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Investigation of grain orientations of melt-textured HTSC with addition of uranium oxide, Y_2O_3 and Y_2BaCuO_5

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Abstract. Local grain orientations were studied in melt-textured YBCO samples processed with various amounts of depleted uranuim oxide (DU) and Y_2O_3 by means of electron backscatter diffraction (EBSD) analysis. The addition of DU leads to the formation of U-containing nanoparticles ($Y_2Ba_4CuUO_x$) with sizes of around 200 nm, embedded in the superconducting Y-123 matrix. The orientation of the Y_2BaCuO_5 (Y-211) particles, which are also present in the YBCO bulk microstructure, is generally random as is the case in other melt-textured Y-123 samples. The presence of Y-211 particles, however, also affects the orientation of the Y-123 matrix in these samples.

1. Introduction

The addition of depleted uranium oxide (DU) to bulk, melt-textured YBCO superconductors [1,2] had created a rich variation of microstructures which deserve to be investigated in detail. It was found that an addition of Y_2O_3 and DU leads to the formation of uranium containing nanoparticles [3]. The composition of these nanoparticles is $Y_2Ba_4CuUO_x$ (U-2411). The resulting grain sizes of these nanoparticles are of the order of 200 nm, so a relatively high spatial resolution of the investigation technique is required to study the distribution of these particles within the YBCO matrix. However, also the basic microstructure concerning the YBCO matrix and the embedded Y_2BaCuO_5 (Y-211) particles may change as well upon doping.

In this contribution, we investigate the variation of the microstructure of YBCO samples with the addition of 0.4 wt.-% DU and varying addition of Y_2O_3, Y-211 and Pt by means of electron backscatter diffraction (EBSD) analysis. By this technique, multi-phase scans can be performed which enables a spatially resolved study of the interplay of the phases within such multi-phase samples. The development of the true three-phase scans resolving also the orientations of the embedded nanoparticles will be described elsewhere [4]. Here, we concentrate on the analysis of two-phase scans (Y-123 and Y-211 phases) in order to visualise the differences in microstructure on changing additions.

