Proton Conductors: Solids, Membranes, and Gels—Materials and Devices. Edited by *Phillippe Colomban*, Cambridge University Press, Cambridge, UK 1992, £ 75, xxxii, 581 pp., hardcover, ISBN 0-521-38317-X.

Phillippe Colomban and the Cambridge University Press are to be congratulated for the production of a quite comprehensive and readable treatise on proton conduction in solids. It is the second of a series on the *Chemistry of Solid State Materials* edited by A. R. West and H. Baxter. Contributions of 38 authors from 12 countries have been coordinated in 39 chapters with a minimum of repetition and a clear English style to give an excellent overview of the literature in this field.

Proton conductors may be either solid electrolytes or insertion compounds having a mixed electronic and protonic conduction. Solid protonic electrolytes are used as ion exchangers, in batteries and fuel cells or electrolyzers, and in microionic devices from sensors to capacitors; the mixed conductors are being studied for cold fusion and are used for hydrogen storage, electrochromic displays, and storage electrodes in secondary batteries. Not discussed is the role of proton conduction in ferroelectric devices; the protonic ferroelectrics support only a displacement current on switching the protons between two possible positions within an asymmetric hydrogen bond.

Long-range protonic conduction may consist of the motion of a bare proton or of a protonic species. Bare protons move diffusively in metallic hydrides, but they may tunnel between the two sites of an asymmetric hydrogen bond; it is argued that at temperatures where extensive water loss occurs from $Mg(OH)_2$, the mobile protons may be thermally excited to energies supporting a long-range tunneling motion. More common, however, is a complex motion consisting of a displacement within an asymmetric hydrogen bond followed by a rotation of the proton to a new hydrogen bond (the Grotthus mechanism). Protonic species only move diffusively. Examples of protonic species are the $OH^{\ominus}$ and $NH_2^{\ominus}$ anions, the neutral H_2O or NH_3 molecules, and the $H_3O^{\oplus}$, $NH_4^{\oplus}$, or $H_5O_2^{\oplus}$ cations. The diffusion of protonic species is referred to as *vehicular protonic motion*.

These several conduction mechanisms may occur in either crystalline solids or in composites containing immobilized water made proton-rich by an acidic solid or proton-poor by a basic solid. Particle hydrates, gels, zeolites and proton-exchange membranes represent wet composites; proton conduction in the aqueous phase via the Grotthus mechanism is more facile the more removed the proton is from a solid surface. Composites supporting fast protonic conduction tend to lose their conducting water below 150 °C, which limits their temperature range of usefulness. On the other hand, oxygen-deficient ABO_3 perovskites containing B cations unstable with less than six-fold oxygen coordination do absorb water below 400 °C, and some water may be held to quite high temperatures. Dissociation of the water within such a perovskite to form $OH^{\ominus}$ species allows for a combination of protonic, $OH^{\ominus}$ ion, and oxide-ion-vacancy conduction at higher temperatures. However, it is not clear that practical ceramic membranes can be made with these materials. Alternatively, ion exchange of a protonic species for a judiciously chosen mobile cation within a framework host can be accomplished without destroying the original ceramic membrane to yield a practical proton electrolyte, but here also the mobile protons tend to be lost at higher temperatures with the desorption of neutral species.

Several authors discuss the techniques of synthesis and phase stability of a variety of protonic conductors as well as the problems of material characterization. They point out how the measurement of physical properties must include the task of unraveling which of the several conduction mechanisms are contributing to the overall conductivity of a particular sample. The discussion of potential applications emphasizes the critical materials parameters and the need to find better protonic conductors.

In a compilation of this type, some topics are inevitably omitted. For example, I was surprised to find that the cathode material NiOOH–$Ni(OH)_2$ was only mentioned in a passing reference to the Cd–Ni secondary battery. More fundamental, there is no discussion of the electronic energy levels of either an electrolyte or an insertion-compound host; these play a critical role in materials selection for any electrochemical system. This omission prevented any discussion of where a guest hydrogen of a hydride is present as a donor versus an acceptor; it was simply assumed to be always present as a donor. Also missed was the opportunity to discuss not only protonic ferroelectrics, but also the role of proton transfer in electrocatalysis at a solid–aqueous interface.

