
Project Title:	<i>Ex-situ</i> Processing of YBCO Precursors
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Project Purpose and FY 2003 Objectives: The purpose of this project is to understand and explore means to fabricate high performance YBCO films by the *ex-situ* technique. Our primary objectives for FY 2003 are:

1. Explore YBCO conversion characteristics over the pressure range allowable by our atmospheric, reduced-pressure and low-pressure conversion systems.
2. Study the effect of precursor thickness on conversion parameters in different pressure ranges.
3. Examine the effects of conversion pressure on sample homogeneity.
4. Compare the conversion characteristics of different precursors.

FY 2003 Performance and FY 2004 Plans: In FY2003, we have improved our capability to understand the *ex-situ* processing of YBCO coated conductors under a wide range of chamber pressures. In addition to our “atmospheric” reel-to-reel conversion chamber, two additional systems, a “reduced” pressure short-sample system capable of operation between 1.3 to 0.1 atm and a “low” pressure short-sample system ($\sim 2 \times 10^{-6}$ to 2×10^{-3} atm) equipped with XRD, are in full operation. Although plans to equip our 22-zone reel-to-reel system with pumping capability have been delayed, a new low-pressure four-zone reel-to-reel conversion system has been assembled and is under test.

In general, high J_c YBCO coated conductors have been converted from “BaF₂” precursors in a wide range of chamber pressures under appropriate conditions. However, the conversion rate as well as super-conductor characteristics can differ. We have continued to use our reel-to-reel atmospheric chamber to “benchmark” the performance of YBCO of various thicknesses, as well as a tool to aid in the development of RABiTS substrates. While the atmospheric pressure reactor can provide good YBCO, we are gathering more evidence concerning the weaknesses of such a system. We believe major shortcomings, such as slow YBCO growth rate, sample inhomogeneity, and strong field dependency, stem from buildup of HF within the reaction chamber.

Modest reductions in conversion times have been obtained using reduced pressures. In addition, samples processed in reduced pressure are more homogeneous and exhibit weaker field dependency compared to the “atmospheric” samples.

Using the low-pressure system, we have been able to follow the decomposition of BaF₂ and growth of YBCO using *in-situ* x-ray diffraction. The conversion times for evaporated BaF₂ precursor using the low-pressure system are similar to those using the reduced pressure system. We have also converted short samples of TFA precursor in collaboration with SNL and have demonstrated that high quality YBCO can be formed in very short times—approximately one tenth the time required to convert evaporated BaF₂ precursor of similar thickness.

Our FY 2004 plan focuses on:

1. Continuing efforts to understand the effects of pressure on *ex-situ* conversion.
 2. Improving the quality and conversion rate of thick-film YBCO.
 3. Comparing the growth and performance of various precursors including BaF₂, TFA, and non-fluorine-based MOD. (A slot die coating system will be set up to facilitate deposition of solution-based precursors and buffers on lengths.)
 4. Understanding the characteristics of precursor(s) that exhibits faster conversion rate, and modifying other precursors to enable faster YBCO formation.
 5. Using our *ex-situ* capabilities to aid in the continuing development of RABiTS, which is aimed at new alloy substrates, alternative buffers, and improved texture.
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FY 2003 Results: High J_c YBCO coated conductors of various thicknesses have been obtained using BaF_2 precursors under a wide range of chamber pressures. Using our reel-to-reel atmospheric chamber, YBCO with high I_c 's have been processed in a continuous fashion. As the film thickness increases, processing parameters such as water partial pressure (P_{H_2O}) need to be adjusted to maintain good superconducting properties. We have, however, gathered additional evidence that HF buildup can drastically reduce the YBCO growth rate. Because of this buildup, a significant, perhaps unacceptable, amount of time may be necessary to fabricate high current capacity, thick, long-length and large-area coated conductors in this manner. In addition to the long processing time, YBCO fabricated under these conditions is more inhomogeneous even across the 1-cm width of our samples. Also, YBCO samples of various thicknesses processed under these atmospheric conditions exhibit a strong field dependency, dropping by a factor of 6 from self-field to 0.5 Tesla.

Short BaF_2 precursors on RABiTS have also been processed in our reduced-pressure system. Parameters including chamber pressure, processing time, P_{H_2O} and conversion temperature have been investigated, and are found to influence the J_c to different extents. In general, lower chamber pressure leads to faster YBCO conversion and high J_c 's. A lower initial P_{H_2O} is more favorable to high quality YBCO growth, especially for thicker films. Furthermore, a high P_{H_2O} results in worse YBCO degradation with over-conversion. Under appropriate conditions, YBCO of equal or higher self-field J_c 's can be fabricated under reduced pressures in shorter times. For example, J_c 's >2 MA/cm² and >1 MA/cm² have been obtained in 0.3- μ m and ~ 1 - μ m films, respectively. Just as important, however, are results that show these YBCO films are more homogeneous and exhibit weaker field dependency compared to the "atmospheric" samples.

The conversion of precursors derived from evaporated BaF_2 , TFA, and nonfluorine MOD routes has been followed in our low-pressure system using *in-situ* XRD. Thin (~ 0.3 μ m) evaporated BaF_2 precursors can be converted at moderate rates (1-2 $\text{\AA}/s$) to YBCO with $J_c > 1$ MA/cm². Higher reaction rates (up to 17 $\text{\AA}/s$) are achievable by adjusting the conditions for conversion but lead to lower J_c 's and incompletely developed YBCO. Similarly, thin (~ 0.25 μ m) TFA precursors can be converted at moderate rates to YBCO with $J_c \approx 1$ MA/cm². By adjusting the conditions for conversion (higher ramp rate and P_{H_2O}), both high reaction rates (>18 $\text{\AA}/s$) and high J_c (~ 1 MA/cm²) are simultaneously obtainable for the TFA precursor. The reason for this difference in reaction kinetics between evaporated BaF_2 and TFA precursors is presently under investigation.

Research Integration: We have collaborated closely with Sandia National Laboratories in examining the conversion characteristics of dip-coated TFA precursor on RABiTS, especially in the low-pressure regime. We are also engaging in active research with Argonne National Laboratory in the decomposition of BaF_2 precursor and growth mechanism of YBCO by combining our reel-to-reel XRD and ANL's reel-to-reel Raman characterization capabilities. Active research is also ongoing with the University of Cincinnati in the *ex-situ* conversion of nonfluorine MOD precursor. In addition, our industrial CRADA partners are regularly updated on our findings.
