Materials Interfaces: Atomic-Level Structure and Properties

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The study of interfaces has boomed since the early 1970s primarily owing to their central role in microelectronics, processing, and phase transformations, to mention just three areas of furtive research in the science and engineering of materials. This book contains 27 chapters spanning much of this immense field, each of which presents a snapshot of "research in progress" by leaders in the field, and many take the reader to the forefront of knowledge. The vast scope of this book sets it apart from earlier collections of papers, and the editors are to be congratulated for undertaking such a major project.

Perhaps one of the greatest uses of the book will be as a source of ideas for new research projects. None of the chapters ends with a note of finality, but rather an appeal for more experiments, more theory, and more computer modeling to answer the many questions that are raised. The impression is that almost all we know is what we do not know, and the challenge is implied time and again to make some sense of it all. Many chapters contain significant new insights and useful distillations of a massive amount of experimental and theoretical data. Conflicting views are expressed by several authors, which make for lively and, at times, amusing reading. The great diversity of the chapters and the slender cohesion between them render the book unsuitable as a graduate-level textbook; nevertheless, it will be very useful for research, at least until it is outdated.

The first two introductory chapters concern the geometry and experimental investigation of grain boundaries. They are both billed as addressing a wider range of interfaces, but the authors seem much more at home with grain boundaries. The geometry is repeated several times in the book, and one wonders why this is necessary or desirable, especially since it is nowhere near as general as recent treatments of bicrystallography. It would also have been appropriate in this book to devote a whole chapter to the thermodynamics of interfaces, which has advanced tremendously in the past 10–20 years and underpins the whole subject.

The editors classify interfaces as bulk, semibulk, and thin film. This classification corresponds roughly to a division of the different experimental techniques used to study interfaces. Bulk interfaces appear between thick crystals, such as grain boundaries in ordinary polycrystalline matter. Interfaces between epilayers and thick substrates are examples of semibulk interfaces, and those in superlattices are examples of thin-film interfaces. Bulk interfaces are treated in six chapters forming Part I of the book, and semibulk and thin-film interfaces are discussed in eight chapters in Part II. Part III contains seven chapters on chemistry of interfaces and Part IV contains four chapters on fracture of interfaces.

Part I on bulk interfaces is mainly concerned with grain boundaries in metals and ceramics, although heterophase interfaces in ceramic composites and wetting of surfaces and grain boundaries are also discussed. Most of the progress in this area has been brought about through the use of high resolution electron microscopy and computer modeling, and the chapter on wetting contains some new theory imported from sol-gel science. The chapter on grain-boundary migration is particularly thought-provoking. This field seems to have reached an impasse, with no clear conception of the atomic mechanisms involved at general high-angle boundaries.

Part II on semibulk and thin-film interfaces contains a wonderful chapter on electronic and magnetic properties of thin films and superlattices, in which the most sophisticated electronic structure calculations are applied to magnetism at surfaces and in multilayers, and structure and bonding at metal-ceramic, metal-semiconductor and semiconductor-semconductor interfaces are studied from first principles. These calculations are made accessible in the context of a useful discussion of models for the Schottky barrier. There is also a comprehensive review of scanning tunneling microscopy of metals on semiconductors, which is both fascinating and very beautiful. Other chapters cover epitaxial growth, monolayers on surfaces and in intercalated compounds, and anomalous elastic behavior in thin films and superlattices. The chapter on nanophase materials is a sober contrast to the wild statements published elsewhere about these materials, such as the "gaslike" structure of the interfaces. It was also nice to see high resolution electron micrographs of nanocrystals, rather than the artist's impressions we see elsewhere. After a systematic review of all the experimental evidence, we read, "grain boundaries in nanophase materials have structures fundamentally similar to those in conventional coarser-grained polycrystalline materials" (pp. 448–450).

Grain boundary segregation is addressed in three chapters in Part III on interfacial chemistry. The treatment covers most aspects of segregation. A chapter on amorphization by interfacial reactions at metal-metal and metal-nonmetal interfaces is very interesting and comprehensively referenced. Chapters on electronic properties of metal-semiconductor and semiconductor-semiconductor interfaces appear in Part III as well. I warmed to the treatment of metal-semiconductor interfaces enormously. It is a highly critical look at current models for the origin of the Schottky barrier based on the concept of Fermi-level pinning. It argues that these models do not account for the observed correlation between the atomic structure of the interface and the Schottky barrier height. Instead, bonding at the interface—involving all valence states, not just those in the gap—is responsible for the charge transfer and hence the interface dipole. Part III concludes with a chapter on metal-polymer interfaces.

Fracture of interfaces is covered in four disappointing chapters in Part IV. The brief chapters address tensile strength of interfaces, microstructure and fracture resistance of metal-ceramic interfaces, and microstructural and segregation effects in the fracture of polycrystals. These chapters are not very informative about these fields.

The quality of the printing is very good, and the book is attractively produced. Many of the chapters take one to the forefront of an impressively wide range of fields. However, it is not a textbook, and as a research reference I suspect its shelf-life will be rather short in this fast moving area of materials research.

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