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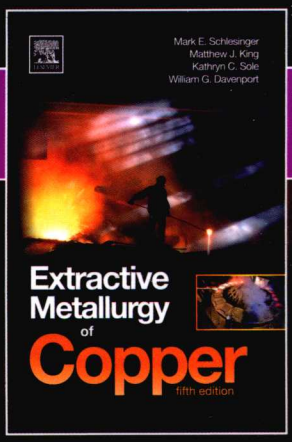

Mark E. Schlesinger,
Matthew J. King,
Kathryn C. Sole,
William G. Davenport 著

铜提取冶金（第5版）

Extractive Metallurgy of Copper (Fifth Edition)

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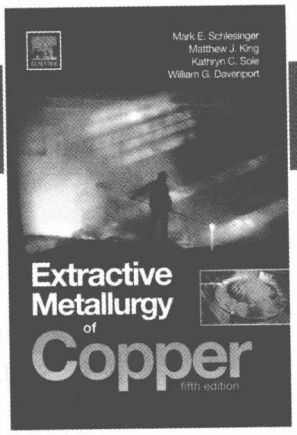

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内容简介

本书主要介绍了从矿石和废料中提取铜的基本原理和先进技术。借鉴大量的国际先进企业经验，全面阐述了从原矿和二次资源提取铜再到铜材产品的系统生产工艺。

本书实用性强，特别介绍了目前广泛应用的粗铜精炼技术，增加的内容有：硫化铜矿澳斯麦特炉和艾萨炉先进熔炼技术、硫化精矿湿法冶金技术、副产品（贵金属）回收和环境保护、电子废料回收、风能和太阳能传输用铜电缆生产。

本书适用于从事冶金、化工和环境等专业研究人员以及企业工程师使用。

作者简介

Mark E. Schlesinger 博士，美国密苏里科技大学环境科学与技术中心、材料研究中心教授。1980 年获密苏里大学罗拉分校冶金工程学士学位，1985 年获亚利桑那大学材料科学与工程硕士学位，1988 年获亚利桑那大学材料科学与工程博士学位。曾在美国犹他大学、密苏里大学罗拉分校任教。曾荣获多项研究及教育奖励。2014 年起担任 TMS – AIME 指导委员会成员。

Preface

The preceding nine years have seen significant changes in the way that copper metal is produced. The most important change is the continuing high price of copper. It has been some time since the industry as a whole has enjoyed such success. This has led to an expansion of the industry, and the list of mines and production facilities is considerably changed from the previous edition.

Technology changes have occurred as well. The most notable of these include:

- The continuing adoption of high-intensity bath smelting for both primary concentrates and secondary materials;
- Significant increase in the use of hydrometallurgical processing technology for sulfide concentrates;
- New technology to mitigate the environmental impact of copper ore mining and processing.

These changes are reflected in this edition, along with expanded coverage of byproduct recovery (important when gold prices are US $1400/oz!) and secondary copper recovery and processing. The continuing search for a replacement for the Peirce–Smith converter is also featured. The day is getting closer when this venerable device will belong to the past!

There has also been a change in the group of conspirators behind this book. We welcome to the group Dr. Kathryn C. Sole from South Africa. Kathy specializes in hydrometallurgical process development, and the addition of her expertise is important to three old-fashioned pyrometallurgists. She improves the diversity of the group in more ways than one!

As with previous efforts, this edition of *Extractive Metallurgy of Copper* is largely a product of the copper industry as a whole, since so many engineers and scientists volunteered their time and expertise (along with photographs and drawings) to make sure we got it right. Our mentors and assistants included:

- Peter Amelunxen and Roger Amelunxen (Amelunxen Mineral Engineering)
- Mike Bernard (Terra Nova Technologies)
- Elizabeth Bowes, Shingefei Gan, Ursula Mostert, Sandip Naik, Ian Ralston, Bernardo Soto, and Gabriel Zárate (Anglo American)
- Alistair Burrows (ISASMELT)
- Leszek Byszyński (KGHM)
- Connie Callahan, James Davis III, David Jones, Steve Koski, Michael Lam, John Quinn, and Cory Stevens (Freeport-McMoRan)
- John Joven S. Chiong (PASAR)
- Felix Conrad (Aurubis AG)
- Frank Crundwell (Crundwell Management Solutions)

