All-MOCVD Technology for YBCO Layer/Buffer Layer Fabrication for Coated Conductors

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***Abstract*— The deposition of all buffer and YBCO layers for coated conductors via MOCVD represents one of the lowest possible capital and operational cost approaches to coated conductor manufacturing. Modular design of our prototype MOCVD system allows for either in-line or parallel fabrication of any number of buffer layers and YBCO layers. World class results of J_c = 3.34 MA/cm^2, I_c = 480 A/cm on short samples, and $I_{c,\ max}$ > 300 A/cm on 1 m long tapes have been achieved in MOCVD YBCO on established PVD buffer layer architectures. I_c > 130 A/cm has been reproducibly demonstrated on all-MetOx all-MOCVD architecture, the best up-to-date result being I_c = 151 A/cm.**

I. Introduction

Several companies around the world report impressive advances in the performance of coated conductors and equip to produce long lengths of 2G superconducting wire [1–4]. The low cost required for coated conductors' breaking into broad market has, however, yet to be attained. This drives R&D efforts to replace expensive PVD processes with chemical deposition techniques [5–6] as well as to reduce the number of buffer layers in coated conductor architectures [6–10]. Chemical deposition of all buffer and YBCO layers [7, 11] is recognised as the most economical approach.

Metal Oxide Technologies Inc. (MetOx) has been developing a cost-effective technology to deposit all buffer and superconducting layers by MOCVD. In order to independently qualify and further optimise our YBCO growth process, we also perform MOCVD of YBCO films on established PVD buffer architectures provided by our collaborators from Oak Ridge National Laboratory (ORNL) and Los Alamos National Laboratory (LANL).

II. Experimental

Substrate and buffered tapes were provided by LANL and ORNL. ORNL substrate is rolled-annealed biaxially textured Ni(3%W), 50 m thick. ORNL RABiTS buffer architecture is 75 nm CeO_2/ 75 nm YSZ/ 75 nm Y_2O_3/ 50 m Ni(3%W). LANL IBAD buffer architecture is 50–250 nm $LaMnO_3$/ 15 nm epi-MgO/ 10 nm IBAD-MgO/ 7 nm Y_2O_3/ 55 nm Al_2O_3/ 100 m Hastelloy.

Oxide buffers and YBCO films have been deposited by MetOx modified MOCVD method described elsewhere [12]. The modular design of the MetOx reel-to-reel production prototype system allows for any number of buffer and/or YBCO deposition modules to be installed in line in order to enable, for example, thicker layers, or faster deposition, or several buffer layer materials. The system can be easily arranged either in an in-line configuration where all layers are deposited during one tape pass or in any number of separate lines to accommodate different tape widths, buffer architectures or tape speeds. At present we use separate buffer and YBCO deposition lines in order to facilitate the independent optimisation of each process.

The films were characterised at MetOx by XRD, SEM/EDX and continuous DC transport I_c measurements. Positional measurements on long tapes as well as field and angular dependence measurements of I_c were performed at LANL and ORNL.

III. Results

The properties of MetOx MOCVD YBCO films on various buffer architectures are summarised in Table 1. High I_c and J_c values of 201 A/cm and 1.54 MA/cm^2, respectively, as well as excellent crystallographic alignment is obtained on ORNL RABiTS buffers. The films on RABiTS also demonstrate good in-field superconducting performance indicated by the low alpha exponent value for I_c field dependence.

The best superconducting properties of MetOx YBCO films have been achieved on LANL IBAD buffers. Very high values of J_c = 3.34 MA/cm^2 (77 K, self-field) and I_c = 480 A/cm have been demonstrated (Table 1). There is certain reduction in J_c with increasing YBCO film thickness. MetOx modified MOCVD process allows for the growth of thick YBCO films thus enabling high absolute current values despite some J_c degradation with thickness. Good in-field performance was found in our YBCO films on LANL IBAD buffers, comparable to that of MetOx YBCO films on ORNL RABiTS (Table 1).

TABLE 1
Properties of MetOx MOCVD YBCO Films

Buffer	$\Delta\Omega$ YBCO	$\Delta\Phi_{true}$ YBCO	Best J_c (MA/cm^2) / YBCO thickness (m)	Best I_c (A/cm) / YBCO thickness (m)	Value α from field dependence
MetOx	3–6	5–7	1.12 / 1	151 / 1.6	No data
ORNL	3–6	5–7	1.54 / 1	201 / 4	0.38
LANL	1–2	2.0–2.5	3.34 / 0.4	480 / 3.9	0.39