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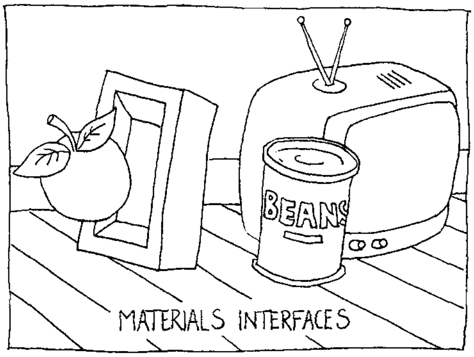
Materials Interfaces: Atomic-Level Structure and Properties. Edited by *D. Wolf* and *S. Yip*, Chapman and Hall, London 1992, XVIII, 716 pp., hardcover, £95, ISBN 0-142-41270-5.

Extensive research efforts over the past several decades in the fields of materials science have concentrated on developing engineering materials of high mechanical capability and structural reliability. The most dramatic improvements have been made by combining materials/phases of dissimilar/similar nature in various ways, whereby interfaces are inevitably created. In fact, there is hardly any material in which interfaces of some kind are not present, and there is no material for which one kind of interface would not be of critical significance. Since the properties of the interface, which are governed by its atomic/microscopic structure, most often limit the overall performance of the material, a thorough knowledge of the structure–property relationship is an essential key to the successful design and proper use of engineering materials. This work is an excellent monograph, providing a fundamental understanding of material interfaces on the atomic scale by combining their largely different scientific and technological aspects into a single volume. It has been prepared by 46 leading international investigators, mostly based in the USA, who have expertise in the topics selected for the chapters.

The book opens with an introduction and two introductory chapters which summarize the general aspects of material interfaces. In the first chapter, an attempt is made to develop a common terminology which can describe the geometry of solid interfaces, and the second chapter discusses the experimental techniques devised to study the structure, physical and chemical parameters associated with the interfaces. The main body of the book is divided into four parts, comprising a total of 25 chapters. The first half is devoted to a comparison of the structures and properties of three distinctive interfaces, namely the bulk interface (Part I) and semi-bulk and thin-film interfaces (Part II), depending on whether and how an interface is embedded in bulk material. The second part is concerned specifically with the effects of interface chemistry and structures (Part III) and some basic aspects of interface fracture (Part IV).



A central theme of much of Part I on bulk or internal interfaces, grain boundaries in particular, concerns the correlation between the interface properties, the underlying structures and energy at the atomic level for some metals and ceramics (Chapters 3–6). Because they avoid the difficulties inherent to experimental investigation of buried interfaces, electronic and atomic-level computer simulations have been extensively used to provide a close-up view of the interfacial region which is controlled by a small fraction of the atoms. Special contributions on melting and solid-state amorphization (Chapter 7), and energetics of wetting between internal surfaces (Chapter 8) are also presented. In the second part, which deals with the semi-bulk (also referred to as epitaxial) and thin-film interfaces, a special focus has been placed on the properties of semiconductor interfaces (Chapters 9–11), due to the enormous technological significance of semiconductors in many engineering applications, especially in the electronics industry. This is supplemented by the extensive coverage of the electronic properties of semiconductors in Part III. Phase behavior of surface reconstructed and chemisorbed monolayers (Chapter 12), and elastic and structural properties of superlattices which are composed of many layers of two or more dissimilar materials (Chapters 13–15) are interesting topics of two extremes of thin-film interfaces.

The features of interface chemistry presented in Part III include segregation and bonding at the grain boundaries (Chapters 17–19), and reactions and diffusion between dissimilar materials (Chapters 20, 23) from both experimental and simulative viewpoints. A comprehensive treatment is given of the structure–electronic properties relationship of semiconductor interfaces (Chapters 21, 22), which has tech-