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Effects of stoichiometric variation and cooling rate on the phase formation and critical current density of Bi-2223 powder-in-tube tapes made from aerosol precursor

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Abstract. Powder-in-tube Bi-2223 is currently the most promising high-temperature superconductor that can be fabricated in long lengths by industrial processes, and is likely to be used as the conductor component in first-generation applications. Intensive investigations of these conductors have revealed that the critical current density of fully processed tapes is influenced by a large number of processing parameters. Among these are the thermomechanical processing schedule and the extent of Bi-2223 phase conversion. These parameters are, in turn, affected by the precursor stoichiometry. In this study, powder precursors with varying Cu content were prepared using an aerosol pyrolysis technique, and powder-in-tube conductors were fabricated using these precursors. Both fast and slow cooling rates were employed during thermomechanical processing, and different treatment schedules are correlated to the critical current density. The results indicate that the effect of excess Cu on J_c is minor compared to the large J_c enhancements obtained by employing one or more slow-cooling steps in the thermomechanical processing schedule.

1. Introduction

For large-scale applications such as transmission cables, motors and generators, long lengths of flexible conductors are required. Currently, the only high-temperature superconductor (HTS) that is capable of being fabricated in long lengths by industrial processes is the powder-in-tube (PIT) (Bi, Pb)$_2$Sr$_2$Ca$_2$Cu$_3$O$_{10}$ (Bi-2223) tape. Although short PIT samples have been shown to possess critical current densities (J_c) as high as a few kA cm^{-2} at 77 K, whether or not this J_c value can be achieved has been found to depend on a large number of processing parameters [1]. These parameters include precursor powder composition [2–4], initial tape deformation conditions [5], initial core density [6, 7], thermomechanical processing parameters [8–11] etc. For example, changes in precursor composition can influence the reaction pathway of Bi-2223 leading to differing amounts of secondary phases as well as modification of the reaction kinetics [2–4]. Since a complete or near-complete conversion of the precursor core is necessary to attain high J_c in PIT Bi-2223, a fast precursor reaction kinetics is needed for the technology to be economically feasible. In response to this need, an aerosol pyrolysis technique was developed to produce Bi-2223 precursor [12]. Powder produced using this method has been shown to be homogeneous and possesses fine particle size. Consequently, Bi-2223 phase conversion can essentially be completed in less than 100 h, while precursor powders manufactured by other methods typically require hundreds of hours for the PIT to be fully processed.

In a previous paper [13], we have reported on the effects of variation in thermomechanical sintering intervals on reaction kinetics as well as J_c of PIT tapes containing aerosol precursor of $Bi_{1.84}Pb_{0.34}Sr_{1.91}Ca_{2.03}Cu_{3.07}O_\delta$ nominal composition, and showed that the PIT properties can be optimized using the proper sintering intervals. In the continuing development of the aerosol powder as a precursor for Bi-2223 PIT conductors, precursor powders of various Cu content were produced in this study. Results from the previous optimization study served as the basis