Thermodynamics of Surfaces and Interfaces

An accessible yet rigorous discussion of the thermodynamics of surfaces and interfaces, bridging the gap between textbooks and advanced literature by delivering a comprehensive guide without an overwhelming amount of mathematics.

The book begins with a review of the relevant aspects of the thermodynamics of bulk systems, followed by a description of the thermodynamic variables for surfaces and interfaces. Important surface phenomena are detailed, including wetting, crystalline systems (including grain boundaries), interfaces between different phases, curved interfaces (capillarity), adsorption phenomena, and adhesion of surface layers. The later chapters also feature case studies to illustrate real-world applications. Each chapter includes a set of study problems to reinforce the reader's understanding of important concepts, with solutions available for instructors online via www.cambridge.org/meier.

Ideal as an auxiliary text for students and as a self-study guide for industry practitioners and academic researchers working across a broad range of materials.

Gerald H. Meier is the William Kepler Whiteford Professor of Materials Science at the University of Pittsburgh. He has authored or co-authored two books and 175 articles, and has worked as a research collaborator or consultant with many companies in the gas turbine and aerospace industries. He has been a Fellow of ASM International since 1996.

Cover Description

A collection of EBSD images (brightly colored) from several steels and SEM micrographs of the same areas overlayed with misorientation points to describe the misorientation across the grain boundaries.

The author gratefully acknowledges Ms. Rita Patel and Dr. Raymundo Ordonez of the University of Pittsburgh for providing these images.

Thermodynamics of Surfaces and Interfaces

Concepts in Inorganic Materials

Gerald H. Meier University of Pittsburgh





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This book is dedicated to my loving wife, JoAnn, with much affection and appreciation.

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Preface

There are two objectives of writing this book. Firstly, the subject of thermodynamics, as it is usually taught in undergraduate courses in Materials Science, Chemistry, Chemical Engineering and Mechanical Engineering, does not include a treatment of surfaces and interfaces, or includes only a cursory treatment. The major reason for this is the lack of a suitable text. Some books do not include the subject at all and others contain only a single chapter. The treatment in the latter is often very condensed. On the other hand, there are excellent monographs on the subject, but these are too large, intimidating and/or expensive for use in undergraduate and lower-level graduate courses. The purpose of this book is to bridge the gap by providing a text that is complete and rigorous enough to be the basis for an auxiliary section in a basic second thermodynamics course. Alternatively, it may be the primary text for a course dedicated to the thermodynamics of surfaces and interfaces in which the instructor would present case studies in addition to those already in the text.

Secondly, there are many young and middle-aged professionals whose formal education lacked a substantial treatment of the thermodynamics of surfaces and interfaces for the reasons described above. Nevertheless, an understanding of the subject is important in their day-to-day activities. These include professionals working in aqueous and high-temperature corrosion, coatings, microelectronics, welding and brazing and various applications of nanostructures. This book provides a straightforward discussion of the thermodynamics of surfaces and interfaces that such professionals should find useful.

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XIV PREFACE

In order to keep to the two objectives, there has been no attempt to provide an exhaustive review of the literature. This would increase the factual content without necessarily improving the reader's understanding of the subject and would, therefore, increase both the size and the price of the book without enhancing its usefulness as an introduction to the subject. Extensive literature quotation is already available in books previously published on the subject and in review articles. Similarly, the treatment of techniques of investigation of surfaces and interfaces has been restricted to a level that is sufficient for the reader to understand how the subject is studied without involving an overabundance of experimental details. Such details are available elsewhere, as indicated. The prime intent is to provide a background for reading the literature and further independent study.

The book begins with a review of the relevant aspects of the thermodynamics of bulk systems (Chapter 1). It then includes a description of the thermodynamic variables employed to describe the behavior of surfaces and interfaces (Chapter 2). In this chapter the distinction between *surface energy* and *surface stress* is made. Then important surface phenomena are described. These include wetting (Chapter 3), surfaces and interfaces in crystalline systems, including grain boundaries (Chapter 4), interfaces between different phases (Chapter 5), curved interfaces (Chapter 6), adsorption phenomena (Chapter 7) and adhesion of surface layers (Chapter 8). The later chapters also contain case studies to illustrate the application of the concepts that are developed. Each of the chapters contains a set of study problems to reinforce the reader's understanding of important concepts.

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Finally, the author gratefully acknowledges the patience and support of his wife, JoAnn, to whom this book is dedicated.