

Yttrium-barium cuprate superconductors on titanium and rutile substrates

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Abstract. The applicability of titanium and titanium oxide as substrate material for coated conductors was investigated. Titanium metal was rolled to a thickness of 1 mm and mechanically polished. The surface of the titanium sheet was first oxidized at 870 °C for four hours in flowing oxygen yielding a dense oxide layer. The oxidized surface was mechanically polished. YBCO superconducting layers were applied to oxidized titanium and to rutile surfaces by screen printing. The samples were then annealed in flowing oxygen at 870 °C. The superconducting layers were characterized by X-ray diffraction, optical and electron microscopy and by electrical and magnetic measurements. The resulting superconducting layers were dense and showed critical temperatures of up to 92 K.

1. Introduction

Metallic substrates for the second generation of superconducting tapes are usually nickel, nickel alloys or stainless steel. In this study the applicability of titanium and titanium oxide as substrate material for coated conductors was investigated. Low density and negligible magnetic behavior make titanium and titanium alloys [1] an interesting substrate material for coated conductors, especially since currently the price of titanium (15 \$/kg; $\rho = 4.507 \text{ g/cm}^3$) even on weight basis is much less than the price for nickel (31 \$/kg; $\rho = 8.908 \text{ g/cm}^3$). This price advantage becomes even more pronounced on a volume basis, making titanium an interesting substrate material. In our first approach we explored the possibility to apply polycrystalline YBCO material to titanium.

2. Experimental

High-purity titanium (ASTM B 265) sheets with a thickness of 5.6 mm were reduced by rolling in 75 steps to a thickness of 1 mm. The tapes were cut into pieces of about $10 \times 10 \text{ mm}^2$ and polished with a $0.05 \text{ }\mu\text{m}$ alumina suspension. The titanium pieces as well as mono-crystalline rutile discs were cleaned in an ultrasonic bath with acetone and ethanol. The titanium pieces were oxidized in flowing air at 870 °C for approximately 4 hours. The oxidized pieces were carefully polished with a $0.05 \text{ }\mu\text{m}$ alumina suspension to avoid the formation of cracks.

Commercially available YBCO powder was calcined at 910 °C for 4 hours in flowing oxygen. A suspension of YBCO powder in terpineol was applied to the oxidized titanium as well as to rutile by screen printing. Experiments on single-crystalline (100) were carried out to learn about optimum

sintering temperatures for YBCO on TiO₂. The specimens were dried at 55 °C over night and then annealed under flowing oxygen at temperatures ranging from 850 °C to 910 °C at a pressure of approximate 1.5 bar.

The superconducting layers were characterized by an X'Pert Pro (Panalytical) diffractometer with Ni-filtered Cu K_α radiation. The surfaces of the specimens were studied by a JSM-6400 (Jeol, Japan) scanning electron micrograph. Further characterizations of the surface and the thickness were performed by optical microscopy. The superconducting properties were investigated by measuring the temperature dependence of the electrical resistance as well as the critical current density at 300 μT. Magnetization was investigated at different temperatures with the field perpendicular to the surface of the titanium substrate.

3. Results and discussion

The oxide layer formed on the Ti-substrates was dense and crack-free. Annealing temperatures between 850 °C and 910 °C were investigated for the YBCO layers. No influence of the annealing temperature on the critical temperature and no significant difference in the XRD spectra were observed (Figure 1).

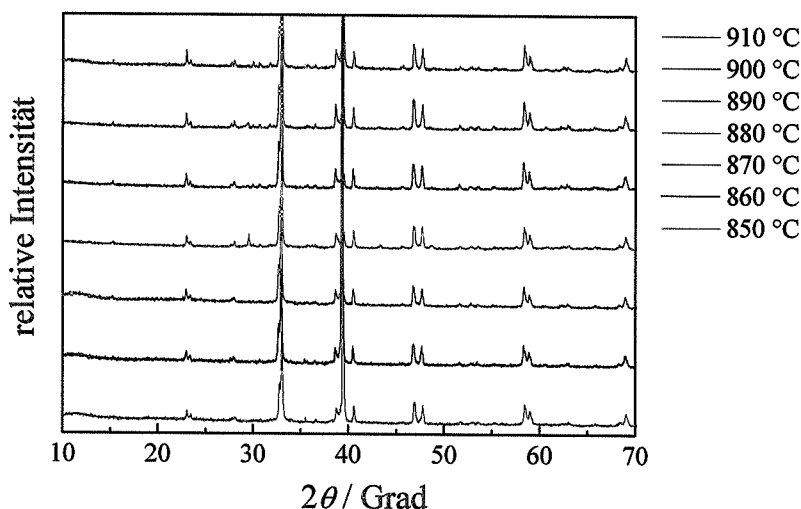


Figure 1. XRD pattern of YBCO on rutile substrates annealed at different temperatures. Ni-filtered Cu K_α radiation.