- Angus Feather (BASF, formerly Cognis)
- Phil Donaldson (Xstrata Technologies)
- Jim Finch (McGill University)
- Mark Firestein (Bateman-Litwin)
- David George-Kennedy, Art Johnston, David Kripner, and Mark Taylor (Rio Tinto)
- Tom Gonzalez (Hatch)
- J. Brent Hiskey (University of Arizona)
- Nicholas Hogan (Incitec Pivot)
- Kun Huang (Chinese Academy of Sciences)
- John Hugens (Fives North American Combustion)
- Cyrus Kets (Moonshine Advertising)
- Hannu Laitala, Robert Matusewicz, Lauri Palmu, and Markus Reuter (Outotec Oyj)
- Pascal Larouche (Xstrata Copper)
- Theo Lehner (Boliden Mineral AB)
- Pierre Louis (PEL Consulting)
- Guangsheng Luo (Tsinghua University)
- Phil Mackey (P.J. Mackey Technology)
- Dennis Marschall (Kazakhmys PLC)
- Michael Nicol (Murdoch University)
- Jan W. Matousek (Chlumsky, Armbrust and Meyer)
- Graeme Miller (Miller Metallurgical Services)
- Michael Moats (University of Utah)
- Tony Moore (MMG Sepon)
- Enock Mponda and Charles Shonongo (Konkola Copper Mines)
- Keith Mathole and Tlengelani Muhlare (Palabora Mining)
- V. Ramachandran (RAM Consultants)
- Tim Robinson (Republic Alternative Technologies)
- Helge Rosenberg (Haldor Topsøe)
- Stefan Salzmann (Bamag)
- Heguri Shinichi (Sumitomo)
- Edwin Slonim (Turbulent Technologies)
- Matthew Soderstrom and Owen Tinkler (Cytec Industries)
- Gary Spence (Encore Wire)
- Nathan Stubina (Barrick)
- Ilya Terentiev (Consultant)
- Mark Vancas (Bateman Engineering)
- Craig van der Merwe (First Quantum Minerals)
- Rob West (BHP Billiton)
- Yutaka Yasuda (Hibi Kyodo Smelting)
- Roe-Hoan Yoon (Virginia Polytechnic Institute)

The fifth edition of *Extractive Metallurgy of Copper* is dedicated to the memory of Prof. Akira Yazawa (1926–2010). Professor Yazawa performed pioneering research on the fundamentals of copper smelting and converting in the 1950s, and continued to make contributions well into this century. His original work is still referenced in this volume, and will likely continue to be in editions to come.

Preface to the Fourth Edition

This edition contains more-than-ever industrial information, all of it provided generously by our industrial friends and colleagues. We thank them profusely for their help and generosity over the years.

The publication we consulted most for this edition was *Copper 99/Cobre99* (TMS, Warrendale, PA [six volumes]). For a near-future update, we direct the reader to *Copper 03/Cobre 03* being held in Santiago, Chile, November 30, 2003 (www.cu2003.cl).

As with previous editions, Margaret Davenport read every word of our manuscript. After 27 years of proofreading, she may well know more than the authors.

Preface to the Third Edition

This edition chronicles the changes which have taken place in copper extraction over the last 20 years. The major changes have been the shrinkage of reverberatory smelting, the continued growth of flash smelting and the remarkable (and continuing) growth of solvent extraction/electrowinning. The use of stainless steel cathodes (instead of copper starting sheets) in electrorefining and electrowinning has also been a significant development.

These industrial growth areas receive considerable attention in this edition as do SO_2 collection and sulphuric acid manufacture. SO_2 capture has continued to grow in importance – only a few smelters now emit their SO_2 to the atmosphere.

Several important volumes on copper extraction have appeared recently, namely: *Copper 91/Cobre 91* (Pergamon Press, New York [four volumes]) and *Extractive Metallurgy of Copper, Nickel and Cobolt* (TMS, Warrendale, Pennsylvania [two volumes]). A volume on Converting, *Fire-refining and Casting* is scheduled to appear in 1994 (TMS) and the proceedings of *Cobre95/Copper 95* will appear in 1995. The reader is directed to these publications for updated information.

