never substantiating the claim or clarifying their feelings as to why or how it is dangerous.

This book is written by authors whose academic background is in policy sciences. However, they are writing about energy--a major part of which is a technical subject. They should have sought the help of a scientist or engineer so they could have "cleaned up" some of the technical blunders. One such serious one being on p. 99, when they talk about "storing heat." According to thermodynamics, heat is defined as energy realized in transition and neither heat nor work can be stored!

All in all, this book is not meant for a technically minded reader and as for the general lay public, there doesn't seem much to be gained from this book. At best, it is a very shallow treatment of two very important and noble ideas.

Varada Charyulu is a professor in the School of Engineering at Idaho State University. He has had varied experience and interests. His main research interests are in fast reactor safety and physics. Recently he was at Kernforschungszentrum Karlsruhe in the Federal Republic of Germany on sabbatical leave where he was doing some work on two-phase flow and fast reactor safety. He has been a consultant to energy conservation firms and has been active in promoting conservation energy programs.

Near-Field Phenomena in Geologic Repositories for Radioactive Waste

Publisher	Nuclear Energy Agency; (Organisation for Economic Co-Operation and Development) (1981)
Pages	408
Price	$20.00
Reviewer	Claudio Pescatore

The disposal of nuclear waste in deep geologic formations may be accompanied by a substantial alteration in the physical, chemical and mechanical properties of the original mined facility. These changes should be well understood, as they may act as negative feedbacks on the performance of the repository. In the early life of a repository, changes in physical, chemical, and mechanical properties are mostly associated with the thermal and radiation fields generated by the stored waste. The localized scale on which these fields play a role is termed the "near-field" of the repository.

The book under review consists of the proceedings of a workshop on near-field phenomena in geologic repositories for radioactive waste held in Seattle, Washington, from August 31 to September 1, 1981. It brings together state-of-the-art contributions by specialists from Belgium, Canada, Finland, France, the International Atomic Energy Agency, Germany, Japan, the United Kingdom, and the United States, all having a vigorous nuclear waste research program.

Radiation-related phenomena are only cursively touched on. Thus, the emphasis is on thermally controlled phenomena. Topics covered include rock mechanics in stressed and heated conditions, thermally induced groundwater flow in fractured rocks, chemical changes to rock surfaces associated with changes in the chemical and thermal environment, chemical solubilities and sorption properties of radionuclides, long-term integrity of containers and packing materials for waste packages, and source terms for irradiated fuel. The contributed papers are conveniently organized into six sessions, each session reporting the round of questions and answers at the end of the various presentations. A seventh session reports on the conclusions reached by working group discussions on (a) granite and crystalline host rocks, (b) salt formations, and (c) other host media (e.g., clay and tuff) and engineered barriers.

Fundamental issues are raised by the participants in this workshop. It is suggested, for instance, that further work should be done in order to include constitutive equations for creep in thermomechanical analyses of repositories, that the effort needs to be greater in the near-field model integration area than in new model areas, and that near-field thermomechanical and chemical phenomena are least understood for tuff and clay formations. Also, a wide consensus is reported about the need for adequate experimental data to support the presented models. At the same time, we learn that thermally driven groundwater flow is possibly the principal transport mechanism in fissured rocks and that estimated migration times for radionuclides are long enough that canister lifetime does not play a role in the dose rate to man unless the canister is extremely long lived (in excess of 10^5 yr!). Indeed, the book is a stimulating one, and areas for further research are consistently indicated.

With few exceptions, the content of the papers is highly technical, which makes them challenging but effective reading for the novice desiring to explore these new areas constructively and desirable reading for the more experienced researcher in the field. I would recommend it to both.

Claudio Pescatore is a recent PhD graduate in nuclear engineering from the University of Illinois at Urbana-Champaign. He has been active in modeling of nuclear waste form leaching during the past four years. He is presently an assistant nuclear engineer on the research staff of the Nuclear Waste Management Group at Brookhaven National Laboratory.

Neutron-Transmutation-Doped Silicon
(3rd International Conference, Copenhagen, August 27-29, 1980)

Editor	Jens Guldberg
Publisher	Plenum Press, New York (1981)
Pages	505
Price	$59.50
Reviewer	Heinz Herzer

The third international conference covered in this publication deals mainly with three different fields of interest (as can also be seen from the list of participants):

1. research reactor facilities and their thermal neutron capacity for silicon irradiation (commercial interest)

2. material modification and quality improvement by neutron transmutation doping of silicon crystals as a starting material for the power device industry (commercial/technological interest)

3. material characterization, study of neutron irradiation induced defects in silicon and related phenomena (technological/scientific interest).

