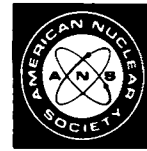


BOOK REVIEWS

Selection of books for review is based on the editor's opinions regarding possible reader interest and on the availability of the book to the editor. Occasional selections may include books on topics somewhat peripheral to the subject matter ordinarily considered acceptable.



Neutron Transmutation Doping in Semiconductors

Editor Jon M. Meese
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Reviewer K. Heydorn

Neutron transmutation doping (NTD) of silicon has become an important activity for many of the world's larger research reactors. Although the idea goes back almost 30 yr, the first commercial NTD silicon was not introduced until 1974, but by 1976, the first conference in this field was held as a one-day seminar at Oak Ridge National Laboratory.

The second International Conference was held at the University of Missouri, Columbia, April 23-26, 1978, and the present book contains the invited and contributed papers presented at this meeting. In the two years between the first and second conference on NTD, the field expanded into a multimillion dollar business, with 50 to 100 tonne of silicon being irradiated during 1978.

The *advantages* of NTD in comparison with conventional doping are the accuracy and the uniformity with which the phosphorus atoms are introduced into the silicon by neutron irradiation. Accurate control of integrated neutron flux is therefore important, and special irradiation facilities are needed to maintain deviations within 5 to 10%, radially as well as axially, for large crystals 3 to 4 in. in diameter over a length of several feet.

Such facilities are installed or being planned in a number of research reactors, and some of these are described in Chap. 4 of the present book. One of the more sophisticated systems will be installed at the University of Missouri Research Reactor, and includes two PDP-11 computers as irradiation control and accounting systems.

The *problems* associated with NTD are the presence of radioactive nuclides in the material and the displacement of silicon atoms by both fast neutrons and recoil.

With float-zone-refined (FZ) silicon as a raw material, impurities are virtually absent, and, after removal of the surface layer by etching, only ^{32}P remains. The use of crucible-grown (CZ) silicon as raw material, as well as the respective decay times needed to reach the U.S. Nuclear Regulatory Commission exempt limit of $2 \times 10^{-4} \mu\text{Ci/g}$, is discussed in Chap. 2. Other candidates for neutron trans-

mutation doping, such as gallium, germanium, arsenic, etc., suffer from the simultaneous formation of quite high levels of radioactivity; they have at this time no commercial prospects.

The defects produced by neutron irradiation in silicon are discussed in a number of papers in Chap. 5. Complete recovery of carrier concentration and mobility can be obtained by a number of different thermal annealing procedures, but minority carrier lifetime recovery is not always satisfactory. Although the subject is far from fully understood, considerable improvements in average lifetimes for NTD material have been achieved since 1976.

Until now the *applications* have been concentrated on high power devices, where the higher price for the NTD material is easily offset by the better quality. This and other potential applications, such as NTD-compensated p-type extrinsic silicon for high sensitivity infrared detector material, are discussed in Chap. 3.

Even moderate reduction in the cost of NTD silicon is likely to bring in new areas of application. If Czochralski-grown (CZ) silicon can be used as a raw material instead of FZ silicon and if the NTD-CZ product attracts commercial interest, the need for additional irradiation capacity and the requirements for handling much larger volumes of material than now will be a challenge to all research reactors. The present book is therefore valuable reading for all those responsible for research reactor utilization and operation.

The editor and the publishers deserve credit for making these contributions available within a year after the meeting. But only in this way can the printed work keep pace with the rapid development of this field. It will be interesting to see how the field has developed during the intervening period until the next conference, to be held in Copenhagen in August 1980.

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