We wish to thank our colleagues in the copper industry for their many contributions to this edition. They have responded to our questions, encouraged us to visit their plants and engaged us in rigorous debate regarding extraction optimization. We would particularly like to thank Brian Felske (Felske and Associates), David Jones (Magma Copper Company) and Eric Partelpoeg (Phelps Dodge Mining Company). Without them this edition would not have been possible.

The manuscript was prepared and proofed by Patricia Davenport and Margaret Davenport. Their perseverance, skill and enthusiasm are happily acknowledged.

Preface to the Second Edition

For this edition we have concentrated mainly on bringing the operating data and process descriptions of the first edition up to date. Typographical errors have been corrected and several passages have been rewritten to avoid misinterpretation. Since most of the new data have come directly from operating plants, very few new references have been added. For collections of recent published information, the reader is directed to the excellent symposium publications: Extractive Metallurgy of Copper, Volumes I and II, Yannopoulos, J. C. and Agarwal, J. C. editors, A.I.M.E., New York, 1976, Copper and Nickel Converters, Johnson, R.E., A.I.M.E., New York, 1979, and to the reviews of copper technology and extractive metallurgy published annually in the *Journal of Metals* (A.I.M.E., New York). Most of the credit for this edition should go to the many industrial engineers and scientists who almost without exception responded to our requests for new information on their processes. We would like in particular to single out Jan Matousek of INCO, Keith Murden of Outokumpu Oy and John Schloen of Canadian Copper Refiners (now a metallurgical consultant) for their help.

September 1979

A. K. Biswas
W. G. Davenport

Preface to the First Edition

This book describes the extraction of copper from its ores. The starting point is with copper ores and minerals and the finishing point is the casting and quality control of electrical grade copper. Techniques for recovering copper from recycled scrap are also discussed.

The main objectives of the book are to describe the extractive metallurgy of copper as it is today and to discuss (qualitatively and quantitatively) the reasons for using each particular process. Arising from these descriptions and discussions are indications as to how copper-extraction methods will develop in the future. Control of air and water pollution is of tremendous importance when considering future developments and these are discussed in detail for each process. Likewise, the energy demands of each process are dealt with in detail. Costs are mentioned throughout the text and they are considered in depth in the final chapter.

The book begins with an introductory synopsis (for the generalist reader) of the major copper-extraction processes. It then follows copper extraction in a stepwise fashion beginning with mineral benefication and advancing through roasting, smelting, converting, refining, casting and quality control. Hydrometallurgy and its associated processes are introduced just before electrorefining so that electrowinning and electrorefining can be discussed side by side and the final products of each method compared. The last two chapters are not in sequence — they are devoted to the sulphur pollution problem and to economics.

As far as possible, the length of each chapter is commensurate with the relative importance of the process it describes. Blast-furnace copper smelting is, for example, given a rather brief treatment because it is a dying process while newer techniques such a continuous copper-making and solvent extraction are given extensive coverage because they may assume considerable importance in the near future.

A word about units: the book is metric throughout, the only major exception to the Standard International Unit System being that energy is reported in terms of kilocalories and kilowatt-hours. The principal units of the book are metric tons (always written tonnes in the text), kilograms and metres. A conversion table is provided in Appendix I. A knowledge of thermodynamics is assumed in parts of the book, particularly with respect to equilibrium constants. For concise information on the thermodynamic method as applied to metallurgy, the reader is directed to *Metallurgical Thermochemistry* by O. Kubaschewski, E. L. Evans and C. B. Alcock, an earlier volume in this series.

The text of the book is followed by four appendixes which contain units and conversion factors: stoichiometric data; enthalpy and free energy data; and a summary of the properties of electrolytic tough pitch copper.

Copper is one of man's most beautiful and useful materials. It has given us great satisfaction to describe and discuss the methods by which it is obtained. Both of our universities have had a long association with the copper industries of our countries, and it is hoped that, through this book, this association will continue.

A. K. Biswas
University of Queensland

W. G. Davenport
McGill University

目　录