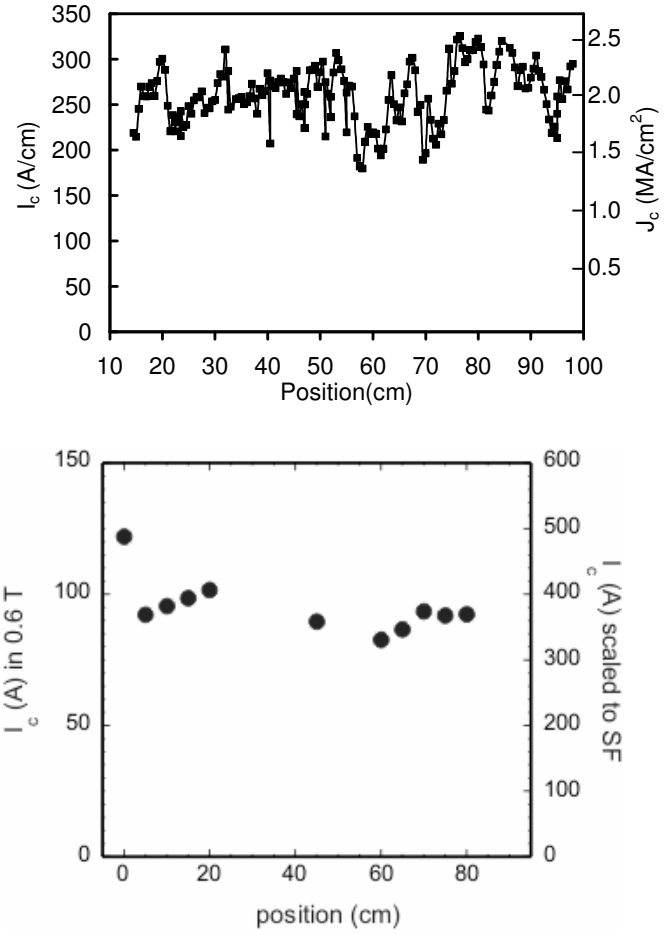

Fig. 1. Positional dependence of I_c for two 1 m long tapes of MetOx YBCO on LANL IBAD template. Self-field values are calculated from results measured in 0.6 T applied field based on measurements done on the same samples at self-field using a patterned bridge. Top graph: 1.3 m thick YBCO film; $I_{c,\,max}$ = 325 A/cm, $I_{c,\,min}$ = 180 A/cm, standard deviation 12%. Bottom graph: 3.9 m thick YBCO film; $I_{c,\,max}$ = 480 A/cm (some sections of the sample were burnt during the measurement).

Several 1 m long coated conductor tapes have been prepared on LANL buffer. Fig. 1 represents the results of positional I_c measurements performed on two such tapes, with excellent maximum I_c values of 325 A/cm and 480 A/cm, respectively. I_c uniformity over the length has to be improved.

Here we report on the superconducting performance of all-MetOx all-MOCVD coated conductors (Table 1, Fig. 2). We have repeatedly demonstrated $J_c > 1$ MA/cm^2 and $I_c > 130$ A/cm. To the best of our knowledge, the best I_c performance of all-MetOx coated conductors of 151 A/cm is the highest reported up to date for all-CVD processed samples. The next step we are trying to make is to match the performance of all-MetOx coated conductors with MetOx YBCO films on ORNL RABiTS buffer. The demonstration of high I_c long tapes with all-MetOx architecture is also on the way.

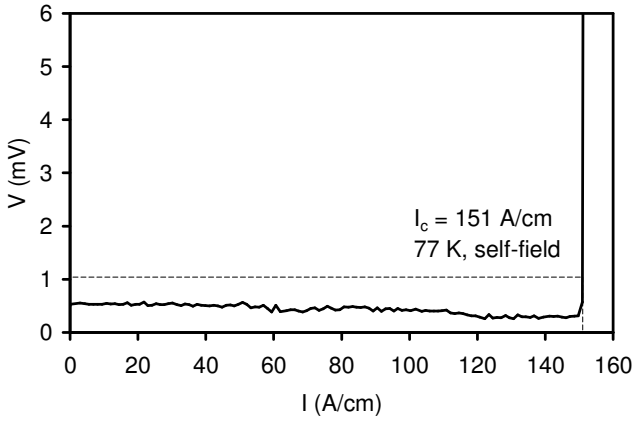

Fig. 2. Critical current measurement data for a YBCO film on MetOx MOCVD buffer layer. State-of-the-art I_c = 151 A/cm for all-MOCVD coated conductors is achieved.

IV. Conclusion

The modified MOCVD process has been qualified as an excellent low cost YBCO fabrication method for coated conductors, producing impressive results on established buffer architectures from ORNL and LANL. The MetOx all-MOCVD coated conductor architecture is undergoing active development with the promise to offer a competitive cost-to-performance ratio in the near future.

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