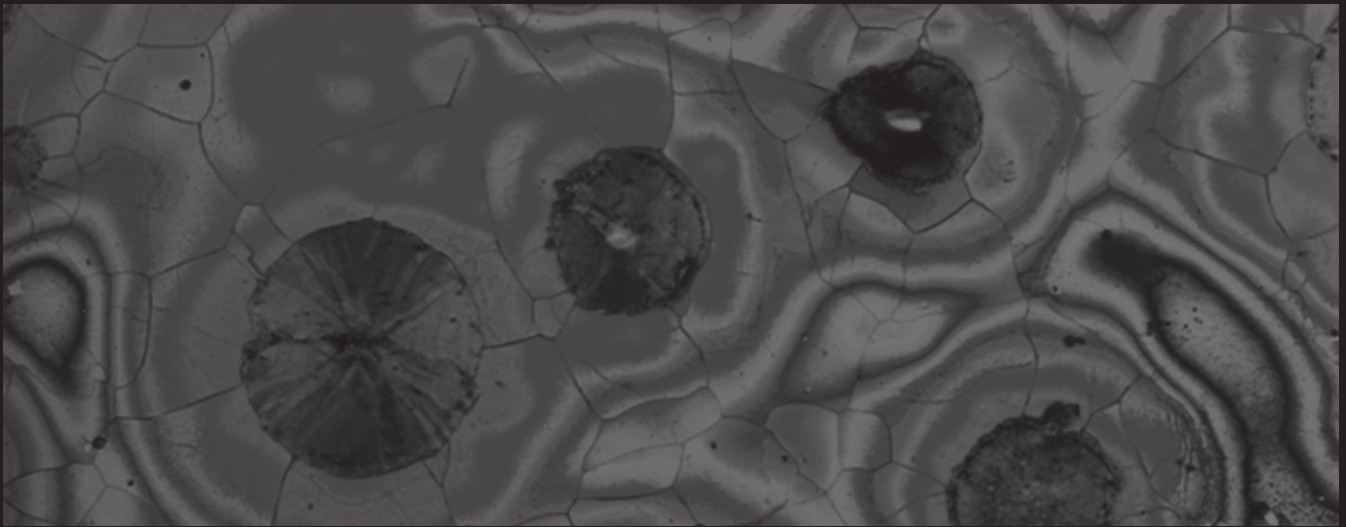


HUBERTUS COLPAERT



# METALLOGRAPHY OF STEELS

Interpretation of Structure and the Effects of Processing

Updated and Translated by André Luiz V. da Costa e Silva



ASM International®  
Materials Park, Ohio 44073-002  
[www.asminternational.org](http://www.asminternational.org)

Originally published and authorized translation from the  
Portuguese language edition as *Metalografia dos Produtos Siderúrgicos Comuns*, 4ª Edição,  
© 2008 by Editora Blucher

Copyright © 2018 by ASM International®  
All rights reserved. Published 2018

No part of this book may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the written permission of the copyright owner.

First printing, August 2018

Great care is taken in the compilation and production of this book, but it should be made clear that NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE GIVEN IN CONNECTION WITH THIS PUBLICATION. Although this information is believed to be accurate by ASM, ASM cannot guarantee that favorable results will be obtained from the use of this publication alone. This publication is intended for use by persons having technical skill, at their sole discretion and risk. Since the conditions of product or material use are outside of ASM's control, ASM assumes no liability or obligation in connection with any use of this information. No claim of any kind, whether as to products or information in this publication, and whether or not based on negligence, shall be greater in amount than the purchase price of this product or publication in respect of which damages are claimed. THE REMEDY HEREBY PROVIDED SHALL BE THE EXCLUSIVE AND SOLE REMEDY OF BUYER, AND IN NO EVENT SHALL EITHER PARTY BE LIABLE FOR SPECIAL, INDIRECT OR CONSEQUENTIAL DAMAGES WHETHER OR NOT CAUSED BY OR RESULTING FROM THE NEGLIGENCE OF SUCH PARTY. As with any material, evaluation of the material under end-use conditions prior to specification is essential. Therefore, specific testing under actual conditions is recommended.

