PHASE DIAGRAMS

UNDERSTANDING THE BASICS

Edited by
F.C. Campbell



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Materials Park, Ohio 44073-0002
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First printing, March 2012

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Prepared under the direction of the ASM International Technical Book Committee (2011–2012), Bradley J. Diak, *Chair.*

ASM International staff who worked on this project include Scott Henry, Senior Manager, Content Development and Publishing; Karen Marken, Senior Managing Editor; Steven L. Lampman, Content Developer; Sue Sellers, Editorial Assistant; Bonnie Sanders, Manager of Production; Madrid Tramble, Senior Production Coordinator; and Diane Whitelaw, Production Coordinator.

Library of Congress Control Number: 2001012345

ISBN-13: 978-1-61503-835-0
ISBN-10: 1-61503-835-3

SAN: 204-7586

ASM International®
Materials Park, OH 44073-0002
www.asminternational.org

Printed in the United States of America

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Preface

Phase diagrams are graphical maps that show the behavior of metal alloys during heating and cooling. In addition, they show the solid phases that are present after an alloy freezes. They are a primary tool in metallurgy because they provide the basis for predicting or interpreting the changes in the internal structure of a material. When an alloy undergoes heating and cooling, it undergoes phase transitions or transformations, in both the liquid and solid state. Therefore, an appreciable amount of this book is devoted to understanding these transformations.

In keeping with ASM's goal in the *Understanding the Basics* series of technical books, many of the mathematical formulations that underlie the theory of phase diagrams have been omitted. There are many excellent texts on chemical thermodynamic that provide this theory. The material in this book can be comprehended by anyone with some degree of a technical background. For those lacking knowledge of basic metallurgical principles, I have included two appendices that are helpful. Appendix A covers the basics of metallic structure, while Appendix B is an introduction to the principles of solidification. This book is helpful to engineers, technicians, production personnel and students with no previous exposure to metallurgy. It is also helpful to metallurgical engineers who have forgotten many of the principles of phase diagrams and need a refresher.

Chapter 1 is a brief introduction to phase diagrams. The next two chapters offer basic information that is helpful in reading subsequent chapters. Chapter 2 is an introduction to solid solutions and phase transformations. While I have attempted to avoid the detailed development of the thermodynamic formulation behind phase diagrams, Chapter 3 gives a somewhat cursory overview of the importance of Gibbs free energy and how it is used to construct and interpret phase diagrams.

The two types of alloy phase diagrams that receive the most emphasis are binary (two metals) and ternary (three metals). While a few quaternary (four metals) diagrams can be found in the literature, computer modeling based on thermodynamic principles (described in Chapter 13) are now almost exclusively used to analyze this degree of complexity.

Important binary phase diagrams involving liquid and solid reactions are covered in Chapter 4 (isomorphous), Chapter 5 (eutectic), Chapter 6 (peritectic), and Chapter 7 (monotectic). Solid-state transformations are covered in Chapter 8 and include the important eutectoid and peritectoid reactions.

Gas-metal reactions are important in metals processing and in-service corrosion; therefore, Chapter 11 covers the basics of these systems where pressure becomes an important variable.

The construction of a phase diagram is a tedious and exacting process. In Chapter 12, some of the important methods that are used in phase diagram determination and construction errors are discussed.

While many of the uses of phase diagrams will become apparent as you progress through the book, Chapter 14 summarizes their usage and gives some real world industrial examples of how phase diagrams were used to solve problems.

While phase diagrams are constructed under as close as possible to equilibrium conditions, many important phase transformations in alloys occur under highly nonequilibrium conditions. There are two chapters that cover these types of transformations. Chapter 15 covers the nonequilibrium cooling ferrous alloys that form the basics for the strengthening of steel by heat treatment. Chapter 16 covers the precipitation hardening process that is important in strengthening ferrous and nonferrous alloys, particularly aluminum and nickel-based alloys.

A first course in materials science would be helpful in understanding the material in this book; however, most of the material is easy to understand and builds as you progress through the book. The purpose of this book is to introduce the basics and not to replace handbooks on engineering alloys.

I would like to acknowledge the help and guidance of Scott Henry and Steve Lampman of ASM, the editorial staff at ASM, and the people that reviewed this manuscript for their valuable contributions.

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