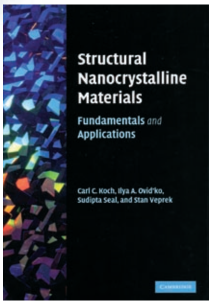
Structural Nanocrystalline Materials



Fundamentals and Applications. By *Carl C. Koch, Ilya A. Ovid'ko, Sudipta Seal* and *Stan Veprek*. Cambridge University Press, Cambridge 2006. 364 pp., hardcover £70.00.—ISBN 978-0-521-85565-5

A casual perusal of the tables of contents of most chemistry or physics journals provides overwhelming evidence of the number of laboratories around the world that are synthesizing and probing nanoparticles of various materials. But are these nanoparticles moving into real world applications? This book gives a useful snapshot of the issues associated with making this important transition for one class of nanomaterials.

It is important for potential readers to note that the materials described in this book are mainly limited to bulk samples of metal and ceramic materials. The only other class of materials that is examined in detail is coatings made of nanostructured layers of immiscible materials. Composites of nanoparticles with polymers, and other materials that incorporate solid nanoparticles, receive only brief mentions. The advantage of this focus is that the book is able to present a very detailed overview of the state of the art for the materials that it covers.

Chapter 1 gives a succinct overview of current and potential applications of structural nanocrystalline materials. As mentioned above, the focus of the book lies primarily with metal and ceramic materials. Chapter 2 reviews methods for producing nanoparticles, and discusses at length a key impediment to practical use of nanoparticles in structural applications: the problem of consolidating these materials into robust macroscopic components that preserve the original nanostructure. I was a little surprised that neither of these chapters included a discussion of safety issues. Health and safety issues during manufacture, and possible environmental impacts, are both topics that are worth careful consideration by anyone planning to produce bulk quantities of nanoparticles.

To understand why consolidation of nanomaterials is intrinsically difficult, it is useful to think about grain growth in polycrystalline materials. This is a staple topic for materials scientists, but may be unfamiliar to many chemists. Simply put, the grains in a polycrystalline material will tend to grow in size to reduce the free energy associated with grain boundaries. This can be catastrophic if a nanomaterial is desired, since it destroys the basic property of interest! Chapter 3 reviews conceptual and theoretical ideas used to describe grain growth, with an emphasis on differences between nanostructured and microstructured materials. Understanding these ideas opens the door to various strategies for reducing or halting grain growth, which are described through a series of examples from the literature.

The mechanical properties of structural nanocrystalline materials are discussed from an experimental point of view in Chapter 4, and then from the standpoint of theory and modeling in Chapter 5. These two chapters provide an interesting juxtaposition. The experimental discussion underscores the ambiguities associated with measuring mechanical properties of nanomaterials, and makes clear that the number of studies in which unusual properties can be ascribed purely to nanoscale effects is at present rather small. The chapter on modeling is considerably longer, and will be valuable reading for people who wish to apply materials modeling methods to these challenging problems. There are many challenging open questions about connecting detailed models with real materials, and Chapter 5 concludes with a summary of these issues.

Chapter 6 discusses corrosion of structural nanomaterials by examining results from the literature for several specific metals and alloys. This area has received only limited attention, so this chapter serves mainly to collect the information that is currently available, rather than to draw any general conclusions.

The final chapter is a sampling of topics where nanomaterials are being applied in various technologies. I found this to be the least satisfying chapter in the book, as the rationale for the choice of examples was not clear. The overall tone of this chapter is closer to that of popular science publications like *New Scientist* than to the more detailed approach in earlier chapters. In this last chapter, the reader learns briefly about ceramic nanocomposites, nanowires, nanoclay–polymer composites, ferrofluids, and a variety of other nanomaterials that are potentially interesting, but were not mentioned at all in the preceding six chapters.

An interesting theme that appears many times throughout the book is that early predictions that nanomaterials would exhibit some exceptional property (hardness, ductility, or elastic properties, to name three) were often less than resoundingly confirmed when careful experiments were performed. Although there certainly are examples where exciting properties have been demonstrated, the above recurring theme sends a clear message regarding the value of dispassionate experiments rather than uncritical acceptance of "nanohype".

This book will be useful to two distinct audiences. For specialists already engaged in the field of structural nanomaterials, it provides a balanced overview of this rapidly moving area. I would also recommend this book to scientists engaged in fundamental studies of nanoparticles, as an avenue to understand the challenges that must be met to enable nanomaterials to move from research laboratories to commercial applications.

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