Nothing contained in this book shall be construed as a grant of any right of manufacture, sale, use, or reproduction, in connection with any method, process, apparatus, product, composition, or system, whether or not covered by letters patent, copyright, or trademark, and nothing contained in this book shall be construed as a defense against any alleged infringement of letters patent, copyright, or trademark, or as a defense against liability for such infringement.

Comments, criticisms, and suggestions are invited, and should be forwarded to ASM International.

*Prepared under the direction of the ASM International Technical Book Committee (2017–2018),  
Steve Yue, Chair.*

*ASM International staff who worked on this project include Scott Henry, Senior Manager; Karen Marken, Senior Managing Editor; Amy Nolan, Content Developer; Madrid Tramble, Manager of Production; Jennifer Kelly, Production Coordinator*

*Editorial assistance by Scott Ryan and Lilla Ryan*

Library of Congress Control Number: 2017950638  
ISBN-13: 978-1-62708-148-1 (print)  
ISBN-10: 1-62708-148-8  
ISBN: 978-1-62708-149-8 (pdf)  
SAN: 204-7586

ASM International®  
Materials Park, OH 44073-0002  
[www.asminternational.org](http://www.asminternational.org)

Printed in the United States of America

ON THE COVER: Ductile cast iron, annealed. The etchant reveals silicon segregation. Silicon content decreases as the distance from the graphite nodule increases. Etched with sodium hydroxide (NaOH), picric acid, and potassium metabisulfite in 100 ml distilled water. Courtesy of J. Radzikowska, Foundry Research Institute, Krakow, Poland.

# Contents

---

Foreword	vii
Preface to the Fourth Edition	ix
Preface to the Second Edition	xiii
Preface to the First Edition	xv
About the Editor	xvii
<b>Chapter 1 Steel as a Material</b>	<b>1</b>
1.1 Steels and Cast Irons	2
1.2 Structure	2
1.3 Crystal Structure of Iron-Based Alloys	3
1.4 Steel Characterization	4
1.5 Chemical Composition of Steels	5
<b>Chapter 2 Processes in Steel Production</b>	<b>9</b>
2.1 Reduction Processes	10
2.2 Steelmaking	14
2.3 Secondary Remelting Processes	23
<b>Chapter 3 Introduction to Metallographic Technique</b>	<b>25</b>
3.1 Grains in Metals	25
3.2 Stereology	28
<b>Chapter 4 Metallographic Technique—Macrography</b>	<b>39</b>
4.1 Sample Preparation for Macrographic Examination	39
<b>Chapter 5 Metallographic Technique—Micrography</b>	<b>69</b>
5.1 Optical Microscopy	69
<b>Chapter 6 Metallographic Technique— Electron Microscopy and Other Advanced Techniques</b>	<b>85</b>
6.1 The Scanning Electron Microscope	87
6.2 The Transmission Electron Microscope	92

