MOCVD of Coated Conductors on RABiTS

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Abstract. In a reel to reel MOCVD system YBCO films and buffer layers were deposited on textured NiW-tapes. The layers of all RTR MOCVD Coated Conductors were grown with excellent in plane and out of plane texture with FWHM of 5-7° and 1.4-4° respectively. The critical current densities of these films were up to 1 MA/cm² at 77 K. MOCVD-YBCO films on MOD CeO2/LZO buffered NiW (delivered by FZ Karlsruhe) could be coated with critical current densities of up to 2 MA/cm². The “End to End” critical current of MOCVD-YBCO on MOD-LZO/NiW (delivered by Nexans Superconductors) was 58 A for a 700 nm thick film onto a 10 mm wide tape.

1. Introduction

The leading companies Superpower, AMSC and Sumitomo demonstrated, that it is technically feasible to produce long length Coated Conductors [1, 2, 3]. Now the production of long length Coated Conductors started in high quantities. These Coated conductors will substitute copper in many electrical power devices, if they can be produced at low costs. The market of Coated Conductors strongly depends on the production costs. Therefore it is very important to use cost efficient techniques and to simplify the layer architecture.

Metallorganic Deposition (MOD) and Metallorganic Chemical Vapour Deposition (MOCVD) are techniques, which can meet the low cost production of large quantities. We used MOCVD and MOD for YBCO and buffer layer deposition on NiW-tapes. In this paper we report MOCVD-YBCO deposition on MOD and MOCVD buffered tapes.

2. Templates

Textured alloyed Ni tapes were used for MOCVD of buffer layers and YBCO. Additional MOD buffered alloyed Ni tapes were produced by FZ Karlsruhe or Nexans Superconductors and then coated with YBCO by MOCVD.

2.1. Textured alloyed Ni tapes

Ni4at%W and Ni5at%W was the standard material for the depositions with a thickness between 80-100 µm and width of 10 mm. The Ni4at%W was produced at the FZ Karlsruhe. Ni5at%W tapes with lengths between 1 and 100 m were delivered by evico GmbH. The Ni4at%W substrates were prepared...
using 99.99 wt% Ni and 99.95 wt% W, melted in an argon-arc furnace, homogenized at 1100°C in Ar-5 vol% H₂ and swaged to rods with 7.5 mm diameter. After a pre-annealing at 800°C for 2 h, the rods were heavily cold rolled down to 0.1 mm with an aspect ratio of $l/d_0 > 1$ ($l$ projected contact length to the rolls, $d_0$ specimen thickness) per pass to obtain a homogeneous deformation. The relative thickness reduction was 98.7 %. After rolling the tapes were recrystallized at 1150°C for 30 min in an Ar-5 vol% H₂ gas mixture to form the cube texture. Figure 1 shows an EBSD measurement of Ni₄W.

2.2. Buffer layers by MOD at FZ Karlsruhe

To prevent diffusion and to have a small lattice misfit concerning the YBCO deposition a buffer architecture with LZO and CeO₂ was chosen. The precursor solutions were prepared by solving Ce(III) 2,4 pentanedionate hydrate (Sigma Aldrich), La (III) 2,4 pentanedionate hydrate (Sigma Aldrich) and Zr (IV) 2,4 pentanedionate hydrate (Alfa Aesar) in propionic acid. The ratio of the concentration of the cations was controlled by means of ICP OES. The liquids contained about 0.4 mol/l La³⁺ and Zr⁴⁺, respectively for the LZO and about 0.25 mol/l Ce³⁺ for the CeO₂ precursor solution. Ni₄at%W substrates from FZ Karlsruhe were degreased with trichloroethylene, acetone and methanol. After that they were chemically treated with a hot mixture of hydrogen peroxide and formic acid and finally supersonically cleaned in methanol [4]. The substrates were dip coated using a withdrawing velocity of about 13 cm/min. The samples were heated in a drying chamber to 200 °C in air. Then they were annealed under Ar/5% H₂ at temperatures between 1000 and 1100 °C for 30 min (LZO) and 15 min (CeO₂). The tapes were quenched to ambient temperature. EBSD measurements showed an excellent cube texture of the buffer layers.

3. All RTR MOCVD

Our MOCVD reel to reel system is reported in [ASC2004, 4MA07]. The deposition of the buffer layers and the YBCO took place in two different MOCVD reactors. Buffer layers and YBCO layers were coated in separated experiments.

3.1. Buffer layers by MOCVD

MgO buffer layers were deposited on W alloyed Ni with transport velocity of 1 m/h at a thickness between 200 nm and 700 nm. We presented in [5] the deposition of MgO on NiW and NiCu tapes and the excellent epitaxial growth of YBCO on MgO buffered Ni alloyed tapes. The YBCO in plane texture and the out of plane texture are between 5-7° and 1.4-3.5°, respectively. However we obtained on these MgO buffer layers only a maximum $J_c$ of 0.7 MA/cm². It is known, that additional buffer
layers on MgO buffer layers enable the growth YBCO films with high critical currents [6]. In order to improve our buffer layer architecture we add another oxide buffer layer on top of the MgO-buffer. This additional buffer layer should avoid the diffusion through the MgO layer.