In the reactor field, the main target is to make use of thermal neutron irradiation capacity as an additional business to, for example, the production of radioactive isotopes. It should be mentioned that from the standpoint of the physical properties only research reactor facilities can be used for the neutron transmutation doping (NTD) technique because of the suitable neutron flux density and temperature conditions in the reactor core. Certainly, besides the commercial interest, a lot of engineering work has to be done to receive accurate and reproducible results, as can be seen from the different contributions of the research reactor centers:

1. Atomic Energy Research Establishment-Harwell (United Kingdom)

2. Risø National Laboratory (Denmark)

3. Centre d'Etudes Nucleaire de Saclay and Grenoble (France)

4. University of Missouri (United States)

5. Institute of Atomic Energy (Beijing, Peoples Republic of China).

Such practical aspects are considered as (a) shielding by neutron flux flatteners and other optimization of nuclear parameters to improve irradiation accuracy as well as (b) the comparison among the cross-section value of thermal neutron capture known from nuclear physics, the transmutation factor as known from nuclear physics, and the transmutation factor as known from the results in silicon irradiation. At first look it appears very simple to find out a transmutation factor by the very sensitive and accurate method of resistivity measurement on semiconductor silicon giving the concentration of phosphorus atoms before and after irradiation. However, there are a number of parameters that can differ from reactor to reactor like the neutron energy spectrum, the ratio between thermal and fast neutrons (cadmium ratio), the neutron flux density, and the temperature during irradiation. Also, parameters can differ from one silicon supplier to another like silicon quality, annealing treatment, and others that are of some influence on the resistivity result in the range of up to 10%. Regarding the transmutation factor, it is therefore quite complex and nearly impossible to speak of a unique physical constant.

In a special contribution to this conference, safety and health aspects are thoroughly considered. It is in the responsibility of the reactor centers to follow the "Regulations for the Safe Transport of Radioactive Materials" (International Atomic Energy Agency) for the means to monitor each silicon ingot after irradiation and to make sure that the residual activity is below the exemption limit of 2×10^{-4} $\mu Ci \cdot g^{-1}$.

The second interest group is the smallest one and represents the silicon manufacturers. They rediscovered the NTD technique as a method for doping silicon homogeneously with phosphorus and within tight tolerances as it is not possible to perform by conventional crystal growth. Their main target in this conference is to demonstrate with the reactor people that the NTD technique is not a limited academic procedure but an up-to-date technique for large scale production. Perhaps this explains the absence of device people who obviously didn't join the conference regarding NTD silicon as a well-established product on the semiconductor silicon market. The few contributions to this conference are given from high voltage dc thyristor specialists showing the superior material performances from the device characteristics that are close to theory regarding, for example, breakdown voltage as a function of bulk resistivity.

Besides thyristor application, the successful use of the NTD technique is reported for intermediate resonance (IR) detectors and nuclear particle detectors where, by the accuracy in generating phosphorus atoms, a precise compensation is performed. In the case of IR detectors, residual shallow acceptors are compensated for in indium-doped silicon improving the infrared responsivity, and, in the case of particle detectors, a starting high resistivity *p*-type material is overcompensated by NTD phosphorus resulting in high resistivity *n*-type material for the manufacture of surface barrier detectors. The first example, which is of great interest for infrared imaging systems, stays for a correction of the silicon bulk properties; this would not be possible to apply during crystal growth. The second example shows a way to produce *n*-type high resistivity material, which is normally done in the conventional way of multiple crystal growth where the trick is to control the evaporation of phosphorus in the vacuum prepasses just to get the right mixture of residual boron atoms and overcompensating phosphorus atoms. The high price resulting from the small yield in conventional crystal growth makes it attractive to start with the more available and cheaper *p*-type silicon and precise overcompensation by NTD.

Since a surface barrier detector represents a device in the process of which no temperature treatment is applied, and since high energy resolution requires low leakage current and high minority carrier lifetime, respectively, it can best demonstrate the quality of the annealing treatment after the silicon irradiation. In a fairly good agreement on this conference and those before, ~800°C is accepted as an annealing temperature sufficient for removing the radiation damage without getting metallic impurities into the bulk silicon. If we look at a common power device process on the diffusion temperatures, which are all in the range of 1200°C and above, it becomes obvious that differences from the irradiation conditions are negligible assuming the total dose of thermal neutrons is right.