Most of the samples were sintered at 870 °C. Figure 2 shows the influence of the duration of the heat treatment on the critical temperature (T_{c0}). Values up to 92 K were achieved. XRD spectra showed practically phase pure YBCO (Figure 3).

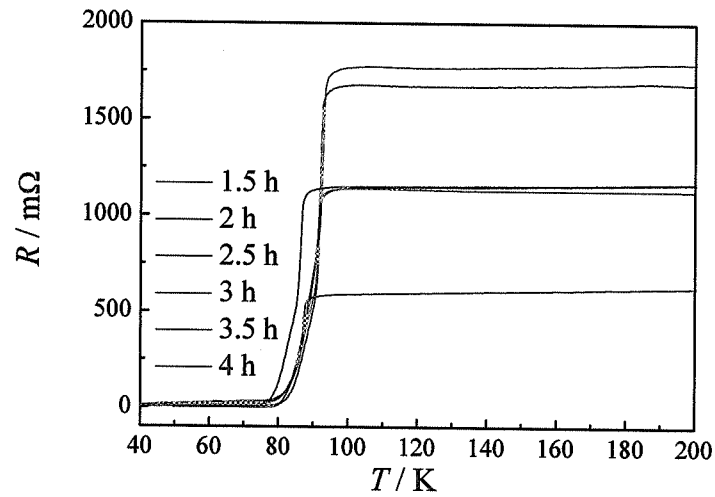


Figure 2. Temperature dependence of the resistance of the YBCO layer on Ti/TiO₂ samples sintered at 870 °C for different sintering times.

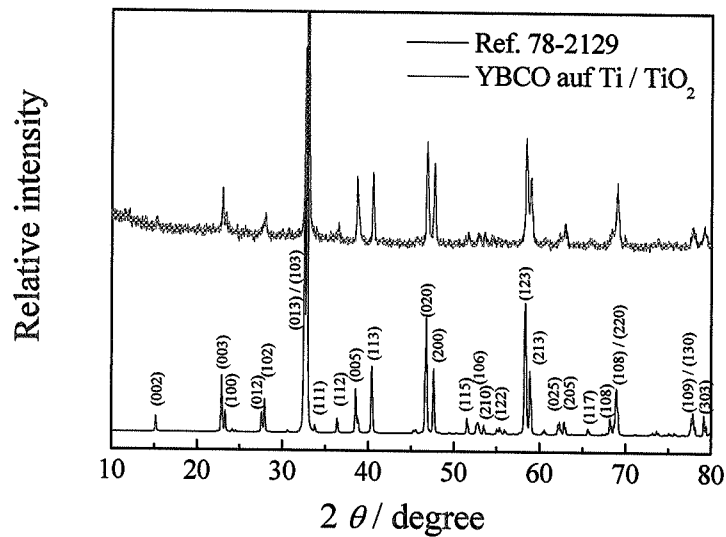


Figure 3. XRD pattern of YBCO on Ti / TiO₂ and reference spectrum [2]. Annealing temperature 870 °C for 2 h under flowing oxygen at a pressure of approximate 1.5 bar. Ni-filtered Cu-K_α radiation.

The YBCO layer was characterized by optical microscopy, the result is shown in figure 4 (A). The surface of the samples was studied by optical and electron microscopy. The electron micrograph given in figure 4 (B) shows that the YBCO layer was dense and crack-free.