3.2. YBCO by MOCVD
The MOCVD buffer layer quality was tested by deposition of a 350 nm thick YBCO film. The films were coated with a velocity of 4 m/h. The length of the coated tapes was between 0.1-1 m. Usually the YBCO film had a preferential c-axis orientation sometimes with small a-axis orientation. Figure 2 shows the Jc-measurements of 14 cm long and 10 mm wide all RTR MOCVD Coated Conductor sample performed by a Cryoscan system (THEVA). The step sizes were 5 mm and 2 mm in longitudinal and transversal direction, respectively. Because of fringe effects only the results of the inner part of the sample are displayed.

![Figure 2. Jc-measurements of 14 cm long and 10 mm wide all RTR MOCVD Coated Conductor sample performed by a Cryoscan system (THEVA).](image)

The j-V Graph represents some typical curves with Jc = 0.7-1 MA/cm². The Jc-map of the tape shows an inhomogeneous distribution with critical current density between 0.3 and 1MA/cm². We assume that these deviations are caused mainly by the quality of the buffer layer. Φ-scans of the MgO(220) confirmed, that some areas of low Jc had a mixed in plane texture. Additionally the crystallinity of the oxide layer on the MgO needs further optimization.

4. MOCVD-YBCO on MOD-buffers
Different MOD buffered NiW tapes were used for MOCVD of YBCO. The buffer layers were coated at FZ Karlsruhe (experimental conditions in 2.2.), IFW Dresden and Nexans SuperConductors (NSC). The buffer layer architecture of FZ Karlsruhe and IFW Dresden is CeO2/LZO/NiW. NSC delivered only single LZO buffered NiW tapes.
Figure 3 demonstrates that YBCO can be deposited by MOCVD with good crystalline quality on different MOD buffered tapes from various groups. Strong preferential c-axis oriented YBCO films with small parts of a-axis were measured. Additional peaks at 31.5°, 37° and 43 might belong to a Y-Cu rich phase and NiO.

![Figure 3. Θ-2Θ measurements of MOCVD-YBCO on different MOD buffered NiW tapes.](image)

4.1. MOCVD-YBCO on MOD-CeO₂/LZO buffer layers (FZ Karlsruhe)

The highest critical current densities were obtained on a short 2.5 cm long 10 mm wide sample with buffer layers produced at FZ Karlsruhe. A 350 nm YBCO film was deposited with 4 m/h. The Jc-map (figure 4) of the middle part of the sample shows values between 0.7-2.1 MA/cm². In the j-V graph some curves of the measurement are selected with Jc-values 1.4-2.1 MA/cm². This result demonstrates, that Jc-values of 1-2 MA/cm² are possible by all MOD buffer layers.

![Figure 4. Jc-measurements of 2.5 cm long and 10 mm wide MOCVD-YBCO/MOD-CeO₂/MOD-LZO/NiW tape performed by a Cryoscan system (THEVA).](image)
4.2. MOCVD-YBCO on MOD-LZO buffered NiW-tapes (Nexans SuperConductors)

RTR MOCVD was used for YBCO deposition on 100 nm thick MOD-LZO buffered NiW-tapes delivered by NSC. The film thickness was 350-1000 nm at a tape velocity of 4-5 m/h. Critical current densities up to 1.1 MA/cm² on 15 cm long pieces were measured by the Cryoscan. The maximum length, which was delivered by NSC and subsequently coated with 700 nm thick YBCO at 4 m/h was 6 m. Figure 5 shows the “End to End” direct current measurements of 4.4 m and 10 cm long pieces. An I_c of 21 A and 58 A could be obtained on this single MOD buffer layer. Evidently the tape exhibits some defects, which limit the critical current. These defects have to be investigated in detail in order to improve the long-length I_c.

![Figure 5. Direct critical current measurements of a 700 nm thick MOCVD-YBCO film on MOD-LZO (Nexans SC) buffered NiW; End to End I_c (4.4 m, 77 K) = 21.0±0.2 A (n-value = 9.8±0.5), End to End I_c (10 cm, 77 K) = 57.9±0.2 A (n-value = 22.4±1.1).](image)

This combination of a single MOD-LZO buffer layer and MOCVD-YBCO is the simplest architecture for Coated Conductors to our knowledge. Both techniques are chemically based and therefore might enable the large scale production of low cost Coated Conductors with very simple layer architecture.

5. Conclusion

Combinations of MOCVD-YBCO/MOD-CeO₂/MOD-LZO, MOCVD-YBCO/MOD-LZO and All RTR MOCVD enable critical current densities of 2 MA/cm², 1.1 MA/cm² and 1 MA/cm² at 77 K on alloyed NiW tapes respectively. The high J_c of a YBCO film on multi coated MOD-buffer layers demonstrate the potential of the MOD buffers for MOCVD-YBCO. The End to End current of a 4.4 m and a 10 cm long MOCVD-YBCO/MOD-LZO tape were 21 A and 58 A. Therefore RTR MOCVD-YBCO on 100 nm thick MOD-LZO is a very promising approach for low cost production of Coated Conductors.

References

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