Microstructure and Properties of High-Temperature Superconductors

Ivan A. Parinov

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With 309 Figures and 44 Tables

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To My Wife, NINA

Preface to the English Edition

In 2006, the scientific society is celebrating the twentieth anniversary of the discovery of high-temperature superconductivity by George Bednorz and Alex Müller. Dynamically developing researches in this field give new scientific results. This caused a significant modernization of the English edition compared to the Russian one [808], which has been written in 2003. Considerable changes have been introduced in Chaps. 1–3 and Appendix A, in particular, new Sect. 3.1.2 is devoted to acoustic emission study of BSCCO/Ag tapes under bending. New Chapter 4 is devoted to carbon problem in HTSC and includes "old" text from Sects. 2.6 and 7.7 of the Russian edition, and "new" text (Sections 4.3 and Appendix B), presenting mathematical modeling of the brittle carbonate formation and following fracture during interaction of YBCO with CO_2. The main aims of the monograph have been retained and connected with Material Science of HTSC and their mathematical modeling. Comparatively, less attention has been devoted to Physics of HTSC. The main results as before have been related to the YBCO and BSCCO families, while the main trends in R&D of other superconductors have also been marked. The author would be grateful for reports of typographical and other errors to be sent via the following web page http://www.math.rsu.ru/niimpm/strl/welcome.en.html, where an up-to-date errata list will be maintained.

I would like to thank all those who have contributed to the preparation of this manuscript at final stage, especially Jacqueline Lenz and Dhivya Balarajan.

Ivan Parinov
Rostov-on-Don, December 2006

Preface to the Russian Edition

The discovery in 1986 of high-temperature superconductors (HTSC) on the basis of copper oxides with the temperature of superconducting transition, that is greater than the temperature of low-cost, non-toxic and accessible liquid nitrogen (77 K), marked qualitative jump in the development and application of new technical conductors, devices for energy transmission, transformation and storage. Together with enough high critical temperatures T_c, an intrinsic brittleness of oxide cuprates, the layered anisotropic structure and the super-short ($\sim 1\,\text{nm}$) coherence length, ξ, presenting itself a spatial characteristic of superconducting electrons, are other main features defining HTSC microstructure and properties. Due to the above-mentioned peculiarities, even the existence of an intergranular boundary could be enough to suppress superconductivity, but the structure-sensitive properties of HTSC systems depend very much on the weak links of intergranular boundaries by manufacturing them in the polycrystalline form, demonstrating coexistence of inter- and transgranular currents. Also, superconductivity can be destroyed at the attainment of the critical value of the external magnetic field H_{cm}. The interfaces of the "superconductor–normal metal", "superconductor–insulator" and other types based on them are the localization places of different defects. The microstructure features, connected with phase composition, domain structure, crystallographic properties, an existence of structure defects, pores, microcracks, inclusions, etc., define directly useful properties of HTSC materials and composites. The main goal of the present monograph is to study microstructure, strength, electromagnetic and superconducting properties. Another aim includes discussion of the optimization directions for the fabrication techniques, superconducting compositions, external loading and thermal treatments to obtain HTSC, possessing improved and more controlled physical and mechanical properties. The link "composition–technique–experiment–theory-model" investigated in the book, assuming considerable HTSC defectiveness and structure heterogeneity, forms the whole picture of modern representations on the microstructure, strength and connected with them the structure-sensitive properties of the materials considered. Special attention in the book is devoted to Bi–Sr–Ca–Cu–O and Y–Ba–Cu–O families that today are most prospective for applications among HTSC.

The monograph is addressed to students, postgraduate students and specialists taking part in the development, preparation and research of new materials. The author thanks the Russian Foundation for Basic Research, Russian Department of Education and Science, Soros Foundation and the American International Program COBASE (Collaboration in Basic Science and Engineering) grants which during the last decade have rendered considerable financial support and promoted to publish this book.

I am also grateful to colleagues and close scientific workers, who have directly or indirectly contributed to the book. In particular, I wish to thank V.P. Zatsarinny, D.N. Karpinsky, E.A. Dul'kin, E.M. Kaydashev, E.V. Rozhkov, A.A. Polyanskii and D.C. Larbalestier.

Corrections and proposals the book will be considered with thanks. They could be to presented by E-mail: ppr@math.rsu.ru.

I. A. Parinov
September 2003

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