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FABRICATION OF 45 DEGREES TEMPLATE GRAIN BOUNDARY JUNCTIONS USING A CaO LIFT-OFF TECHNIQUE.

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45 degrees grain boundary junctions have been made using (100) MgO substrates, a CeO_2 template layer and an $YBa_2Cu_3O_7$ top layer. To minimize the damage to the MgO surface, which will occur if the CeO_2 is structured using ion milling, the CeO_2 layer has been structured using the CaO lift-off technique. Electrical measurements of these junctions as a function of temperature, microwave irradiation and magnetic field will be discussed in this paper.

1. INTRODUCTION

Several types of grain boundary junctions have been discussed in literature [1-3]. Among them, the template grain boundary junction (TGBJ) offers the possibility of being placed at any wanted position on the substrate. This kind of junction consists of a template layer on part of the substrate and a toplayer of superconducting material, optionally protected from the substrate and template layer by a bufferlayer. Several possibilities exist for the choise of substrate, template and buffer material [2,4]. The preparation of 18 degrees grain boundaries on MgO as reported earlier [5] does seem to be strongly dependent on the batch of substrates.

In this paper the preparation and electrical characterization of TGBJs consisting of an MgO substrate, a CeO_2 template layer and an $YBa_2Cu_3O_7$ toplayer will be discussed.

The deposition of all layers has taken place using the pulsed laser deposition technique.

2. PREPARATION

Structuring the CeO_2 by means of Ar ion beam etching, causes several peculiarities because the MgO substrate will also be etched. Firstly, if a step is etched in the MgO the $YBa_2Cu_3O_7$ grows with its c-axis perpendicular to the local MgO surface [3]. Furthermore $YBa_2Cu_3O_7$ grown on an etched substrate is growing 45 degrees rotated with respect to the cubic to cubic growth normally obtained [5]. Etching of the CeO_2 layer with Ar ions leads to severe problems concerning the definition of one single grain boundary.

To improve this definition the CaO lift-off technique [6] is used to structure the CeO_2. To define the edge of the CeO_2 first a photoresist mask (thickness 1.4 μm) is deposited and structured using standard photolithography, such that the remaining resist covers half of the substrate. Next a 400 nm thick amorphous CaO layer is deposited, followed by lift-off of the photoresist using aceton p.a. (dried with K_2CO_3). Deposition of a 10 nm thick CeO_2 layer is followed by dissolving the remaining CaO in distilled water in 10 minutes, leaving half the substrate covered with CeO_2. A 100 nm thick $YBa_2Cu_3O_7$ layer is deposited, followed by structuring of the actual junctions (width 5-25 μm) using Ar ion beam etching. More details about the deposition and structuring of the layers will be published elsewhere [5].

3. RESULTS

3.1. Material aspects

The process steps prior to deposition of the $YBa_2Cu_3O_7$ layer might cause contamination and structural damage of the MgO surface. RBS has been used to look for remainders of Ca after rinsing the

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substrate in water. No remainders have been found [5]. Possible damage of the MgO surface due to the water has been checked using (AR)XPS, by comparing the O(1s) and the Mg(2p) peak of a treated substrate with a fresh substrate, before and after annealing both substrates to 750 °C for 30 minutes in 25 Pa oxygen. A difference between the O(1s) peak of the treated and the fresh substrate is observed, and is probably caused by an adhesion of OH or H_2O to the MgO surface. This difference disappeared after the heat treatment.

All orientatiens of the layers have been checked using XRD. CeO_2 and $YBa_2Cu_3O_7$ both grow in-plane plane cubic to cubic on the MgO. The $YBa_2Cu_3O_7$ on top of the CeO_2 is 45 degrees rotated with respect to the cubic to cubic growth.

3.2. Electrical measurements

Apart from RSJ like IV curves of the junctions, measured at temperatures between 15 K and T_c, also much more rounded curves with reduced critical current densities are observed which will not be discussed here.

I_cR_n values of the junctions are typicly 0.5 mV at

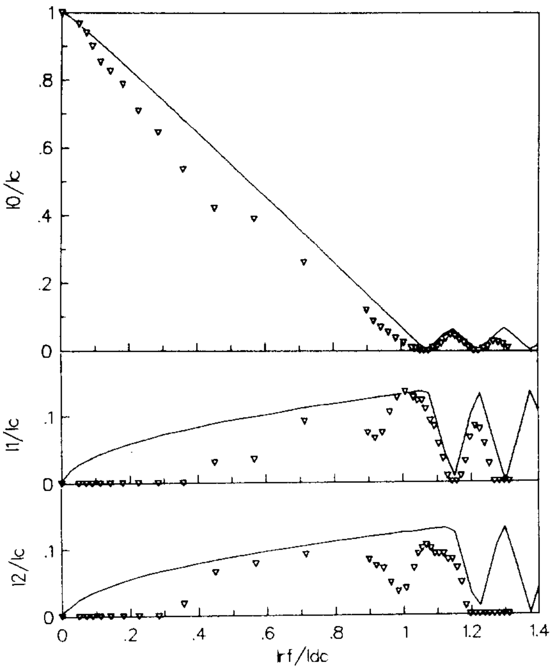

Figure 1. Normalized critical current and amplitude of the first and second Shapiro step as a function of the microwave power, including a fit according to the RSJ model.

20 K and decreasing to zero at about 70 K. R_n values are of the order of a few Ohms between 20 K and T_c.

In figure 1 the amplitude of the critical current and the first and second Shapiro step are given as a function of the 9.64 GHz signalpower at 44.6 K for a 25 µm wide junction. J_c of this junction at this temperature is $1.8 \cdot 10^4$ A/cm^2, R_n as determined by the slope of the IV curve at 100 µV is 0.8 Ω. Also a fit according to the RSJ model is given, using a value for the I_cR_n product of 285 µV, comparable to the value of the I_cR_n product determined in the IV curve. A good fit is obtained, indicating a good Josephson behaviour that can be well described with the RSJ model.

Critical current measurements as a function of the applied magnetic field parallel to the substrate surface and the grain boundary at 55 K, show a modulation down to zero critical current. At lower temperatures this suppression is not complete.

4. CONCLUSIONS

The 45 degrees template grain bondary junctions, of which the template layer is structured using the CaO lift-off technique show I_cR_n values up to 0.5 mV at 20 K and good Josephson behaviour. Most junctions have RSJ like IV curves. Good agreement can be obtained between the amplitudes of the induced Shapiro steps and predictions by the RSJ model. The critical current can be modulated down to zero, by applying a magnetic field parallel to the substrate surface and the grain boundary.

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