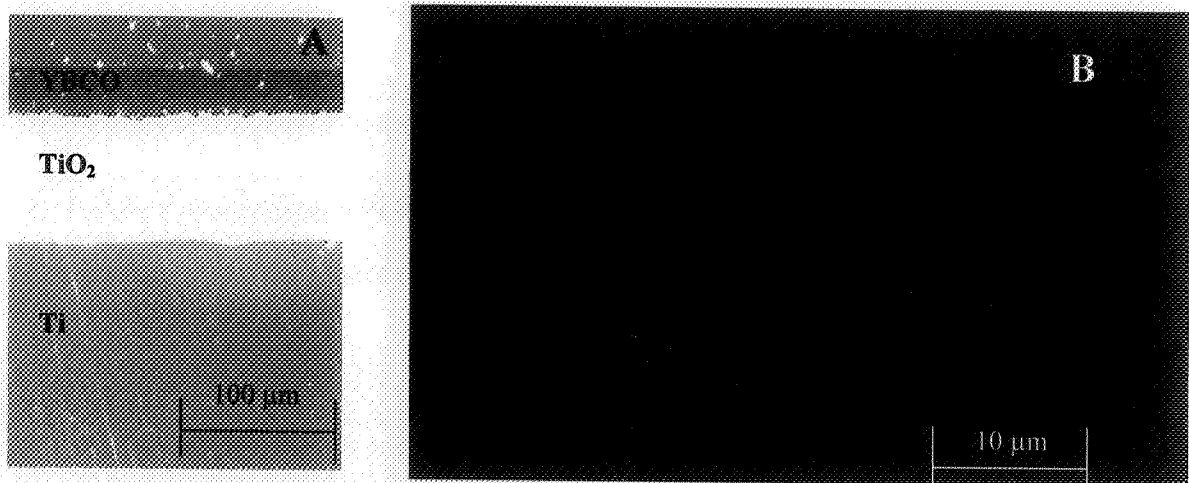


Figure 4. Cross section (A) and surface (B) of the YBCO layer on TiO_2/Ti .

Magnetic measurements at $300 \mu\text{T}$ with the field applied perpendicular to the substrate surface confirmed a critical temperature of approximately 92 K (Figure 5). VSM – loops (field perpendicular to the substrate surface) at different temperatures (Figure 6) show an asymmetric behaviour at low magnetic fields. This indicates significant flux trapping between the grains. No inter-grain currents could be evaluated from the loop measurements.

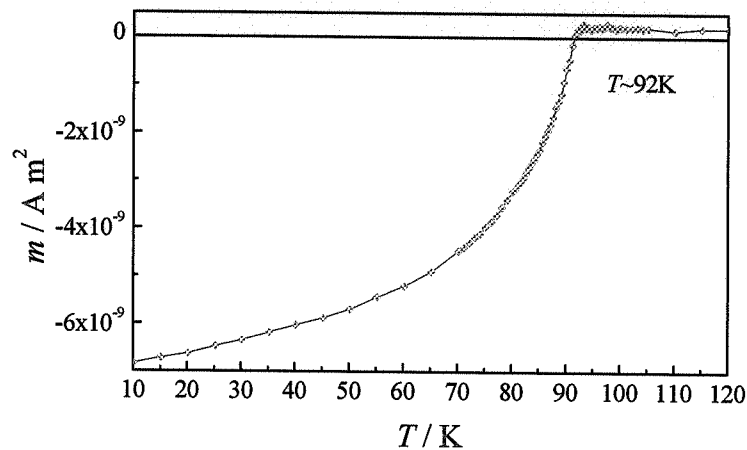


Figure 5. Temperature dependence of the magnetic moment of the YBCO layer on Ti / TiO_2 samples. The magnetic field was applied perpendicular to the substrate surface.

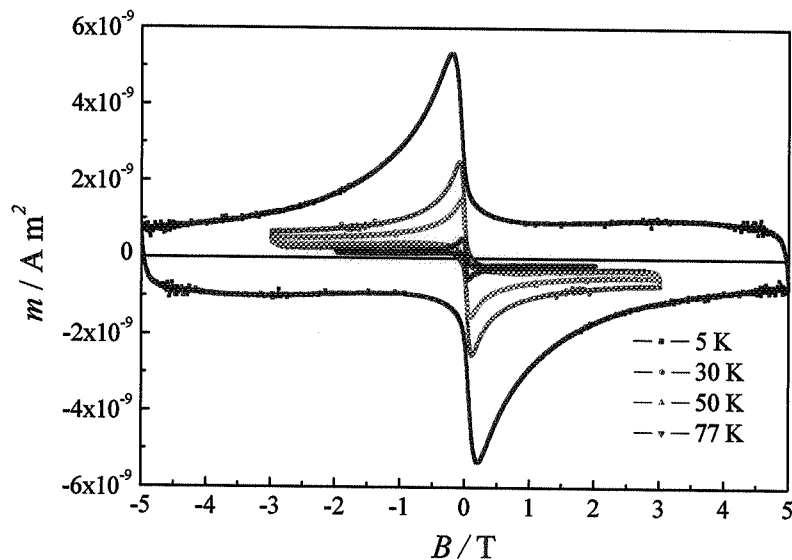


Figure 6. VSM – Loops. The magnetic field was applied perpendicular to the substrate.

Conclusion

Polycrystalline YBCO layers with a thickness of 30 – 40 μm were successfully applied to titanium substrate material buffered with TiO_2 . The layers were dense and crack-free. Critical temperatures (T_{c0}) of 92 K were observed by resistance and by magnetic measurements. Thus the possibility of fabricating superconducting layers on titanium could be established, although screen-printing as the method of applying the YBCO layer did not result in textured films and thus in low critical currents.

Acknowledgments

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References

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