Preface to the Second Edition of Steels: 
Processing, Structure, and Performance

In this twenty-first century, steel, in its many chemistries and forms and as a major material for load-carrying applications, is under intense pressure from many directions: to reduce energy and find just the right time and temperature in processing to achieve the best combination of structure and properties, to optimize alloying, to improve properties for vehicle weight reduction and safety, and to increase life in demanding applications. The last ten years have seen dynamic responses to these challenges, and production, research, development, technical conferences, and publication have not stopped. Hence, a second edition of Steels: Processing, Structure, and Performance. Every chapter in the first edition has been examined, and not only has recent information been added, but also important references to past discoveries and insights, not included in the first edition and in danger of being forgotten, have been added and discussed.

Structure is the unifying key to understanding steels, and the need to characterize the many elements of structure continues to expand. Where earlier, microstructure as resolved by light microscopy was emphasized, now macrostructure, crystal structure, substructure, and nanostructure and their length scales are integrated with microstructure as a function of chemistry, processing, and performance. This integration is being accelerated by analysis techniques such as electron backscatter diffraction (EBSD) and atom probe tomography (APT), only widely used since the first edition of Steels, as well as improvements in established light and electron microscope techniques and specimen preparation.
This second edition of Steels is actually the fourth volume on steels I have authored. The first volume, entitled Principles of Heat Treatment of Steel, American Society of Metals, 1980, was a rewritten version of Principles of Heat Treatment by M.A. Grossmann and E.C. Bain. As I noted in the preface of the 1980 volume, “Principles of Heat Treatment covered developments between 1935 and 1964, and Grossmann, Bain, and their contemporaries did their work so well that the heat treatment and metallurgy of carbon steel was almost taken for granted.” Certainly, tremendous advances in understanding steels have occurred, but the statement regarding the expertise of Grossmann and Bain still rings true with respect to hardenability, a field in which austenitic grain size is no longer considered a major factor as outlined by Grossmann and Bain. Reasons for this shift are discussed in this second edition of Steels.

Color has been added to the second edition of Steels, in part to highlight microstructural features but also because new characterization techniques, such as EBSD and APT, provide so much data that color is necessary to differentiate various parameters. Almost all chapters have been updated with figures and/or discussion to illustrate structures and phenomena as well as to present new information. In addition to hardenability, the peritectic reaction and other steelpmaking aspects, some new sheet steel developments, microalloying, boron effects, spherical carbide dispersions, new views of tempering, the strengthening components of tempered martensitic steels, pearlitic wire and rail steels, cracking during primary steelp processing, reheat cracking in welds, hydrogen embrittlement, residual-stress development and oxidation in carburizing, and effects of rolling-contact stresses on high-carbon steel microstructures are among the topics that have been added or have received substantial modification. I hope these additions to the tutorial baseline of structures and steel products in the first edition of Steels will be of value to experienced ferrous metallurgists as well as new generations of individuals from many backgrounds in the materials and manufacturing communities that must produce, use, and study steel.

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This edition of Steels is dedicated to the men and women who make, use, study, and design with steel. It is an entry into the broad, dynamic physical metallurgy of steels, with an attempt to summarize the state-of-the-art just past the turn into the twenty-first century. Eleven new chapters expand the coverage in previous editions, and other chapters have been reorganized and brought up to date. The interrelationships between chemistry, processing, structure, and performance, i.e., the elements of physical metallurgy, are integrated for all the types of steel discussed, but as before, descriptions of the evolution, characterization, and performance of steel microstructures, with increased emphasis on deformation and fracture, are major objectives of this text. Heat treatment remains a vital aspect of the manufacture of steel products, and the coverage of thermal processing and its effect on steels is expanded in this edition. However, heat treatment has been dropped from the title of this edition to reflect a broader view of steels. Also, the chapter on cast irons, included in the 1990 edition, has been dropped in view of the sharper focus on steels.

There have been dramatic changes in steel manufacture in the 15 years since the publication of the 1990 edition. Low-carbon sheet steels have experienced the most dynamic changes: thermal processing of sheet steels on a massive continuous scale has produced new grades with only subtle changes in chemistry. Low-carbon sheet steels, together with strengthening mechanisms, developments in microalloyed forging steels, steels with bainitic and a variety of ferritic microstructures, quench and tempered steel performance, high-carbon steels for rail and ultra-high strength wire, and the causes of low toughness and embrittlement are all discussed in new chapters. I have made some brief comments on the history of steel and