6.3 Scanning Transmission Electron Microscopy	93
6.4 Atom Probe Tomography	94
6.5 Atomic Force Microscopy	96
6.6 Laser Scanning Confocal Microscopy	97
<b>Chapter 7 Equilibrium Phases and Constituents in the Fe-C System</b>	<b>101</b>
7.1 The Phases of Iron and Its Alloys	102
7.2 Ferrite	104
7.3 Austenite	106
7.4 Cementite	109
7.5 Pearlite	111
7.6 Intermediate Structures—Hypo-Eutectoid and Hyper-Eutectoid	118
<b>Chapter 8 Solidification, Segregation, and Nonmetallic Inclusions</b>	<b>129</b>
8.1 Continuous Casting and Ingot Casting	130
8.2 Solidification Shrinkage	130
8.3 Segregation	132
8.4 Microporosity	150
8.5 Segregation in Steel Products	151
8.6 Hot Cracking	158
8.7 The Structure of Castings, Ingots, and Continuous Casting Products	158
8.8 Macrosegregation	168
8.9 Monitoring the Quality of Continuous Casting Products	170
8.10 Nonmetallic Inclusions	173
<b>Chapter 9 Conventional Heat Treatments—Usual Constituents and Their Formation</b>	<b>193</b>
9.1 Austenite Decomposition	194
9.2 Austenite and the Measurement of the Austenitic Grain Size	223
9.3 Ferritic Microstructures	240
<b>Chapter 10 Conventional Heat Treatment—Basic Concepts</b>	<b>273</b>
10.1 Annealing	274
10.2 Normalizing	285
10.3 Quenching and Tempering	294
10.4 Tempering	320
10.5 Selective Quenching	332
10.6 Martempering	337
10.7 Austempering	338
10.8 Patenting	338
10.9 Thermochemical Treatments	339
<b>Chapter 11 Hot Working</b>	<b>353</b>
11.1 Hot Working and Cold Working	353
11.2 Main Effects of Hot Working	354
11.3 Forming Finished Parts	388
11.4 Defects in Hot Working	391
<b>Chapter 12 Mechanical Work of Steels—Cold Working</b>	<b>403</b>
12.1 Cold Work	403

---

12.2 The Effects of Subcritical Annealing in Steels for Forming	409
12.3 Crystallographic Texture	411
12.4 Following Recrystallization Using Microscopy	418
12.5 Medium-Carbon Steels	428
12.6 Electrical Steels	428
12.7 Warm Working—Working in the Intercritical Region	430
12.8 Cold Forming of Parts—Fasteners as Examples	433
12.9 Defects in Cold Forming	436
<b>Chapter 13     Advanced Steels for Forming Operations</b>	<b>445</b>
13.1 Low and Extra-Low Carbon Steels (Interstitial-Free)	447
13.2 High-Strength Low Alloy and Carbon-Manganese Structural Steels	447
13.3 Dual-Phase and Complex-Phase (or Multiphase) Steels	447
13.4 Transformation-Induced Plasticity Steels	454
13.5 Ferritic-Bainitic Steels	460
13.6 Steels Subjected to Quenching and Partitioning Heat Treatment	460
13.7 Coatings	462
<b>Chapter 14     Structural Steels and Steels for Pressure Vessels, Piping, and Boilers</b>	<b>475</b>
14.1 Fine-Grained Structural Steels	476
14.2 Quenched and Tempered Structural Steels	476
14.3 Controlled Rolled (Thermomechanical Treatment) Structural Steels	479
14.4 Steel for Concrete Reinforcement	483
14.5 Steels for High-Temperature Pressure Vessels	493
14.6 Welding of Structural Steels—Metallographic Aspects	496
<b>Chapter 15     Engineered Special Bar Quality Steel (Engineering Steels)</b>	<b>519</b>
15.1 Quenched and Tempered Steels	519
15.2 Coatings	532
15.3 Medium and High-Carbon Steels	533
<b>Chapter 16     Stainless Steels</b>	<b>551</b>
16.1 Relationships Between Chemical Composition and Structure	552
16.2 Martensitic Stainless Steels	553
16.3 Ferritic Stainless Steels	554
16.4 Austenitic Stainless Steels	557
16.5 Duplex Stainless Steels (Ferritic-Austenitic)	565
16.6 Precipitation Hardening Stainless Steels	567
16.7 Intercrystalline or Intergranular Corrosion	571
<b>Chapter 17     Cast Irons</b>	<b>583</b>
17.1 White Cast Irons and Gray Cast Irons	586
17.2 White Cast Irons	593
17.3 Gray Cast Irons	598
17.4 Mottled and Chilled Cast Irons	627
17.5 Nodular Cast Iron or Ductile Cast Iron	634
17.6 Compacted Graphite Iron (CGI) or Vermicular Graphite Iron (VG or GGV)	642
17.7 Malleable Cast Irons	645

