ISD-grown superconducting DyBCO coated conductors investigated by TEM

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Coated conductors are today's best performing high-temperature superconducting wires and yield very large critical current densities in high magnetic fields. Currently, different technologies exist for their fabrication. For preparing coated conductors by Inclined Substrate Deposition (ISD) [1] a bi-axially textured MgO buffer layer is deposited on a randomly oriented Hastelloy substrate by e-beam evaporation, i.e. a PVD process. The substrate surface normal is tilted by an angle of about 30° with respect to the evaporation flux maximum. The physics of the bi-axially textured growth is not fully understood so far and is one motivation for the TEM analysis. On top of the MgO buffer layer a DyBCO superconducting film is deposited resulting in a highly bi-axially textured film containing only small-angle grain boundaries. Such films are required to avoid suppression of the intergrain critical current density by large-angle grain boundaries. The orientation and microstructure of the ISD films are, however, markedly different (Fig.1) from the films prepared by other technologies such as RABITS and IBAD. This has direct consequences also for the growth mode of the superconducting films and their properties. Superconducting properties were measured and the critical current density (transport) was determined as a function of temperature, magnetic field and orientation of the magnetic field. TEM analysis was performed by preparing the films in cross-section by Focused Ion Beam (FIB) studying the various interfaces but also the micro- and nano-structure of the superconducting film. Details of the FIB preparation process will be presented. The interface between MgO buffer and superconducting layer was found to be strongly faceted, with facets parallel to {002} planes of the MgO. The individual facets exhibit very planar interfaces. The lattice mismatch between MgO and DyBCO is f_{aa}=7.8% and f_{ab}=9.3% at room temperature and the superconducting film is under tensile stress. It appears that epitaxial growth occurs despite the large misfit. Amazingly, no evidence for a-oriented DyBCO growth was found. Aoriented growth is unfavorable for achieving large critical current densities. The orientation relation between the MgO and DyBCO layers could be established and threading dislocations were observed. The grain size of the DyBCO superconductor was found to be about 1 μm, which is small compared to a maximum grain size of about 40 μm found in YBCO films grown by RABITs. Grains are separated by small-angle grain boundaries and dislocations were found in the grains of the film and both extended defects are relevant for flux line pinning. A detailed analysis by diffraction contrast of the extended defects present in these films will be presented. Besides their technological importance ISD films allow to study how a strongly anisotropic crystal structure (DyBCO) grows on a substrate (MgO) (i) with large misfit and (ii) on a substrate that has a strongly faceted, atomically rough surface. The interplay of interface energy vs. volume energy (strain) of the films yields the observed nanostructure of the superconducting films and will be discussed.

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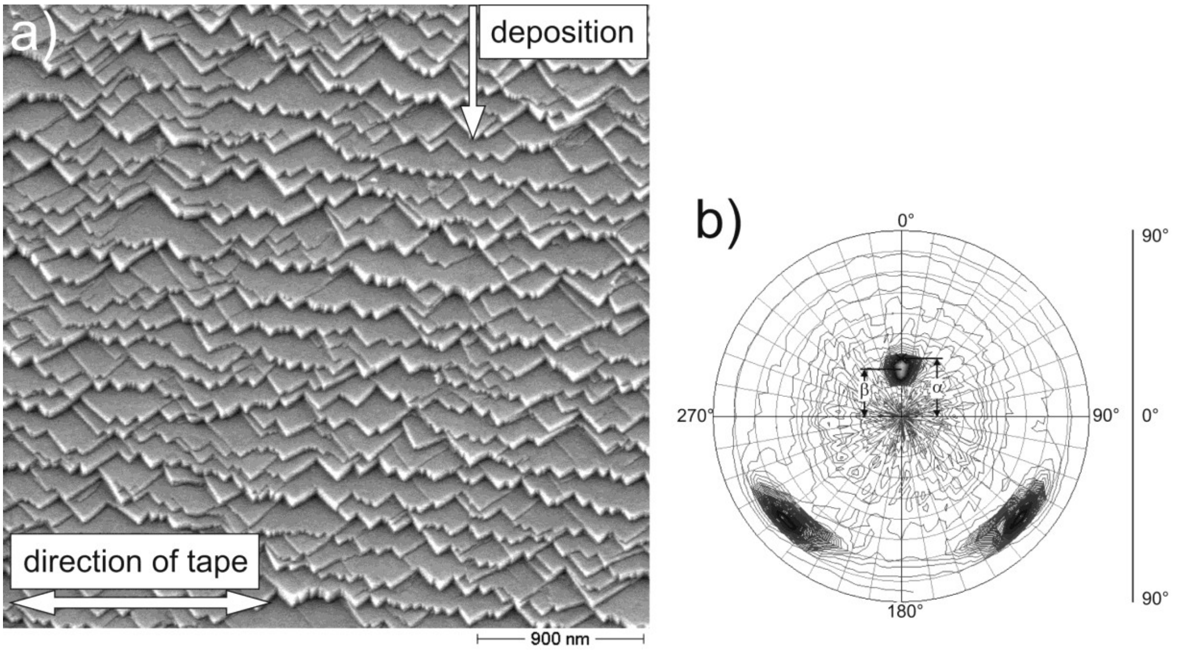

Figure 1. a) SEM secondary electron image of the surface of the MgO buffer layer cap b) xray pole figure of the MgO buffer layer.

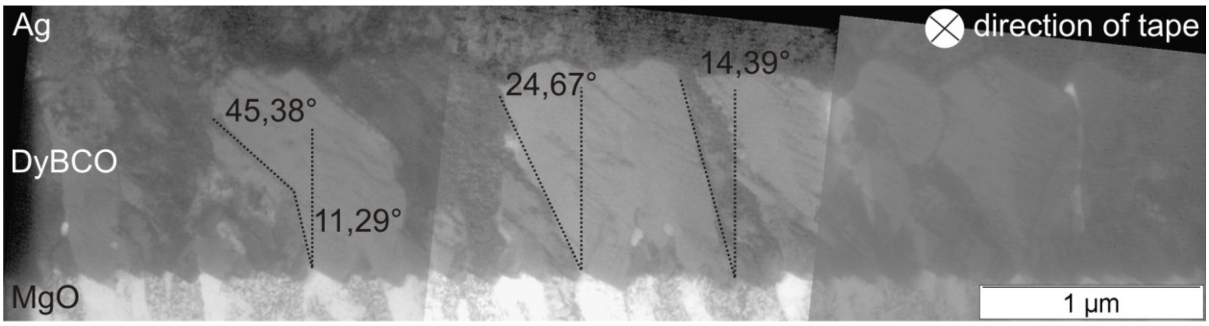

Figure 2. Bright-field overview TEM image of the DyBCO layer in cross-section. Note the faceted interface MgO/DyBCO. The DyBCO/Ag interface is rough (roughness: ~200 nm). The DyBCO grains are about 1 µm in size and appear in diffraction contrast. The TEM sample was prepared by FIB.

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