Structure-property correlation of CSD processed coated conductors at different length scales

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Chemical solution deposition (CSD) grown superconducting YBCO coated conductors impose great scientific and technological challenges due to the complex route by which these films are formed and due to the large degree of freedom with respect to their chemical composition. Coated conductors require a sophisticated film architecture, in this paper coated conductors deposited on rolling assisted biaxially textured nickel tungsten substrates (RABiTS) will be dealt with. Such coated conductors consist of a biaxially textured substrate upon which one or more buffer layers (a few 100 nm thick) are deposited followed by a superconducting layer (thickness < 1 µm). The superconducting film must have very good both in-plane and out-of-plane texture such that only small-angle grain boundaries are present. The properties of the superconducting YBCO layers are governed not only by the oxygen stoichiometry, but also by the texture, the micro and nanostructure and the effect of various extended crystal defects. The first technological challenge for coated conductors is to deposit high-quality buffer layers. Therefore, we spent considerable effort to study $La_2Zr_2O_7$ buffer layers deposited on nickel tungsten substrates (RABiTS) by CSD and results of this study will be summarized. The buffer layer growth was studied for different annealing temperatures and buffer layers plus their substrate interfaces were carefully studied by TEM showing exciting structural features (i) the biaxial texture on substrates with large misfit and atomically rough surfaces, (ii) high-density of small-angle grain boundaries yielding grain sizes in the buffer layer of 100 nm compared to 40 µm in the substrate, (iii) the nanoporosity and (iv) C content. Long-length CSD fabrication technology for coated conductors impose significant challenges for the characterization. A complete set of quantitative SEM and TEM methods were used and applied for CSD grown coated conductors that yield a fast and thorough characterization on various length scales (fig.1). For a reliable control of the film thickness and homogeneity, a quick non-destructive quantification method with a high spatial resolution is necessary and SEM-EDX is the method of choice. We established two different SEM-EDX film thickness determination methods: (a) current dependent and (b) current independent. Calibration curves were generated which contain parameters of the EDX spectra as a function of buffer layer thickness. For establishing the calibration curves we analysed four samples of different buffer layer thicknesses (from 80 nm to 325 nm) previously measured by alternative methods, i.e. ellipsometry, which has a poor spatial resolution and cross-sectional transmission electron microscopy, which is very time-consuming. The local thickness determination by SEM EDX is particularly useful for quickly analyzing macroscopic defects in the films. For a better understanding of EDX spectra of LZO buffer layers, Monte-Carlo simulations were made to calculate EDX spectra of single layer LZO thin films on Ni substrates. Such calculations are particularly important when applying the method for more complicated buffer layer architectures and YBCO layers. For fully CSD processed coated conductors CeO_2 and superconducting YBCO layers were grown on the

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LZO buffer layers and the nanostructure was carefully studied. It differs from that of PVD deposited films, i.e. (i) a larger number of secondary phases on various length scales and (ii) surface segregation of secondary phases relevant for multilayer deposition are observed. Plan view (fig.2) and cross-section TEM was applied to study the nanostructure of the coated conductors, particularly the superconducting films. A new and efficient chemical mapping method yielding high accuracy was established by FIB prepared TEM lamellae in combination with elemental maps acquired by energy-filtered transmission electron microscopy (EFTEM).

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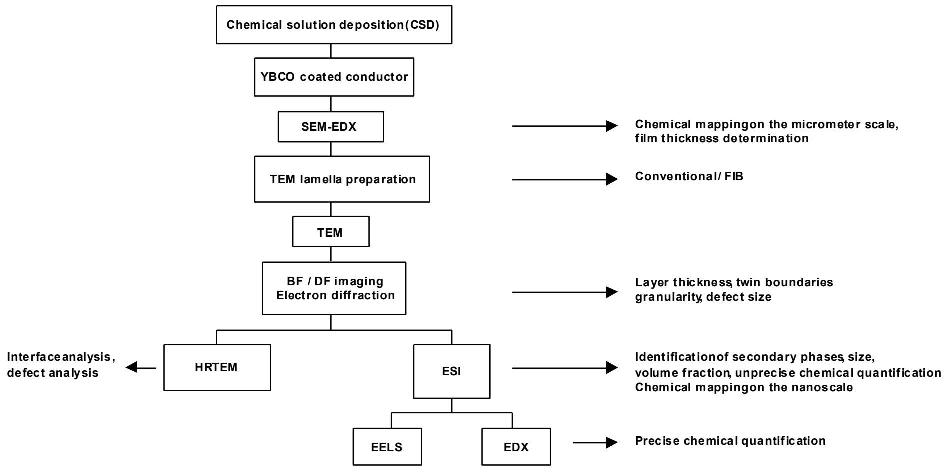
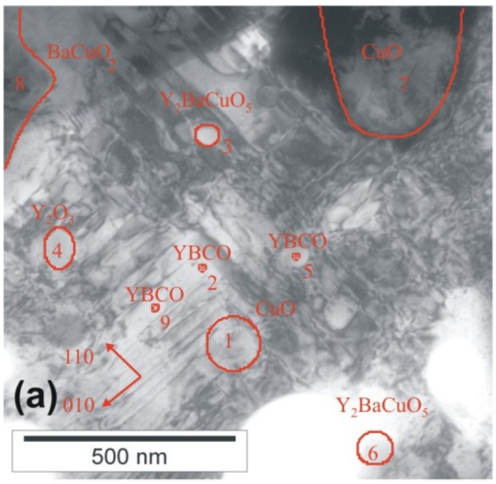


Figure 1. Schematic diagram of the strategy used for the electron microscopy analysis of fully CSD processsed YBCO coated conductors.



Spectrum No.	Y (at %)	Ba (at %)	Cu (at %)	Phase	Size (nm)
1	3.82	5.38	90.8	CuO	70
2	18.19	34.51	47.3	YBCO	Matrix
3	62.4	17.81	19.79	Y_2BaCuO_5	30
4	89.36	5.24	5.4	Y_2O_3	40
5	19.4	45.2	35.41	YBCO	30
6	48.43	21.89	29.68	Y_2BaCuO_5	40
7	0.64	0.91	98.46	CuO	> 200
8	7.04	13.47	79.49	$BaCuO_2$	> 100
9	22.1	32.7	45.2	YBCO	Matrix

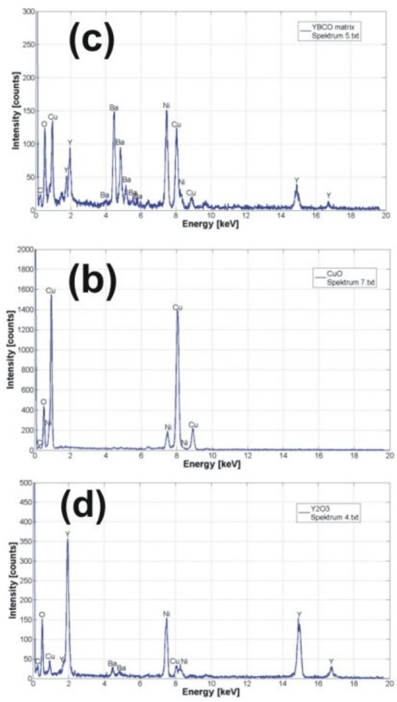


Figure 2. (a) TEM bright field image of a CSD prepared YBCO film. (b-d) EDX spectra of various areas of (a). Quantitative analysis of spectra and assignment of phases are given in the table.

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