Preface

At the time of writing this book, in the summer 2014, the highest superconducting transition temperature T_c remains 135 K which was recorded in 1993 for one of the copper oxide compounds. The "silence" period over 20 years is the longest since the recorded history of superconductivity started from 1911. The second longest silence was between 1973 and 1986, the period between the discovery of Nb_3Ge with $T_c = 23$ K and the discovery of high-T_c superconductivity in copper oxides. During this period between 1973 and 1986, researchers of superconductivity were pessimistic for further rising T_c, and superconductivity at liquid nitrogen temperature was only a dream, as it was believed that superconductivity was a very low-temperature phenomenon. However, in the present silence period, researchers are no longer pessimistic, since they know that high-T_c superconductivity is real and that there is no reason that T_c does not increase beyond 135 K. So, it is a realistic challenge in material sciences to search for new superconducting materials with higher T_c and/or to enhance T_c of the known superconducting materials.

In contrast to the long silence in T_c, several material families have successively been found to show superconductivity at temperature higher than the old record 23 K such as MgB_2 and iron arsenides. Like copper oxides, most of them were not expected to be superconductors before their discovery. Notably, these superconductors are from completely different material families than copper oxides, encouraging researchers to search for new high-T_c superconductors in materials yet to be investigated.

To unravel the mechanism of high-T_c superconductivity in copper oxides remains a challenging problem of physics. Nevertheless, there has been well advanced understanding of their unusual physical properties, various ordering phenomena other than superconductivity, and in particular of the electronic and structural parameters that influence T_c. We now understand why T_c of one copper oxide is higher than T_c of another one. T_c of conventional superconductors is rather a trivial problem. It is basically understandable in the framework of the Migdal-Eliashberg theory developed from the original Bardeen-Cooper-Schrieffer (BCS) theory, even though the theoretical calculations do not necessarily reproduce T_c of real material precisely. On the other hand, T_c's of most of the high-T_c superconductors show a broad distribution within each family due to unusual sensitivity to electron concentration, lattice disorder in the lattice, and so on. This, in turn, will give an experiment-based strategy for enhancing T_c. in the known high-T_c families. Also, we have learned from various different high-T_c families what the common ingredients are among these families, which will provide a guide for searching out new high-T_c superconductors. Thus, it is now possible to develop a new approach to the problem of T_c on the basis of the results from the long and extensive study of the copper oxides and the lessons learned from a plethora of different high-T_c families. This is a main objective of this book.

This book has been written aiming to provide non-specialist readers with an in-depth overview of the past, present, and future of high-temperature superconductivity. Specialist readers will be given up-dated information on the research forefront of the study of various high-T_c families and some hints on the possibility of enhancing T_c and on finding new high-T_c materials. A message that the author would like to pass to researchers of the younger generation and graduate-course students is not to give up the challenges to the problems of high-temperature superconductivity.

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