



郭祝崑 林祖纘 严东生 著

# 高温相平衡与相图

HIGH TEMPERATURE PHASE  
EQUILIBRIUM AND PHASE  
DIAGRAMS

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上海科学技术出版社

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Ohu-Kun Kuo, Zu-Xiang Lin and Tung-Sheng Yen

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## 内 容 提 要

高温相平衡和相图的基本理论及实验结果已广泛应用于材料科学、地质矿物学、冶金、晶体生长等学科中。本书分为相图基础、实验方法、相图解析、从热力学数据计算相图、介平衡相图、多晶转变和相图应用等七部分。在内容方面力求完整性,包含高温相图学科的新进展;在写作方面力求系统性,层次清楚,采用实例方式说明一些典型问题。本书可作为学习和应用高温相图的一本有效的参考书或教学用书。

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## 序 言

长时期来,高温相图和材料科学之间有着广泛和密切的联系,如在发展新材料、改善材料性能和设计制备流程时,高温系统的相关系与平衡作用常常是考虑的主要因素之一,而在原料合成和材料制备过程中所达到的平衡状态,有时是介平衡状态,则决定着最终产物的显微结构和性能。

关于非金属系统高温相图的工作可追溯至本世纪初叶,测量了二氧化硅和含二氧化硅矿物系统的相图。由于这些系统与传统陶瓷、耐火材料、水泥和玻璃的组成十分类似,因此其研究结果迅速为当时的陶瓷学家所采用,并在陶瓷科学中开辟了相平衡和相图的研究领域。半个多世纪来,高温相图工作的进展主要可归纳为两个方面:(1)系统组元的变迁。早期研究的组元主要是氧化硅、氧化铝、碱和碱土金属的氧化物,至四十、五十年代间出现了技术陶瓷,如纯氧化物陶瓷、电子陶瓷和特种玻璃等,在这些新型材料的探索和发展中,相图工作曾经起过有益的参考和指导作用,而相图的研究系统中也引进了氧化钛、铌、锆、硼和铀等新组元。特别是近十余年来,除氧化物外,高温相图的组元更扩展至硫系化物、氮化物、氧氮化物和碳化物等。目前,高温相图所研究的系统广泛涉及结构材料和各种功能材料。高温相图工作除材料科学家外,还吸引了地质矿物、冶金、晶体生长、固体化学和固体物理科学家及有关工程技术人员的注意。(2)相图工作本身的进展。由于实验方法改善和采用新的实验技术后使相图研究的组元范围扩大和精度提高,近年来的重大实验进步遍及高温发生、温度测量与控制、高压技术、物相分析和结构与显微结构分析等各个方面。此外,自七十年代以来,由于计算机的应用、高温热化学数据的积累以及高温热力学和相图基本理论的发展,使通过热力学计算获得相图

和多相平衡数据成为现实，并与实验测定相图的方法互相映证和互为补充。

两年前，上海科学技术出版社和本书作者郭祝崑及林祖纘共同拟定了写作一本有关高温系统相图书籍的计划，从高温相图的进展及其广泛应用来看，这是一项有意义的工作。其内容包括相图基础、实验和计算方法、应用实例等部分，并包括了作者们在从事高温相图工作中所积累的一些经验和研究结果。这本书出版后，希望能得到读者们的支持，并欢迎对内容和写作方面提出补充和给予指正。

严东生 1985年11月

## Review

The high temperature phase equilibrium and phase diagram are closely associated with geology, mineralogy, metallurgy, and the physics and chemistry of condensed matter, and particularly, in many respects with materials science. Demands for high technology materials of special properties and for better application of existing and new developed materials have prompted the studies on the high temperature system. Recently the subject of phase diagram has been brought into the materials science as one of its theoretical foundations. It is the purpose of this book to provide the concepts, methods and applications of the phase diagram needed by material engineers and scientists as well as the chemists or physicists who are working in this field and interested in the applications.

There are seven chapters included. The chapter 1 is designed to define the scope of this book and review the recent progress in the studies on the high temperature system and their relations to the materials science and the related fields. Some 70 phase diagrams published in Chinese journals are listed. The second chapter which gives basic concepts may either be read at the beginning or referred to as needed depending on the background of the reader. In the chapter 3, experimental approaches are mentioned, including the preparation of starting materials, methods of equilibrium measurement, and phase identification. The chapter 4 concerns mathematics and applications. A variety of information can be picked out from the high temperature phase diagrams.

Examples are provided for the transformation calculation of coordinates of multicomponent points, the calculation of phase composition, and the plotting of projection and section figures. The application part outlines here four topics of studies published by Chinese authors on the ceramic material using phase equilibrium data. The calculation of phase diagram through thermochemical or thermodynamic data which is a field of considerable interest in the high temperature studies is mentioned in the chapter 5. Steps of the calculation are described in separate sections. In particular, two computer programs for the phase diagram computation and their examples are detailed. The sixth and seventh chapters concern the phase transition in solids and metaequilibrium diagrams. The phase transition is discussed in view of thermodynamics with some structure considerations. The phase stability in solid solution is involved. As shown in Table 7.1, the metastability is found to be common in the ceramic system. The last chapter aims to analyze and discuss the relationship between the free energy and the stability of the phase, thereby making it possible to calculate the metaequilibrium phase diagrams.

The present book is intended to cover most topics in the phase equilibrium and diagram discipline. This has been done to make the book more flexible, to provide a useful book of university course and of reference and to stimulate further interest in these topics. Moreover, the contributions of Chinese scientists to the fundamentals, experimentals and applications of the high temperature phase diagram are particularly included.

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