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Materials Handbook

A Concise Desktop Reference

2nd Edition

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Dedication for the First Edition

The ***Materials Handbook: A Concise Desktop Reference*** is dedicated to my father, Antonio, and my mother, Claudine, to my sister, Elsa, and to my spouse Louise Saint-Amour for their love and support. I want also to express my thanks to my two parents and my uncle Consalvo Cardarelli, which in close collaboration have provided valuable financial support when I was a teenager to contribute to my first fully equipped geological and chemical laboratory and to my personal comprehensive scientific library. This was the starting point of my strong and extensive interest in both science and technology, and excessive consumption of scientific and technical literature.

François Cardarelli

Dedication for the Second Edition

The ***Materials Handbook: A Concise Desktop Reference*** is dedicated to my father, Antonio, and my mother, Claudine, to my sister, Elsa, and to my wife Elizabeth I.R. Cardarelli for their love and support. I want also to express my thanks to my two parents and my uncle Consalvo Cardarelli, which in close collaboration have provided valuable financial support when I was a teenager to contribute to my first fully equipped geological and chemical laboratory and to my personal comprehensive scientific library. This was the starting point of my strong and extensive interest in both science and technology, and excessive consumption of scientific and technical literature.

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Acknowledgements for the Second Edition

Mr. Anthony Doyle (senior engineering editor), Mr. Oliver Jackson (associate engineering editor), and Mr. Nicolas Wilson (editorial coordinator) are gratefully acknowledged for their valued assistance, patience, and advice.

Units Policy

In this book the only units of measure used for describing physical quantities and properties of materials are those recommended by the *Système International d'Unités* (SI). For accurate conversion factors between these units and the other non-SI units (e.g., cgs, fps, Imperial, and US customary), please refer to the reference book by the same author:

Cardarelli, F. (2005) *Encyclopaedia of Scientific Units, Weights, and Measures. Their SI Equivalences and Origins*. Springer, London New York. ISBN 978-1-85233-682-1.

Author Biography

Dr. François Cardarelli (Ph.D.)
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Canadian citizen

Academic Background

- Ph.D., chemical engineering (Université Paul Sabatier, Toulouse, France, 1996)
- Postgraduate degree (DEA) in electrochemistry (Université Pierre et Marie Curie, Paris, 1992)
- M.Sc. (Maîtrise), physical chemistry (Université Pierre et Marie Curie, Paris, 1991)
- B.Sc. (Licence), physical chemistry (Université Pierre et Marie Curie, Paris, 1990)
- DEST credits in nuclear sciences and technologies (Conservatoire National des Arts et Métiers, Paris, 1988)

- Associate degree (DEUG B) in geophysics and geology (Université Pierre et Marie Curie, Paris, 1987)
- Baccalaureate C (mathematics, physics, and chemistry) (CNED, Versailles, France, 1985)

Fields of Professional Activity

The author has worked in the following areas (in chronological order) since 1990.

(1) Research scientist at the Laboratory of Electrochemistry (Université Pierre & Marie Curie, Paris, France) for the development of a nuclear detector device for electrochemical experiments involving radiolabeled compounds;

(2) research scientist at the Institute of Marine Biogeochemistry (CNRS & École Normale Supérieure, Paris, France) for the environmental monitoring of heavy-metal pollution by electroanalytical techniques;

(3) research scientist for the preparation by electrochemistry in molten salts of tantalum protective thin coatings for the chemical-process industries (sponsored by Electricité de France);

(4) research scientist for the preparation and characterization of iridium-based industrial electrodes for oxygen evolution in acidic media at the Laboratory of Electrochemical Engineering (Université Paul Sabatier, Toulouse, France);

(5) registered consultant in chemical and electrochemical engineering (Toulouse, France);

(6) battery product leader in the technology department of ARGOTECH Productions, Boucherville (Québec), Canada, in charge of electric-vehicle, stationary, and oil-drilling applications of lithium polymer batteries;

(7) materials expert and industrial electrochemist in the lithium department of ARGOTECH Productions, involved in both the metallurgy and processing of lithium metal anodes and the recycling of spent lithium polymer batteries;

(8) materials expert and industrial electrochemist in the technology department of AVESTOR, Boucherville (Quebec), Canada, in charge of all strategic raw materials entering into the fabrication of lithium polymer batteries, as well as being in charge of the recycling process of spent lithium batteries;

(9) principal chemist, materials, in the technology department of RIO TINTO Iron and Titanium, Sorel–Tracy (Québec), Canada working on the electrowinning of titanium metal from titania-rich slags and on other novel electrochemical processes;

(10) principal electrochemist at Materials and Electrochemical Research (MER) Corp., Tuscon (Arizona, USA) working on the electrowinning of titanium metal powder from composite anodes and other materials related projects.

Contents

Introduction

Despite the wide availability of several comprehensive series in materials sciences and metallurgy, it is difficult to find grouped properties either on metals and alloys, traditional and advanced ceramics, refractories, polymers and elastomers, composites, minerals and rocks, soils, woods, cement, and building materials in a single-volume source book.

Actually, the purpose of this practical and concise reference book is to provide key scientific and technical materials properties and data to materials scientists, metallurgists, engineers, chemists, and physicists as well as to professors, technicians, and students working in a broad range of scientific and technical fields.

The classes of materials described in this handbook are as follows:

(i) metals and their alloys;
(ii) semiconductors;
(iii) superconductors;
(iv) magnetic materials;
(v) dielectrics and insulators;
(vi) miscellaneous electrical materials (e.g., resistors, thermocouples, and industrial electrode materials);
(vii) ceramics, refractories, and glasses;
(viii) polymers and elastomers;
(ix) minerals, ores, and gemstones;
(x) rocks and meteorites;
(xi) soils and fertilizers;
(xii) timbers and woods;
(xiii) cement and concrete;
(xiv) building materials;
(xv) fuels, propellants, and explosives;

(xvi) composites;
(xvii) gases;
(xviii) liquids.

Particular emphasis is placed on the properties of the most common industrial materials in each class. The physical and chemical properties usually listed for each material are as follows:

(i) physical (e.g., density, viscosity, surface tension);
(ii) mechanical (e.g., elastic moduli, Poisson's ratio, yield and tensile strength, hardness, fracture toughness);
(iii) thermal (e.g., melting and boiling point, thermal conductivity, specific heat capacity, coefficients of thermal expansion, spectral emissivities);
(iv) electrical (e.g., resistivity, relative permittivity, loss tangent factor);
(v) magnetic (e.g., magnetization, permeability, retentivity, coercivity, Hall constant);
(vi) optical (e.g., refractive indices, reflective index, dispersion, transmittance);
(vii) electrochemical (e.g., Nernst standard electrode potential, Tafel slopes, specific capacity, overpotential);
(viii) miscellaneous (e.g., relative abundances, electron work function, thermal neutron cross section, Richardson constant, activity, corrosion rate, flammability limits).

Finally, detailed appendices provide additional information (e.g., properties of the pure chemical elements, thermochemical data, crystallographic calculations, radioactivity calculations, prices of metals, industrial minerals and commodities), and an extensive bibliography completes this comprehensive guide. The comprehensive index and handy format of the book enable the reader to locate and extract the relevant information quickly and easily. Charts and tables are all referenced, and tabs are used to denote the different sections of the book. It must be emphasized that the information presented here is taken from several scientific and technical sources and has been meticulously checked and every care has been taken to select the most reliable data.