To study NTD silicon, the generation of defects, their interaction with impurities, and their impact on device parameters by the different measuring techniques like

1. four-point probe resistivity

2. spreading resistance

3. lifetime measurement

4. IR absorption

5. photoluminescence

6. Raman scattering

7. trap analysis by the double correlation technique of deep level transient spectroscopy (DDLTS) in the range from as-irradiated up to ~600°C

is of never ending interest and therefore reported in great detail by the third group mentioned at the beginning. Besides the improvement of measurement equipment and the advent of new systems, the change of the silicon quality justifies a continuous investigation in the sense of material characterization and, as a consequence, establishment of the specification parameters of a well-defined starting material creating an advanced device technology. To show the trend, this year's conference has been organized by the U.S. National Bureau of Standards, Washington, D.C., and in January 1984, the next will be joined to the American Society for Testing and Materials conference.

Heinz Herzer studied physics at the University of Heidelberg where he received the degree of Diplom Physiker in 1967, and in 1971 the degree of Dr. rer. nat. He performed experimental work on ion implantation into silicon and germanium and the fabrication of semiconductor detectors for nuclear radiation at the Max Planck Institute for Nuclear Physics at Heidelberg from 1966 to 1973. He was a research associate from 1971 to 1973.

In 1973 he joined Wacker-Chemitronic and has been working on float zone silicon development and material characterization. In the past six years he completed various projects on the growth of large diameter float-zone crystals, float-zone silicon for extraterrestrial solar cells, and silicon NTD. Herzer was an advising member of the Spacelab Committee in the Ministry for Research and Technology at Bonn from 1973 to 1975. In 1977 he was chairman of the Third International Symposium on Silicon Materials Science and Technology in Philadelphia. In March 1979 he was appointed manager for float-zone silicon at Wacker-Chemitronic.

Nuclear Engineering for an Uncertain Future

Author	Keichi Oshima, Yoshitsugu Mishima, and Yoshio Ando
Publisher	Plenum Publishing Corporation, New York (1981)
Pages	260
Price	\$45.00
Reviewer	John M. Christenson

This book contains the edited texts of papers presented at an international symposium on "The Role of Nuclear Engineering for an Uncertain Future." The symposium was held in Tokyo in late 1980 on the occasion of the 20th anniversary of the Nuclear Engineering Department of the University of Tokyo. The 14 papers are all by internationally recognized experts in their fields and are organized under six topics: international cooperation, an acceptable fuel cycle, engineering philosophy on safety, breeder reactors, fusion technology, and nuclear engineering and technical innovation. The volume concludes with a 17-page record of a panel discussion on the future role of university nuclear engineering education and research.

The papers are interesting and well written (all in English) and provide an excellent overview of the current status of most aspects of the energy production applications of nuclear technology. The level of the presentations is surprisingly uniform and should be readily understandable to anyone with a technical background. One of the strengths of the book is the perspective it provides. The authors of the papers are nearly evenly divided between Europe, Japan, and the United States. For example, following Manson Benedict's fuel cycle paper is a paper by Cyril Buck on European fuel reprocessing technology, and this is followed by a paper by Ryohei Kiyose on Japanese fuel cycle developments. Although the information presented is probably common knowledge to most fuel cycle specialists, I do not know of any place else where such an international overview is readily available to the nonspecialist. Similar remarks can be made about most of the other presentations, particularly those on reactor safety, fast breeder reactors, and fusion technology. Of particular interest to this reviewer was the American reaction to the Three Mile Island accident (T. H. Pigford) and the contrasting European perspective (A. Jahns). Such balance can hardly be accidental and the organizers of the symposium are to be commended for producing a worthwhile review of the current status of nuclear technology in many parts of the world.

What is the message of this book about the uncertain future? All of the authors are positive about the role of nuclear technology, and readers of this journal will doubtless share their view, at least in the long term and in the world perspective. However, as W. Kenneth Davis states in the leadoff paper, "Despite the . . . advantageous factual case . . . nuclear power is in critical shape in the United States and is having a variety of difficulties in many other countries." Today, over two years later, one could still make the same remark, and I believe that Davis would agree that most of the problems described in his paper still exist. However, some progress has been made, even though at times it seems agonizingly slow. Perhaps that is the message: the times are critical and the evidence of the last two years does not indicate that this state of affairs is likely to change rapidly. Even so, nuclear power is a well-established technology that continues to survive and to produce an increasing fraction of the world's electric power. If these circumstances continue then perhaps the uncertain future will eventually lead to a new nuclear era.

John M. Christenson has been a faculty member in the Department of Chemical and Nuclear Engineering at the University of Cincinnati since 1970. In 1973 he was an ASEE-Ford Foundation industrial resident with Northern States Power at the Prairie Island Nuclear Generating Plant. On academic leave in 1979, he was a member of the Reactor Safety and Control Division of the Halden Reactor Project. He has served as a consultant for several national laboratories and nuclear utilities. His current interests are in the areas of applied reactor analysis, the determination of reactor operability rules, and the medical applications of nuclear technology.