<b>Chapter 18</b>	<b>Metallographic Evaluation—Guidelines for Performing and Reporting</b>	<b>667</b>
18.1	The Objectives of Metallographic Evaluation	667
18.2	The Measurement of Micro- or Macrostructural Features	668
18.3	Testing a Hypothesis	674
18.4	The Investigation	676
18.5	The Report	678

# Foreword

---

The names of three archaeological eras are described by their dominant structural materials: the stone age, the bronze age, and the iron age. While the metals in the bronze age were obtained by smelting, early use of iron relied on finding the metallic form, mostly from meteorites. Its scarcity, together with its softness and tendency to corrode, limited its application. With time, however, extraction methods from ores and techniques such as surface hardening to improve the properties, broadened the application of iron. The first steel was made in the early iron ages but did not become a significant commodity until the middle of the nineteenth century when Henry Bessemer invented a new steelmaking process, which started the second phase of the industrial revolution. Around the same time, the introduction of microscopic investigation of materials led to a better understanding of steel properties and soon thereafter books on the metallography of steel were being published.

Metallography has a long tradition in Brazil going back to the early twentieth century. Metallography became a pillar in quality control of the construction materials used in the rapid expansion of the Brazilian railway system in the late 1920s. At this time, Hubertus Colpaert, at the Institute of Technological Research in São Paulo, began systematic work on the study of the metallographic characteristics of ferrous metals. In 1951, this work resulted in the publication of the book *Macrographic and Micrographic Metallography of Common Steel Products*. This book offered a unique combination of a metallography atlas, manual of metallographic techniques, and introduction to the fundamentals of phase transformations and thermal treatment of these alloys, and quickly became the most important Brazilian reference book for those working on processing and treatment of ferrous alloys. A second and third editions of this book was published in 1959 and 1969, respectively.

Since the publication of the third edition, advanced microscopy techniques became widely available and a significant number of new steel products have been developed. These developments are reflected in the fourth edition of the book while maintaining the spirit of the original edition, being a unique

combination of a metallography atlas, manual and textbook. For publication of the English edition, the title of the book was changed from the Portuguese original *Metallography of Common Steel Products* to *Metallography of Steels: Interpretation of Structure and the Effect of Processing*. Although this title better indicates that the book offers much more than metallography alone, it still does not fully reflect the rich content of the book.

The editor of the fourth edition, André Costa e Silva, is a professor at the Universidade Federal Fluminense in the Rio de Janeiro area, Brazil. He is an expert in the processing-properties-performance relations in steel with a focus on computational thermodynamics and its applications to steelmaking and advanced steel processing. He is also experienced in specification, inspection and failure analysis of metallic materials.

Ursula R. Kattner  
National Institute of Standards and Technology  
Materials Science and Engineering Division,  
Thermodynamics and Kinetics Group



# Preface to the Fourth Edition

---

**D**uring one semester in 1975, my Tuesday mornings were devoted to preparing, observing, and recording macrographs and micrographs of steels and cast irons under the guidance of Edil Patury Monteiro, with support of the book *Metalografia dos produtos siderúrgicos comuns* by Hubertus Colpaert. At the same time, I was being exposed to the theory of the kinetics of phase transformations with José Roberto Costa Guimarães. From this time on, Colpaert's book became to me—as to many Brazilian students, technicians, and engineers—a fundamental reference in academic and professional life. A very well-balanced mix of textbook and atlas of metallographic structures, for decades the book has been the companion of Brazilian metallographers, metallurgists, and steelmakers. At the end of 2006, when Paulo Mei and I concluded the second edition of *Steels and Specialty Alloys*, I was honored by the invitation from our editor, Edgard Blücher, to consider updating the text and images of the Colpaert's book. The opportunity to collaborate on incorporating technological developments to this outstanding book was an irresistible challenge.

