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Effect of Al and Ca co-doping, in the presence of Te, in superconducting YBCO whiskers growth

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High-T_c superconducting cuprates (HTSC) such as $YBa_2Cu_3O_{7-x}$ (YBCO) are promising candidates for solid-state THz applications based on stacks of intrinsic Josephson junctions (IJJs) with atomic thickness. In view of future exploitation of IJJs, high-quality superconducting YBCO tape-like single crystals (whiskers) have been synthesized from Ca–Al-doped precursors in the presence of Te. The main aim of this paper is to determine the importance of the simultaneous use of Al, Te and Ca in promoting YBCO whiskers growth with good superconducting properties (T_c = 79–84 K). Further, single-crystal X-ray diffraction (SC-XRD) refinements of tetragonal YBCO whiskers (*P*4/*mmm*) are reported to fill the literature lack of YBCO structure investigations. All the as-grown whiskers have also been investigated by means of X-ray powder diffraction (XRPD), scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). Our results demonstrate that the interplay of Ca, Te and Al elements is clearly necessary in order to obtain superconducting YBCO whiskers. The data obtained from SC-XRD analyses confirm the highly crystalline nature of the whiskers grown. Ca and Al enter the structure by replacing the Y and the octahedral coordinated Cu1 site, respectively, as in other similar orthorhombic compounds, while Te does not enter the structure of whiskers but its presence in the precursor is essential to the growth of the crystals.

1. Introduction

Stacks of intrinsic Josephson junctions (IJJs) with atomic thickness are naturally present in layered high-T_c superconducting cuprates (HTSCs), such as $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi-2212), $La_{2-x}Sr_xCuO_4$ (LSCO) and RE-123 (RE = Y, Eu, Gd, Dy, Ho, Er, Tm and Lu), as a result of their crystal structure (Kawae *et al.*, 2005; Kleiner *et al.*, 1992; Kubo *et al.*, 2008; Okutsu *et al.*, 2008). IJJs can be employed as modular elements in the realization of several cryogenic devices such as THz sensors in Wang *et al.* (2001) and emitters in Ozyuzer *et al.* (2007), micro-SQUIDs in Sandberg & Krasnov (2005) and quantum computers based on macroscopic quantum tunneling phenomena (Inomata *et al.*, 2005; Martinis *et al.*, 2005). Among the possible IJJ applications, high-frequency devices can take advantage of the large Josephson plasma frequency found in some HTSCs. In particular, $YBa_2Cu_3O_{7-x}$ (Y-123) has the highest Josephson plasma frequency, close to a few THz, because of its low anisotropy and high critical current density (Shibata & Yamada, 1997), which makes it a suitable candidate for the fabrication of these kinds of devices. Furthermore, such properties could be modulated, for instance, by chemical substitutions, as already noticed for Pb-doped Bi-2212 in Kambara *et al.* (2011). Within this context, we recently investigated the effect of different cationic substitutions