

Book Reviews

Fantastic Voyagers?

***Nanotechnology: Research and Perspectives* by B. C. Crandall and James Lewis, editors**

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Nanotechnology is a collection of papers presented at the First Foresight Conference on Nanotechnology held in October, 1989. The meeting was to address "the technical challenges and social consequences of molecular engineering." Nanotechnology is a field spawn from the imaginations of a diverse array of "molecular nanotechnologists" who, in the words of the conference's chairman, K. Eric Drexler, use techniques which "are an elaboration of chemistry, in the same sense that modern computer technology can be viewed as an elaboration of electromagnetism and solid state physics."

In 1960, the field's elected father figure, the late Richard Feynman, pointed out the immense amount of space available for manipulation at the atomic level in his lecture entitled "There's plenty of room at the bottom: an invitation to a new field of physics." More recently, much of the recent surge in interest in nanotechnology can be traced to the publication of *Engines of Creation* (Anchor Press/Doubleday, 1986), K. Eric Drexler's treatise on the potential form, function, and impact of nanotechnology. From atomic force microscopes, micromachines, protein engineering, to quantum effects electronics, scientists, engineers, and dreamers have begun to unite themselves in this emerging field. Indeed, much has happened since Feynman's original challenge to build a 1/64-inch electric motor back in 1960.

The volume begins appropriately enough with the first nonbiological molecular microassembler, the scanning tunneling microscope, where the quantum fields associated with individual atoms can be imaged and manipulated. Scanning probe microscopes have progressed far beyond the state of the field in 1989, and the book's one contribution in this area from John Foster cannot hope to address all the promising avenues that are currently being developed. After chapters describing work on protein engineering, the development of self-assembling molecules, and current activities in Japan associated with nanotechnology, Drexler presents a discussion on engineering molecular systems in what may be the volume's most relevant chapter. Beginning with existing technology, Drexler explores several paths that may lead to the development of molecular assemblers (nano-scale constructs that have the ability to assemble molecular-scale systems), including combining synthetic folded polymers with nano-scale positioners derived from atomic force microscopes. In addition, using what he terms "exploratory engineering," Drexler explores various mechanical and systems charac-

teristics for prototypical advanced assemblers and nano-scale mechanical computers.

Unfortunately, the detailed chapter by Tracy Handel from the DeGrado duPont group is the only chapter which emphasizes a biological approach to nanotechnology. This is a pity, since the most versatile micromachines were invented by nature long ago in the forms of such common biological elements as DNA polymerase, the bacteriophage, and contractile elements. In fact the meeting seems to miss almost entirely the promise of applying molecular biology techniques, such as polymerase chain reactions, to the need for microassembly tools. It is almost as if the participants of this field evolved on a separate planet, where silicon replaced carbon as the building block of the smallest machine.

Still, given the tremendous technological base which has been built up to support the information revolution, the appeal of harnessing these technologies in the manufacture of artificial systems is clear. Nanotechnologists argue that even though evolution has found one solution that may be ideally suited to the harsh realities of survival in a hostile world, the industrial and information revolutions have taught us much about the tremendous potential that can be tapped by *de-signing* specialized systems that address specialized needs.

If nanotechnology is to be defined as giving us "thorough and inexpensive control of the structure of matter," then extending existing design and fabrication principles in microelectronics may hold the greatest promise for the manufacture of arbitrary systems in the near term. Much of the second section of *Nanotechnology* is devoted to the exploration of the state of the art in areas which will have a significant impact on the development of practical systems in the future, including chapters discussing electronic systems based on molecular interactions and quantum phenomena, theoretical limits on computation imposed by physical restraints, and an interesting if dated chapter on current efforts to manufacture micromachines using integrated circuit fabrication technologies.

The final section of the volume addresses the various implications of nanotechnology for medical applications, large scale computation, social policy, and the environment.

Ultimately, the success of nanotechnology will depend on the collaborative efforts from two normally distinct groups. The first is engineers who tend to design functional systems from simpler, well understood components, typically working in large, distributed development teams. The second

group is scientists who are more accustomed to experimentally determining how existing systems function, typically working in smaller, isolated research groups. Integrating the bottom up engineering approach with the top-down scientific approach may be the biggest hurdle faced by those wishing to further the development of nanotechnology.

Nanotechnology represents the results of a first step toward integration, by bringing together an impressive interdisciplinary cross-section of researchers to discuss the prac-

tical problems involved in developing nanotechnology, as well as to chart a course for future development. This volume is basically a transcription of the meeting with a significant amount of work by the editors and authors put into faithfully reproducing the figures and meeting discussion. As with other compendiums of this sort, some of the chapters unfortunately read like transcriptions and lack the force of effective writing. Still, *Nanotechnology* serves as a highly accessible introduction to an interesting and expanding field.