Globally the steel industry is enjoying a time of rare expansion and vigor, with more than 1,400 Mt of steel produced each year and several years of significant increases in production. Furthermore, the production and processing of these iron-based alloys has reached an admirable degree of sophistication and control. In average quality steels, many elements are controlled to the level of parts per million in mass (1 ppm in mass is 1 g in 1 mt!) and the structure of the steels is controlled to a degree of precision never before experienced.

Metallography is one of the essential tools that made it possible to attain this degree of sophistication. It is a tool widely used in the whole field of metallurgy, in particular, for the whole spectrum of iron and steel products, from steel used in nails, springs, nuclear reactors and packaging and to cast irons used in engines, fittings, railroad parts, and so on. Metallographic techniques have evolved along with the steel industry. Besides the use of visible light, techniques that use other types of interactions with matter and in special in-

teractions between electrons and matter have become common. Techniques aimed at quantifying structural features have also greatly evolved, and the past decade has seen a dramatic advance in the techniques of three-dimensional reconstruction of material structures. If during Colpaert's time the breadth of knowledge and experience needed to write such a book were already rare—this being one reason for my respect for his work—in these days it is almost impossible for a single person to have all of the knowledge needed to bring this work up to date. Thus, the help and collaboration of many have been essential to creating an updated version with a depth and breadth comparable to the original work. Luckily the same fascination Colpaert's work exerted over me is present in a whole generation of renowned metallurgists in our country. I met enthusiastic collaboration in companies, universities, and laboratories where people volunteered to help. This has certainly been one of the most interesting technical experiences of my career. A remarkable brotherhood of people interested in steel seems to exist all over the world; indeed, the willingness of people to help me, in Brazil and abroad, was outstanding.

To all of these collaborators, who have given essential contributions to this project, I offer my thanks in the next section.

Due to the difficult decision that had to be made regarding which images of the previous editions should be replaced or removed, Editora Blucher kept all of the old images available at their website.

I hope this revised and updated edition may be as useful to today's metallurgists as the previous editions have been to me, and to a whole generation of enthusiasts of steel and cast iron development.

## ***Acknowledgments***

It is extremely difficult to decide the proper order for acknowledging all who helped me on this project. Each of the groups or individuals have in some way contributed to the success of this work. Some helped with images, some with encouragement, and others with discussions and suggestions.

In the first place, I must thank Edgard Blücher and Hubertus Colpaert's family for trusting me with this task and staying with me along the way.

The support of colleagues from the steel industry in Brazil and other countries, with images and enlightening discussions, has been essential to this project. I present them by alphabetical order of the companies (using the company names in 2008).

In Brazil: Sergio Augusto de Almeida Ferreira, ArcelorMittal Aços Longos—Juiz de Fora; Francisco Boratto, ArcelorMittal Monlevade; Jardel Prata Ferreira and João Batista Ribeiro Martins, ArcelorMittal Brasil (Tubarão); Carlos Henrique Lopes, BR Metals Fundições Ltda.; Fátima Cunha, CBV-FMC—Rio de Janeiro; Walter da Costa Reis, Antonio Augusto Martins, Nilza Cristina S.B. Zwirman and Simone Pereira Santos, CSN—Volta Redonda; Luiz Antonio Iapichini and Cícero Tavares, FIBAM Cia. Industrial Ltda.—São Bernardo do Campo; Henrique Aché Pillar, MRS Logística—Rio de Janeiro; Mauro Souza, Neumayer-Tekfor—Jundiaí; Marcelo M. Moraes, NUCLEP—Itaguaí; Gerson Ronelli, PL Fundação e Serviços Ltda.; Marcelo Martins, Sulzer-Fundinox—Jundiaí; Wilson Guesser, Tupy Fundições S.A.—Joinville; Antonio Sérgio Fonseca, Alfredo Figueiredo, Ricardo Nolasco and Osvaldo Neto, V&M Tubes do Brasil—

Belo Horizonte; Marcos Stuart, Edson Mendes Vieira, Celso Barbosa, Leonardo Sandor, Ismael Polidori, and Cristiane S. Gonçalves, Villares Metals S.A.—Sumaré.

