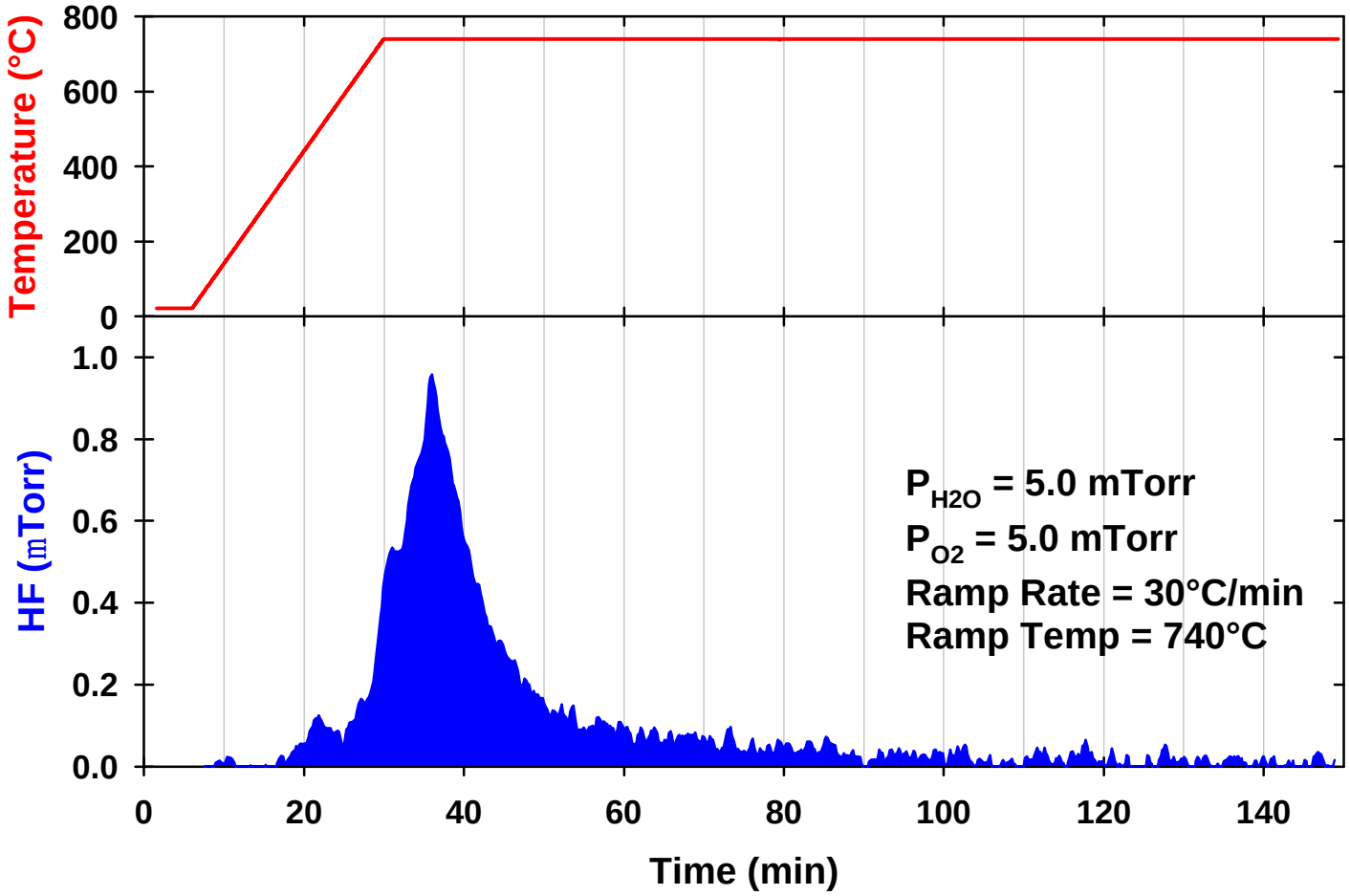
Crystalline phase development and gas phase desorption can be monitored during conversion.



Simulated Data

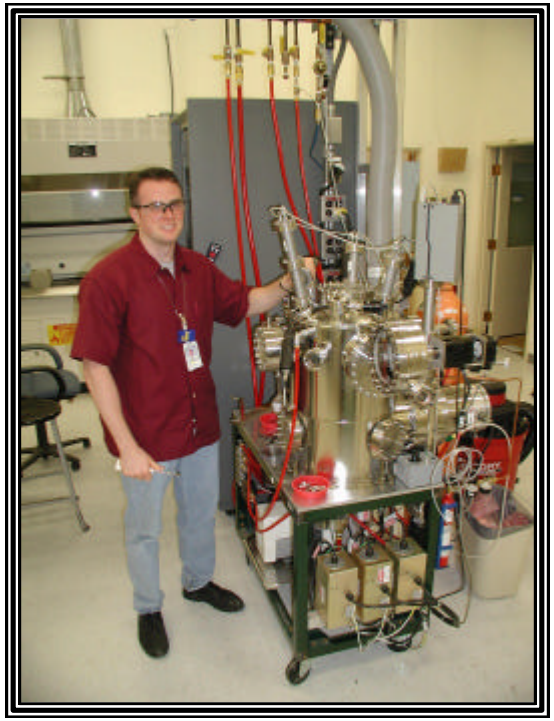


Evolution of HF during precursor conversion has been directly observed with RGA.



