Diffusion process for superconducting YBa₂Cu₃O_x-thin layers

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DIFFUSION PROCESS FOR SUPERCONDUCTING $\text{YBa}_2\text{Cu}_3\text{O}_x$ -THIN LAYERS

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In this paper a method is described by which superconducting thin $\text{YBa}_2\text{Cu}_3\text{O}_x$ -layers are formed by a solid state diffusion reaction between a substrate and a thin layer, both of non-superconducting starting compounds.

1. INTRODUCTION

Thin superconducting $\text{YBa}_2\text{Cu}_3\text{O}_x$ (123)-layers can be made by e.g. plasma-spraying, laser-ablation and sputtering (e.g. 1,2,3). Examination of the phase diagram (4,5), led us to a new method for the fabrication of superconducting thin 123-layers. This method is based on the formation of a superconducting thin layer by a solid state diffusion reaction at the interface between a non-superconducting substrate and a non-superconducting coating.

2. EXPERIMENTAL PROCEDURE AND RESULTS

BaCuO_2 layers of about 3 μm thickness were deposited on hot-pressed $\text{Y}_2\text{Cu}_2\text{O}_5$ substrates by laser-ablation (substrate temperature 400°C) from sintered targets. The samples were annealed for two hours at 850°C in O_2 . The resistance of such samples was measured as a function of temperature by a standard d.c. four-probe technique. A broad superconductive transition was observed. Repeating the annealing gave better results. The T_c of this sample was 80 K and a relatively high room-temperature resistance of 120 ohm was measured. The X-ray diffraction (XRD)-pattern of this sample showed the presence of Y_2BaCuO_5 , CuO , $\text{Y}_2\text{Cu}_2\text{O}_5$ and BaCuO_2 , in addition to weak reflections originating from the 123-compound.

The as-deposited BaCuO_2 -layer appeared to be very reactive with CO_2 or H_2O from the air. In order to avoid these reactions, an $\text{Y}_2\text{Cu}_2\text{O}_5$ capping of about 1 μm thickness was applied, on top of the BaCuO_2 layer. This capping was also deposited by laser-ablation. Six capped $\text{Y}_2\text{Cu}_2\text{O}_5$ / BaCuO_2 samples were heat-treated for various times between 0.5 and 6 hours and at various temperatures between 825 and 900°C in O_2 . Now most of the XRD-patterns showed the orthorhombic

123-compound as the main phase. In fig. 1 an R-T curve of the sample with the highest T_c is shown. On the SEM fractograph of this sample, shown in fig. 2, cracks through the layers can be observed. These cracks might be due to a difference in thermal expansion coefficients and phase transformations in the layers.

Superconducting 123-thin films were also formed by a solid state diffusion reaction between a sintered CuO substrate and an $\text{Y}_2\text{Ba}_4\text{O}_7.\text{CO}_2$ thin layer. In fig. 3 an R-T curve is shown of a sample which was heat-treated for 4 hours at 850°C in O_2 . The $\text{Y}_2\text{Ba}_4\text{O}_7.\text{CO}_2$ -layer was deposited by plasma-spraying. In ref. 6 results are described which were obtained by using the laser-ablation technique for the $\text{Y}_2\text{Ba}_4\text{O}_7.\text{CO}_2$ -layers as well as more experimental details for both types of samples.

3. DISCUSSION

In capped $\text{Y}_2\text{Cu}_2\text{O}_5$ / BaCuO_2 samples after annealing, two regions in which Y, Ba and Cu prevail have been detected by EDAX, (fig. 2.) In the samples without capping, only one such layer can be formed at the interface between the deposited layer and the substrate. In the XRD-patterns a clear difference is observed between the samples without an $\text{Y}_2\text{Cu}_2\text{O}_5$ capping on top of the BaCuO_2 layer on the one hand and those with such a capping on the other hand. From the samples without capping only very weak 123-lines, originating from the underlying 123-interface, were detected. In contrast strong 123-lines, apparently originating from the 123-top layer, appeared in the XRD-patterns of the capped samples. In none of the layers any preferential orientation was detected by XRD. Annealing for two hours at 850°C

appeared to be an optimal treatment for the capped $\text{Y}_2\text{Cu}_2\text{O}_5$ / BaCuO_2 samples so far.

In contrast to what was aimed at, the whole capping layer was converted to the 123-compound. Therefore in order to obtain a real interface layer, a thicker capping layer should be applied. This not only prevents chemical degradation but it also gives a better illustration of the idea to form a superconducting thin layer within a solid body.

4. CONCLUSIONS

It is shown that it is possible to form superconducting thin 123-layers by a solid state diffusion reaction between two non-superconducting starting materials. After annealing a CuO substrate with an $\text{Y}_2\text{Ba}_4\text{O}_7\text{CO}_2$ layer a rather broad superconducting transition is obtained. A better result is obtained by using an $\text{Y}_2\text{Cu}_2\text{O}_5$ substrate covered with a BaCuO_2 layer and provided with an $\text{Y}_2\text{Cu}_2\text{O}_5$ capping. For the latter samples a superconducting layer on top of the

BaCuO_2 layer was found. This indicates that it is worth considering to make a superconducting 123-layer on other polycrystalline substrates by depositing a sequence of layers and applying a heat treatment.

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Fig. 1. R-T curve of the $\text{Y}_2\text{Cu}_2\text{O}_5$ / BaCuO_2 sample with capping after annealing for 2 hours at 850°C in O_2 . Note the low resistance above T_C and a relatively sharp superconductive transition.

Fig. 3. R-T curve of the CuO / $\text{Y}_2\text{Ba}_4\text{O}_7\text{CO}_2$ sample after annealing for 4 hours at 850°C in O_2 . The layer was deposited by plasma-spraying.

Fig. 2. SEM fractograph of $\text{Y}_2\text{Cu}_2\text{O}_5$ / BaCuO_2 diffusion-layer annealed for 2 hours at 850°C in O_2 . The light top layer is an orthorhombic 123-layer, formed from the original capping layer. Below the cracked boundary a thin 123-layer is present which is formed on the original substrate surface.