

# Review on the book Nuclear Doping of Semiconductor Materials

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## Abstract

Review on the book Kharchenko V. A., Smirnov L. S., Solov'ev S. P., Stas' V. F. Nuclear Doping of Semiconductor Materials (second edition, revised). Executive Editor, Dr. Sci. (Engineering) V.A. Kharchenko

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## Keywords

semiconductors, doping, nuclear reactions, silicon single crystals, neutron irradiation, radiation defects, annealing, electrophysical properties.

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The discovery of nuclear reactions has led to the ultimate dream come true of alchemists – the transformation of elements, but, as it is always the case, not exactly the way they have hoped it to be. Indeed, the production of radioactive isotopes has become a profitable branch of industry, but obtaining gold through nuclear transformations has proven to be too expensive – much more expensive than gold itself. This is what we know well since schooldays. However, producing isotopes inside solid bodies is a completely different task. The possibility of producing technologically important impurities in semiconductors through matrix element transmutation reactions was first reported by Lark-Horowitz in 1951 [1]. However this possibility would have remained just a curious fact in the history of science had it not been for a special circumstance: whereas impurity atoms exhibit the tendency of clustering during crystal growth from melt, isotopes of matrix elements do not. Indeed,  $\text{Si}^{30}$  transmutation (the natural abundance of this isotope is 3.05%) to  $\text{P}^{31}$  as a result of thermal neutron trapping has allowed obtaining *n*-type silicon with an unparalleled homogeneity of phosphorus doping which is the key requirement in a wide range of important applications. However, as it always turns out to

be, the road from the birth of the idea to its practical implementation was thorny. The resultant material should not be radioactive. One should eliminate without a trace any structural defects which are an inevitable collateral effect of neutron irradiation. The electrical and recombination parameters of transmutation doped semiconductors should comply with the highest industry standards, and, last but not least, the technology should be economically viable. All these tasks have been solved by means of neutron transmutation doping of silicon. Naturally, neutron transmutation doping of other semiconductors has also been investigated, as well as potential usage of irradiation with gamma quanta, high-energy protons and alpha particles in transmutation doping reactions, but these efforts have not yielded any practically valuable results, at least as yet.

These and many other aspects of semiconductors doping through nuclear reactions were discussed in detail in the first edition of the book written by L.S. Smirnov, S.P. Solov'ev, V.F. Stas' and V.A. Kharchenko [2]. The book was published in 1981 and has become a rare book since long. Therefore the second expanded and enlarged edition prepared

by V.A. Kharchenko, an internationally renowned pioneer in neutron transmutation doping of semiconductors [3], is quite a timely publication which

will doubtlessly find a wide audience of interested readers among physicists and engineers in semiconductor science and technology.

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## Nuclear Doping of Semiconductor Materials

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Vyacheslav Kharchenko

**Nuclear Doping of  
Semiconductor Materials**

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The monograph discusses the physical foundations of a new method of doping semiconductors, the basic element of which is nuclear reactions that occur in the volume of a semiconductor under the influence of fast charged particles, neutrons, high-energy gamma radiation, as well as the inevitably occurring side effects - the formation of radiation defects, the kinetics of their accumulation and annealing. Detailed data are presented on the technology of uniform irradiation of bulk ingots with neutrons depending on the specific design of the nuclear reactor, the medium and modes of annealing of radiation defects, the requirements for the starting material, and the electrophysical properties of doped silicon crystals are considered. The sources of radioactive contamination of the ingots during the irradiation process and the technological methods of their deactivation to a safe level are analyzed.

The monograph is designed for scientists and production personnel interested in the problems of solid state radiation physics and radiation materials science of semiconductors and devices based on them, as well as graduate students and students of relevant specialties.

Vyacheslav A. Kharchenko, Engineer-Physicist, Dr. Sci. (Eng.)



He completed a series of research works on the development of a new technology for doping semiconductors using nuclear reactions and the creation of a production line based on the WWR-t nuclear reactor (Obninsk, Kaluga Region). Subsequently, he was engaged in the introduction of new equipment and technologies at the enterprises of the semiconductor industry. Currently, a leading researcher at the Institution of Russian Academy of Sciences Dorodnicyn Computing Centre of RAS. Scientific research is related to the modeling of semiconductor elements of basic heterostructures used in various electronic devices.