ACCI: New Staff on the ORNL Team

- **Permanent: Sy Cook, Lee Heatherly**
- **Post-doctoral fellows: Robert Grabovickic, Matthew Kowalewski, Keith Leonard**



FY 2001 Plans and Performance

- To identify and prepare suitable, high quality, laboratory space for use by DOE laboratories and partners.
  - Renovation of ~2200 sq. ft. of lab space began December, 2000 and was completed April, 2001.
  - Formal ribbon cut ceremonies were conducted April 19, 2001.
- To begin staffing to support ACCI activities.
  - Two permanent staff members have been hired.
  - Three post-doctoral associates have been hired.

FY 2001 Plans and Performance (cont.)

- To develop new equipment needed for more rapid preparation and characterization of coated conductors.

Equipment in operation

- *In situ* Auger analysis is now used routinely during buffer layer growth.
- Reel-to-reel dip coater is operational and producing quality buffers in lengths.
- Initial results from a new low-pressure conversion system have been obtained.

Equipment under test

- Reel-to-reel surface roughness apparatus is being tested.
- Batch conversion system has been design, built, and tested.
- Reel-to-reel Jc apparatus is to be tested.

FY 2001 Plans and Performance (cont.)

- To develop new equipment needed for more rapid preparation and characterization of coated conductors.

Equipment being assembled

- New reel-to-reel X-ray system is in the final stage of assembly.
- High-rate buffer deposition system has been designed and is being assembled.
- Variable flow conversion system has been designed and assembled.

Equipment on order

- Effusion cells have been ordered to stabilize precursor deposition.
- Warm-bore, 9T magnet for Jc characterization has been ordered.
- Rolling mill for deformation studies has been ordered.

FY 2002 Plans

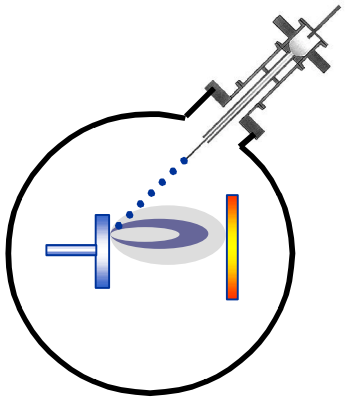
- To determine the efficacy of both low pressure conversion and batch conversion to produce rapidly YBCO coated conductor.
- To add an energy dispersive XRD module to the reel-to-reel seed layer deposition system for in-line structure determination.
- To continue to provide CRADA partners with timely conductor characterization (incl. XRD, J_c, surface roughness).

FY 2002 Plans (cont.)

- To accelerate the development of schedules for rolling and heat treatment of metal substrates using on-site rolling mill.
- To provide opportunity to CRADA partners and DOE labs to visit and participate in research.
- To explore the potential of pulsed electron deposition as an alternative method for high rate YBCO deposition.

YBCO growth by Pulsed Electron Deposition (New Cooperative Agreement with Neocera, Inc.)

- A unique **physical vapor deposition** technique using a self-pinched, pulsed electron beam to ablate from a solid target
- Comparable to PLD, but a flange mounted gun with 20 kV power supply **replaces 100 W excimer laser** and optics
- ***Cooperative Agreement:***
  1. Optimize YBCO on $SrTiO_3$ (growth at Neocera, characterization at ORNL)
  2. Optimize YBCO on RABiTS (growth at Neocera, RABiTS and characterization by ORNL)
  3. Install PED unit at ORNL
  4. Discuss issues related to scalability



Research Integration

- On-site visitation – 3M, AMSC, MCT, LANL
- Extended on-site visitation – U. Schoop (AMSC)
- Information Exchange
  - Surface roughness equipment – OST (in-bound)
  - Energy dispersive XRD – 3M (in-bound)
  - Sulfur template – 3M, AMSC, OST
  - Reel-to-reel equipment design – LANL (bi-directional)
  - Heater design – AMSC (in-bound)
- Precursor conversion for CRADA partners – ~10 m
- Licensee Information Meeting -- April 19, 2001
- XRD conductor characterization – >1 km