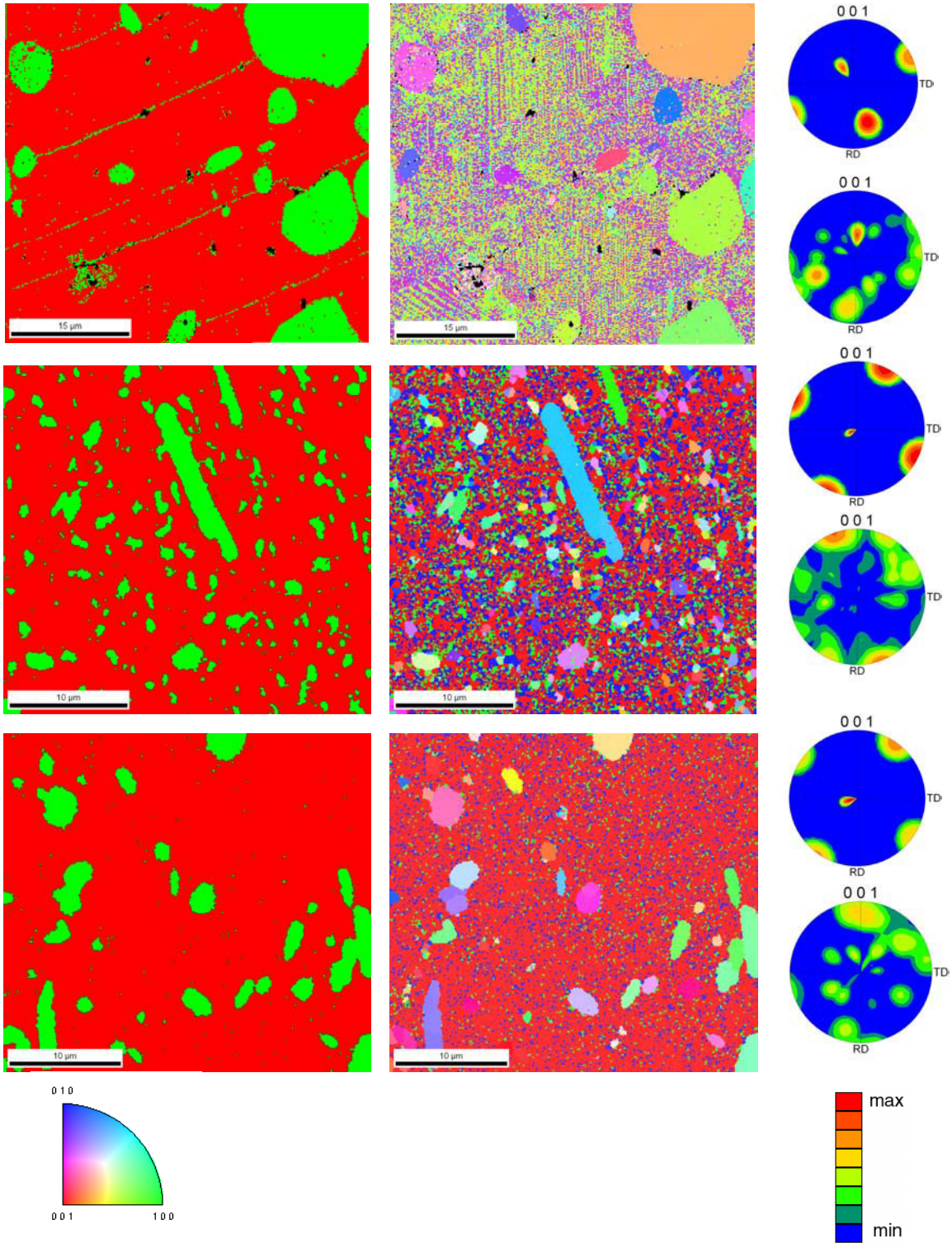

Figure 1. EBSD phase maps (left) and inverse pole figure (IPF) maps in (001) direction (right) of samples (1)-(3). In the phase maps, Y-123 phase is indicated in red, while Y-211 is indicated in green. The crystallographic orientations for the IPF maps are given in the stereographic triangle (orthorhombic) below. The right column gives the pole figures in (001) direction for Y-123 (upper chart) and Y-211 (lower chart), respectively.

2. Experimental procedure

Melt-textured YBCO samples were produced using a standard top seeded melt growth (TSMG) procedure [5], but with a small amount of DU, Y_2O_3, and Y-211 added to the starting powder prior to melt-processing. The investigated samples are as follows: Y-123 + 30 mol-% Y_2O_3 + 0.4 wt.-% DU (sample 1), Y-123 + 30 mol-% Y_2O_3 + 0.4 wt.-% DU + 0.1 wt.-% Pt (sample 2), and Y-123 + 30 mol-% Y-211 + 0.4 wt.-% DU + 0.1wt.-% Pt (sample 3). The fully melt-processed samples were oxygenated in a separate process in the usual way to obtain the superconducting $YBa_2Cu_3O_{7-x}$ phase (Y-123). The surfaces were subsequently dry-polished using 3M polishing papers as described in Ref. [6], using only ethanol for cleaning purposes. This procedure yields high image quality Kikuchi patterns and has been demonstrated to work well even on various polycrystalline YBCO samples [6,7]. The high image quality is a prerequisite for the EBSD multi-phase scans.

The employed EBSD system consists of a FEI dual beam workstation (Strata DB 235) equipped with a TSL OIM analysis unit [8]. The Kikuchi patterns are generated at an acceleration voltage of 20 kV, and are recorded by means of a DigiView camera system, allowing a recording speed of the order of 0.1 s/pattern. The time may be slightly longer in the case of a multi-phase scan. To produce a crystallographic orientation map, the electron beam is scanned over a selected surface area and the resulting Kikuchi patterns are indexed and analysed automatically (i.e. the Kikuchi bands are detected by means of the software). A detailed description of the measurement procedure can be found in Refs. [9,10].