Outside of Brazil: M. Nishimura, Daido-Steel Co., Japan; James Casey, Do-fasco, Canada; Giorgio Polonioli, Metalcam, Italy (Breno); Tooru Matsumiya and Masaaki Sugiyama, Nippon Steel, Japan; Carlos Cicutti, Tenaris, CINI, Argentina.

Laboratories: Research institutes and academia in Brazil and abroad have been very generous, sharing images, clarifying points, and showing great patience with my many urgings and requests.

Following is the alphabetical order of countries.

Belgium: Frans Mampaey, Sirris.

Brazil: André Pinto, Instituto Militar de Engenharia—Rio de Janeiro; Annelise Zeemann, Tecmetal—Rio de Janeiro; Antonio Gorni; Antonio Jorge Abdala, IEAv, CTA—São José dos Campos; Antonio Ramirez, LNLS—Campinas; Carlos de Moura Neto, CTA—São José dos Campos; Carlos Sérgio da Costa Viana, Paulo Rangel Rios, Tânia Nogueira, and Carlos Xavier, EEIMVR-UFF—Volta Redonda; Fernando Rizzo, PUC-Rio; Fernando Landgraf and Hélio Goldenstein, USP—São Paulo; Luiz Henrique Dias Alves; Margareth Spangler Andrade, CETEC—Belo Horizonte; Hans-Jurgen Kestenbach, UFSCar—São Carlos; Ibrahim Cerqueira Abud, INT—Rio de Janeiro; Ronaldo Antônio Neves Barbosa and Dagoberto Santos, UFMG—Belo Horizonte.

Canada: Alec Mitchell, University of British Columbia, Vancouver.

England: Graham Thewlis, South Yorkshire; H.K.D.H. Bhadeshia and Bill Clyne, University of Cambridge.

France: Bernard Marini and Caroline Toffolon, CEA; Jacques Lacaze, CIRI-MAT, NSIACET, Toulouse.

Germany: Dietmar Lober; H.W. Viehrig, FZD, Dresden; Frank Mücklich and Alexandra Velichko, Universitaet des Saarlandes, Saarbruecken.

Italy: Paolo Emilio Di Nunzio, CSM, Roma; Stefania Bruschi, Università degli Studi di Padova, Padova.

Japan: S. Mizoguchi; Toshi Emi, IRIS, Sha-Steel; Fujio Abe, National Institute for Materials Science (NIMS); Kiyohito Ishida, Tohoku University.

Netherlands: Jilt Sietsma, Technische Universiteit Delft.

New Zealand: Milo Kral, University of Canterbury, Christchurch.

Poland: Leszek Zabdyr; Janina Radzikowska, Polish Foundry Research Institute, —Krakow.

South Korea: Sunghak Lee, Pohang University.

Spain, Tomas Gómez-Acebo, San Sebastian; Jon Sertucha, AZTERLAN—Durango; Carlos García de Andrés, Carlos Garcia-Mateo, Carlos Capdevila Montes, and Francisca G. Caballero, Materialia Research Group, CENIM-CSIC—Madrid.

Sweden: Mats Hillert and Malin Seleby, KTH, Stockholm.

