MOCVD of coated conductors with electrically conductive buffer layers and their electrical field

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Abstract. A new MOCVD technique was developed for the deposition of oxides at a controlled low oxygen partial pressure, which enable to coat textured metal tapes with electrical conductive perovskites. In a RTR MOCVD-system metal tapes were coated with electrical conductive \((\text{La},\text{Ba})\text{MnO}_3\), \((\text{La},\text{Sr})\text{MnO}_3\), \((\text{La},\text{Sr},\text{Pb})\text{MnO}_3\) and \((\text{La},\text{Ba})_2\text{CuO}_4\) buffer layers and YBCO. In the same RTR-system YBCO was deposited on different buffered metal tapes. Computer calculations were used to characterise the behaviour for a weak superconducting part of a CC-tape with a conductive buffer layer system.

1. Introduction

It was impressively demonstrated by Fujikura [1] and IGC-Superpower [2], that 100 m long Coated Conductors can be produced with high \(I_c\) of 70-126 A at 77 K. This shows, that the Coated Conductors become feasible to its practical use. If the Coated Conductors should work reliable in applications, the electrical and thermal stabilisation is essential in order to avoid “hot spots”, when the current locally becomes higher than \(I_c\). Additional it is important, that the superconducting layer is electrically connected with the metal substrate, so the breakdown voltage is not exceeded. If the substrate is coated with conductive buffer layers, Th substrate can be used as shunt and electrical stabilisation [3]. Substrates with low resistance can provide an excellent stabilisation of the Coated Conductor for motors, generators and other applications. This promises reduced production costs and simple layer architectures.

For fault current limiters and transport cables it would be beneficial, if the substrate has a high resistance and the shunt is as weak as possible. If a fault current strains the Coated Conductor, the generated heat is limited by the resistance of the shunt and the metal tape. For such applications the generated heat of a fault current must be limited, so the superconductor is not overheated. An electrical
breakdown can destroy the superconductor in these applications, but a conductive buffer layer could avoid such breakdown.

2. Simulation

Simulations with current-flow were carried out for a coated conductor system. The calculated system consists of a Ni5at%W substrate, 40 nm LBMO, 200 nm LSMO and 400 nm YBCO. To simulate the HTS characteristics the method described in [4] was used.

The imposed current was $0.5 J_c$ ($J_c = 2 \text{MA/cm}^2$ @ 77 K) and the critical temperature of the HTS 88 K. In the middle of the superconductor a normal conducting part was modelled by applying a fixed temperature of 100 K. The rest of the model was kept at a constant temperature of 77 K. Such a local quench can happen due to hot-spots in many technical applications [5]. Because of the current flow into the layer-substrate system, the electrical field rises in the vicinity of the hot-spot. Since the high electrical field may lead to an electrical breakdown inside or a flashover outside of the coated conductor, the allocation of the electrical field in that area is of particular interest (figure 1). The simulations showed a maximum of the electrical field below 1 kV/m. The breakdown voltage of liquid nitrogen is about 50 kV/mm [6]. Therefore no electrical breakdowns inside (solid body) and flashovers outside (liquid nitrogen) of the coated conductor are to be expected.

![Figure 1](image1.png)

Figure 1. Cut-out of simulated allocation of the electrical field in the model. The dimension of the electrical field is given in V/m.

3. Experimental

The textured NiW tapes were produced by IFW Dresden, evico GmbH and the Forschungszentrum Karlsruhe. The tapes were 1 cm wide and 80-100 µm thick.

The La-, Mn-, Pb-, Y-, Ba-, Sr- and Cu-(thd) precursors (thd = tetramethylheptanedionate) were solved in m-Xylene. In a so called band evaporator [6] the solution is transported into a first evaporation zone, were the solvent is evaporated at 60-100 °C. Then the precursors are evaporated in a second temperature zone at 260-300°C. Between the two evaporation zones nitrogen gas flows are lead into the evaporator. These gas flows divide the solvent vapour from the precursor vapour, which is delivered into the tape reactor.

A Reel to Reel system was used for MOCVD of the layers. First a (La,Ba)MnO$_3$ (LBMO) buffer layer was deposited at low oxygen partial pressure of $10^{-17}$-10$^{-15}$ bar onto textured Ni-tapes, so no NiO
formation can take place. This process is described elsewhere [8,9]. A second buffer layer of (La,Sr)MnO₃ (LSMO), (La,Sr,Pb)MnO₃ (LSPMO), or (La,Ba)₂CuO₄ (LBCO) was deposited at 1 mbar oxygen partial pressure on the LBMO/Ni5%W tape. YBCO films were grown at 0.25-1 mbar oxygen partial pressure on different tapes. The temperature in the hot wall reactors used for buffer layers and YBCO layers were 600-800°C and 730-800°C and the transport velocity of the tapes were 0.5-5 and 2-5 m/h respectively.

4. Results and Discussion

LBMO, LSMO, LSPMO (figure 2) and LBCO films were deposited crack free with in plane and out of plane texture of FWHM ≤ 6° and ≤ 3° respectively on Ni5%W tapes. The doping with Pb can enhance the diffusion by volatile surfactant assistance [10], which can lead to the better crystal growth and enabled us to lower the deposition temperature in comparison to LSMO.

Figure 2. Θ-2Θ, Φ scan and rocking curve of a (La,Sr,Pb)MnO₃ film deposited on (La,Ba)MnO₃/Ni5at%W with a transport velocity of 3 m/h at 630 ºC.

Figure 3. Θ-2Θ scan of YBCO/(La,Ba)₂CuO₄/(La,Ba)MnO₃/Ni5at%W and Φ scan of overlapped LBMO(110) and YBCO(103) (all films coated by RTR MOCVD).

The LBCO films on LBMO/Ni5%W tapes contain in some cases a-axe and polycrystalline parts. The deposition should be further optimised, in order to obtain high quality YBCO films.
The YBCO films deposited on LBCO/LBMO/Ni5%W tapes were superconducting at at $T_{\text{onset}} = 84$ K and $j_c < 0.1$ MA/cm$^2$ (77 K). The XRD measurements of these tapes show c-axis oriented YBCO with small intensities of the (103) and (200) YBCO peak and good in-plane texture (figure 3). This means that parts of the YBCO film are a-axis oriented and polycrystalline. However YBCO films were obtained under similar deposition conditions on single crystals and PVD buffered tapes [11] with $j_c > 1$ MA/cm$^2$ at 77 K. Therefore the buffer layers must be further optimised, which is in progress.

5. Conclusions

The electrical field was calculated for electrical conductive LSMO/LBMO and LBCO/LBMO buffered NiW-tapes with a computer code in the case of a non superconducting weak part. No electrical breakdowns inside and flashovers outside of the coated conductor are to be expected.

LSMO, LSPMO and LBCO films were deposited crack free by MOCVD on LBMO/Ni5at%W tapes with in plane and out of plane texture of FWHM $\leq 6^\circ$ and $\leq 3^\circ$ respectively. XRD measurements show that YBCO films on these buffer layer systems were preferential c-axis oriented with small polycrystalline fraction, which depend on the buffer layer quality. On LBCO/LBMO buffers the YBCO was superconducting at $T > 77$ K with low $j_c$. The buffer layer deposition should be further optimised in order to obtain high quality Coated Conductors.

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