Chemical solution deposition of textured BaTiO$_3$ buffer layers on cube textured Ni-tapes fabricated from commercially available nickel

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**Abstract.** Barium titanate buffer layers were successfully applied to cube textured Ni-tapes fabricated from commercially available nickel by a chemical solution deposition route. Barium acetate solutions in anhydrous acetic acid were mixed with bis(pentane-2,4-dionato)-titanium(IV)-oxide dissolved in methanol. A slight excess of acetic acid anhydride assured the anhydrous medium. The precursor solution was spin-coated to the Ni-substrate. Heat treatment at 1000 °C under a reducing atmosphere (Ar + 6.5 vol-% H$_2$) resulted in dense c-axis oriented, a-b in-plane aligned buffer layers.

1. **Introduction**

The second generation of superconducting tapes is based on the coated conductor technology. Coated conductors consist of (textured) metal substrates covered with one or more buffer layers. Buffer layers are necessary to suppress both the diffusion of metal atoms from the substrate to the superconducting phase and of oxygen to the metal tape to limit oxidation of the substrate. In addition buffer layers must promote texture of the superconducting layer.

In order to reduce production cost, all chemical approaches have been investigated to prepare both the buffer layer(s) and the superconducting layer by an all chemical wet deposition technology. Examples for buffer layers deposited from solution are BaZrO$_3$, SrTiO$_3$, CaZrO$_3$, LaAlO$_3$, CaTiO$_3$ [1], La$_2$Zr$_2$O$_7$ layers [2, 3, 4], Y$_2$Ti$_2$O$_7$ [2] and Ce-Gd-O layers [3]. In this paper we report on the fabrication of dense c-oriented and a-b aligned BaTiO$_3$ buffer layers on textured nickel substrates from anhydrous solutions of barium acetate in a mixture of acetic acid, methanol and acetic acid anhydride.

2. **Experimental**

Ni pellets were cold rolled to tapes of 100 - 200 µm thickness. The thickness reduction in each step was less than 10 %. The approximately 30 cm long tapes were cleaned with acetone and annealed in a tube furnace under a reducing atmosphere (Ar + 6.5 vol-% H$_2$) at temperatures between 800 and 1300 °C. The heat-treatment lasted between 60 and 240 min. The re-crystallized Ni substrates were cut in samples of 1 cm x 1 cm and cleaned with acetone and ethanol in an ultrasonic bath.

For the fabrication of the BaTiO$_3$ buffer layers, BaCO$_3$ was added to glacial acid forming a 0.5 mol dm$^{-3}$ Ba(CH$_3$COO)$_2$ solution. A surplus of acetic anhydride was added to the acetic acid to react with water to acetic acid.

$$
\text{BaCO}_3 + 2\text{CH}_3\text{COOH} \rightarrow \text{Ba(CH}_3\text{COO)}_2 + \text{H}_2\text{O} + \text{CO}_2
$$

$$(\text{CH}_3\text{COO})_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{CH}_3\text{COOH}$$
Then a 0.5 mol dm$^{-3}$ bis(pentane-2,4-dionato)-titanium(IV)-oxide solution in methanol was mixed with the acetic acid solution to obtain a 0.25 mol dm$^{-3}$ solution with respect to BaTiO$_3$. The viscosity of the mixture, measured with an Ubbelohde viscometer had values between 1.7 – 1.75 mPa s (25 °C). The solution was applied to the substrates by spin coating at 5 000 rpm for 4 – 45 s. The buffer layers were formed in a tube furnace at 900 °C and annealing times from 5 – 60 min in reducing atmosphere (Ar with 6.5 vol.% H$_2$).

An X’Pert Pro (Panalytical) diffractometer was used for X-ray measurements with Ni-filtered Cu K$_{\alpha}$ radiation. Scanning electron micrographs were obtained with the help of a JSM-6400 (Jeol, Japan). Thermogravimetry was carried out on a STA 449 C Jupiter (Netsch, Germany).

3. Results and discussion

3.1. Ni substrates

Fig. 1 shows X-ray diffractograms of Ni-tapes sintered at different temperatures. c-axis alignment was found for sintering temperatures between 800 and 1 300 °C. a-b in-plane texturing was analyzed by pole figure measurements. Best results for both c-axis orientation and a-b alignment were obtained for temperature of 1 000 °C and a heat treatment time of 180 min. Higher temperatures resulted in extensive grain growth and twin formation. Lower temperatures produced poor a-b alignment. Textured Ni-substrates prepared as described above were used throughout this study.

![Figure 1. XRD pattern of Ni substrates (180 min annealing). Ni-filtered Cu K$_{\alpha}$ radiation](image)

3.2. BaTiO$_3$ buffer layers on Ni

A thermogravimetric analysis was carried out of the precursor solution. Figure 2 showed that the conversion to BaTiO$_3$ was completed around 900 °C. In an additional experiment the precursor solution was evaporated and the residue was calcined at 1 000 °C under Ar + 6.5 vol.-% H$_2$. The XRD spectrum given in Fig. 4 together with the reference spectrum [4] showed that phase pure BaTiO$_3$ was formed.
Figure 2. Thermal decomposition behavior of the precursor solution for the fabrication of BaTiO₃

Figure 3. XRD pattern of BaTiO₃ powder prepared from non-aqueous solution the reference spectrum [4]. Ni-filtered Cu-Kα radiation. Sintering temperature 1 000 °C for 4 h in Ar + 6.5 vol-% H₂ and.

Figure 4 shows a typical REM image of the surface of a BaTiO₃ buffer layer deposited on a Ni substrate annealed at 900 °C for 10 min. The layer is dense and crack free.
Figure 4. REM image of a BaTiO$_3$ buffer layer on Ni substrate. Deposition conditions: 5 s spin coating, annealed at 900 °C for 10 min.

Figure 5 shows a $\theta$ / $2\theta$ scan of BaTiO$_3$ on textured Ni. The dominating peak at 51.8 ° belongs to (200) Ni. The cubic (200) peak of BaTiO$_3$ at 44.9 ° dominates in the XRD spectrum of the buffer layer; the strongest peak in polycrystalline BaTiO$_3$, the (110) signal at 31.3 °, is barely visible. $a$-b Alignment of the BaTiO$_3$ is confirmed by pole figure measurement.

Figure 5. XRD pattern for BaTiO$_3$ buffer layer on Ni substrate annealed at 900°C for 10 min

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