United States: Sridhar Seetharaman and Eric Schmidt, Carnegie Mellon University, Pittsburgh; George Krauss, John Speer, Michael (Mike) Kaufman, John Chandler, Colorado School of Mines, Golden; Scott Chumbley, Iowa State University, Ames; Stephen W. Banovic and Ursula Kattner, NIST, Gaithersburg; Doru M. Stefanescu, Ohio State University, Columbus; Donald Koss and Zi-Kui Liu, Penn State University, State College; Alan Cramb, Rensselaer Polytechnic Institute, Troy; Donald Susan, Sandia National Laboratories, Al-

buquerque; Robert DeHoff, University of Florida, Gainesville; Christoph Beckermann, University of Iowa, Iowa City; Roger K. Pabian, University of Nebraska, Lincoln.

I thank all of you for the friendship, support, encouragement, suggestions, advice, patience, and interest in sharing your remarkable knowledge about metallography and iron and steel products. This has made a tremendous difference in this new edition. To anyone I might have forgotten, my apologies and my thanks!

Whenever possible, I have tried to give the proper credit in all images and refer to the proper texts used as the basis of this publication. There will likely be mistakes, for which I apologize in advance.

Finally, I thank my family for the support, patience, and encouragement over the long nights and weekends dedicated to this project.

André Luiz V. da Costa e Silva  
*Rio de Janeiro, August 2008*

# Preface to the Second Edition

---

**P**ublished in mid-1951 by the *Instituto de Pesquisas Tecnológicas (IPT-SP)* [Technological Research Institute of São Paulo State], Bulletin no. 40 about the metallography of common iron and steel products has helped fulfill an important demand in the mechanical and metallurgical sectors, which needed a technical book that could serve as a manual for solving problems related to the properties and applications of iron and steel products.

Notwithstanding the fact that it has been solely distributed by *IPT-SP*, the first edition went out of stock in a few years, due to its high technical and scientific quality and the excellent documentation, all in a very didactic presentation format.

Although the guidelines to be adopted for the second edition had already been defined, the sudden passing away of the author in January 1957 rendered impossible the satisfactory conclusion of the revised work.

Having had the opportunity to collaborate with Colpaert for more than 12 years, having followed the lecture notes prepared by him that led to Bulletin no. 40, and being familiar with the use of this publication as a textbook, I was honored with the task of performing the revisions needed for this second edition.

In the first edition, some of the fundamental principles were presented in a simplified manner or even omitted. During use as a textbook, it was noted that this simplification in some chapters, such as the one on micrography and heat treatment, ended up creating barriers to the best understanding. This classroom experience suggested a complete revision of these chapters, particularly the one focused on heat treatments. The simplified presentation of transformation diagrams in the austenite decomposition processes that in the first edition was made in the form of a “critical segment” was replaced with the presentation of isothermal and continuous cooling transformation diagrams. The atomic mechanisms involved in these processes were discussed in more detail so that the changes observed by the metallographic examination could be better understood.

The chapter on cast irons could not be further improved because due to the complexity of the subject, from a didactic point of view, a simplified pre-

sentation that would offer a first view acting as a basis for further studies was preferred to a detailed discussion of the graphitization processes, which could make the text almost inaccessible to those being introduced to the subject.

Alberto Albuquerque Arantes  
*São Paulo, November 1959*

# Preface to the First Edition

---

**D**uring the recent and solemn commemoration of the 50th anniversary of this Instituto de Pesquisas Tecnológicas [Technological Research Institute], the beginning and the further development of various technological sectors of the institute were remembered. Among these, the field of microscopic metallography has received deserved attention; having started almost at the same time as this field was developed in Europe, it is one of the oldest in the institute.

It is an important fact that in 1910, the head of the Office of Strength of Materials, Hippolyto Pujol Jr., was already teaching and applying in the country such a novel science, far in advance of our industrial development. In 1926, it was up to Ary Frederico Torres to give further drive to these studies, creating strong interest and promoting the specialization of many students from the Polytechnic School [today the Polytechnic School of the University of São Paulo]. The author of this volume was among those and in 1928 was raised to the position of head of the Metallography Section.