3. Results and discussion

Figure 1 gives the EBSD phase maps and the so-called inverse pole figure (IPF) maps of samples (1)-(3). Also included are the pole figures for the phases Y-123 and Y-211 for each sample. In sample (1) (without Pt), large Y-211 grains of micrometre-size are formed. Small grains of Y-211are located in the typical cracks within the Y-123 matrix. The orientation of the Y-211 phase is found to be random as observed in other samples [4]. The Y-123 phase is relatively homogeneously oriented and exhibits the twin structure. The resulting orientation of the Y-123 phase is here (100), while the twins have a violet orientation. In sample (2), the Y-211 particles are found to be much smaller as a consequence of the Pt-addition, but are also oriented randomly. Here, the Y-123 phase has a dominating (001) direction, but also a large amount of (010)-oriented areas are present. Some orientations of the Y-211 phase produce misorientations in the Y-123 matrix, which was also observed earlier [11]. Sample (3) contains a large amount of Y-211 particles, including a large number of small particles with sizes around 500 nm. This type of sample was investigated previously using polarised light microscopy [12]. The Y-123 matrix is in this case oriented mainly in (001) direction. However, due to the presence of the Y-211 particles, also many misoriented small Y-123 particles can be observed, mainly of (010) orientation. Also included in figure 1 are the corresponding pole figures in (001) direction for Y-123 and Y-211. The orientation of the Y-123 phase can be clearly seen from the pole figures, the misorientations are visible as secondary maxima. In all three samples, the orientation of the Y-211 phase is practically random.

Figure 2 presents two charts indicating the determined misorientations within the Y-123 phase (left); the right diagram shows the misorientations within the Y-211 phase. The Y-123 phase exhibits a large amount of misorientations below 10° (the largest amount is found for sample (2)), and a peak at 90°, corresponding to the presence of (010)-oriented particles. The Y-211 particles show in contrast a large amount of misorientations at higher angles, which corresponds to the nearly random distribution of orientations.

4. Conclusions

By means of EBSD two-phase scans the differences in microstructure for several DU containing YBCO samples are revealed. The addition of Pt is effective to reduce the size of the Y-211 particles also here. Characteristically for the samples with addition of DU is the presence of (010)-oriented Y-123 particles, while the orientation of the Y-211 particles is found to be nearly random.

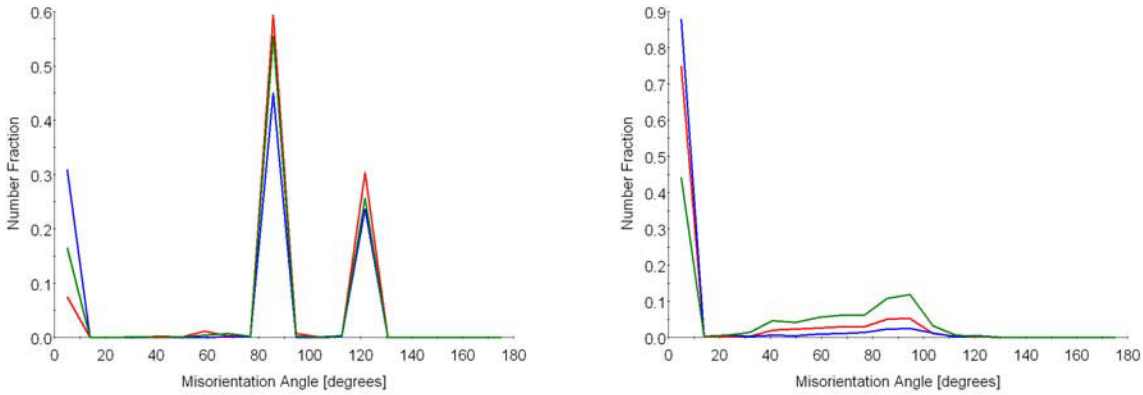

Figure 2. Misorientation angles for Y-123 (left) and Y-211 (right) for samples (1) – red, (2) – blue and (3) – green.

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