In the past 25 years, the application and research work performed in the Metallography Section of IPT has resulted in a very refined technique and precise documentation with more than 10,000 macrographs and micrographs.

In addition to these activities, focused on the industrial segment, the Metallography Section has paid special attention to education, either teaching the students in various courses of the Polytechnic School or opening opportunities for interns who come here in search of deeper knowledge.

Among the educational resources, one that has been extremely successful is the distribution of illustrated pamphlets condensing the subjects presented in class. The simple and accessible presentation, not only of the metallographic technique but also of the laws and basic metallurgical facts—indispensable to the understanding of metallography and useful to the steel industry—quickly garnered great interest. This intertwining of steelmaking and processing concepts with specialized metallographic concepts may seem

strange at first, but at least in our community and for the time being, this is the orientation that has proven most efficient for the desired objectives.

After various successive editions of these pamphlets, and faced with an ever-increasing demand and the growing collection of experiments, the institute has decided to publish its material in a more permanent form and in more copies, asking the author himself to collect them, after revision and considerable expansion of the illustrations, in a printed volume that came to be the present bulletin.

Maintaining the initial aim, certain theoretical concepts are presented in a simplified way while others are omitted, not because they are useless but because they can be dispensed of in view of the character and aim of this publication.

To those wishing to research the problem more deeply, the cited bibliography, however small, offers additional information. After the bibliography, the conference proceedings and the specialized journals are yet additional sources which the reader can make use of to get properly familiarized with this constantly evolving science.

The macrographs and micrographs that were reprinted in Bulletin no. 40 were selected as among the most significant cases studied in the section. For each type of occurrence, many examples were presented to illustrate the variability that certain aspects may present and to warn the less experienced metallographer about the risk of possible confusion. In the choice and presentation of this vast documentation, it was our intention to offer to those interested a real atlas of “standard aspects” that could help in interpreting cases one might face in practice. Furthermore, there was always the aim of presenting the original documents in the best way possible, without reduction and with maximum sharpness, to make it easier for the reader to properly appreciate the features in the structures.

In the course of the text, the main errors related to technique and interpretation are discussed, along with their consequences and how to avoid them.

With the goals above described, the Instituto de Pesquisas Tecnológicas hopes to have extended the usefulness of this publication to all, whether in the plant or in the laboratory, who apply metallography.

Hubertus Colpaert  
*São Paulo, June 1951*



# About the Editor

---

**A**ndré Luiz V. da Costa e Silva graduated as a metallurgical engineer from the Military Institute of Engineering (IME), Rio de Janeiro, in 1976. He earned his M.A.Sc. from the University of British Columbia, Vancouver, in 1979 and his Ph.D. from the University of Florida, Gainesville, in 1994. His career started as an engineer in Eletrometal Aços Finos S.A. (currently Villares Metals S.A.). He was the materials engineering manager at CBV Industria Mecanica S.A. (Currently TechnipFMC plc) and took part in pioneer projects on deepwater oil-field completion and production. He was technical director of the Brazilian Institute for Nuclear Quality, where he was certified as a Level III Inspector and a Level III Expert in the Engineering Materials area. He is currently professor at the Metallurgical Engineering School in Volta Redonda, Universidade Federal Fluminense.

His main professional interests are the processing-properties relationships in materials and the application of computational thermodynamics to the processing and development of materials in special steels and superalloys, areas in which he consults for many organizations. He has published three books on steels and has more than 205 publications. André was the chair of the Alloy Phase Diagram International Commission (APDIC) from 2008 to 2013. He was awarded the 2014 Hume Rothery Award, for distinguished achievements in relation to phase transformations by IOM<sup>3</sup>, England, and in 2017 became the fifteenth recipient of the triennial Hubertus Colpaert Silver Medal for his contribution in metallography and physical metallurgy by ABM, Brazil. He is a member of ASM International, ABM, and TMS. André is married and has one daughter and two grandchildren.

