Semiconductors, Vol. 39, No. 3, 2005, pp. 374–375. Translated from Fizika i Tekhnika Poluprovodnikov, Vol. 39, No. 3, 2005, pp. 393–394.

BOOK REVIEW

A Review of the Book *Atomy legiruyushchikh primeseĭ v poluprovodnikakh* (Atoms of Doping Impurities in Semiconductors) by V.I. Fistul' (Moscow: Fizmatlit, 2004)

In recent years, monographs concerning semiconductors have not been published in Russia. Understandably, we were pleased when, in 2004, the Fizmatlit publishing house released the book that is reviewed here, which is concerned with a generalization of the data on the state and behavior of impurities in semiconductors. A special feature of this book is the fact that it was written by a man who has been deeply involved with this subject for a long time. The author, Professor V.I. Fistul', himself has made an appreciable contribution to the development of the current concepts concerning the nature and properties of various classes of impurities in elemental semiconductors and in III–V semiconductor compounds and their solid solutions. The reviewed book encompasses a great variety of impurities. The data on the solubility and migration of the most important impurities in various semiconductors are critically analyzed. In addition, the role of the interaction of these impurities with the accompanying impurities and inherent point defects of a crystal lattice is established in a conclusive way.

Although there is little to differentiate the general structure of the book from previously published works, the author's concept and understanding of the phenomena under consideration, as well as the allowance made for new data, is clearly communicated in each chapter of the book. In this review, we would like to draw attention to the book's notable features and a number of new treatments of the subject offered by Fistul'.

It is particularly important to note that the author considers three approaches to calculating the equilibrium concentrations of point defects in a crystal, including the atoms of doping impurities. One of these approaches, based on the method of quasi-chemical reactions (the Kröger–Brauer method), is well known; the second approach involves a method of minimization for the free energy in a system that consists of a crystal and an external phase; and the third approach, based on the quantum-mechanical method, is comparatively new and has not been described so far in any monographs.

The main limitations of the first method are related to the facts that the partial thermodynamic characteristics of the components involved in the reactions are unknown and possible interactions between existing defects are disregarded. The second method is free from these disadvantages but requires well-defined thermodynamic concepts in the context of a specific model of solid solutions. This limitation is removed to a great extent for semiconductor–impurity solid solutions if various regular-solution approximations are used. It is understandable, therefore, that Fistul' gives preference to the second method.

The third method was suggested by V.I. Fistul' himself in collaboration with D.A. Volkov. In spite of the fact that this method requires time-consuming calculations and is debatable from the standpoint of the theoretical concepts used, it undoubtedly offers the prospect of further development.

A major portion of the book is devoted to a description of the state and behavior of various classes of impurities in semiconductors. These classes include hydrogen-like impurities; impurities with partially filled electronic shells (the *d* and *f* impurities); and amphoteric, isovalent, and gas-forming impurities. This is practically the first time that such a comprehensive consideration of impurities, accompanied by a profound analysis of their behavior, has been carried out.

Chapter 4 is of particular interest as it is devoted to the theory of the solubility of impurities developed by Weiser. Fistul' attributes the main flaw of this theory to the so-called radius approach used in the Weiser theory; i.e., the radii of vacancies, self-interstitials, and impurity atoms are assumed to be constant. In order to remove this limitation, it is suggested that a rearrangement of the energy spectrum of the doping-impurity atoms when the atoms are transferred from a lattice site to an interstice is taken into account. This approach is realized by V.I. Fistul' and V.A. Shmugurov and represents undoubted progress in the development of ideas about the nature of impurity solubility.

Chapters 7 and 8 of the book illustrate the extent to which our ideas about the diffusion-related phenomena in semiconductors have been extended and expanded in recent times. Nowadays, one cannot disregard the special features of the interaction between existing point defects, and this circumstance is clearly outlined by Fistul' when considering the migration processes involving impurities. The main results of this treatment are analytical expressions that quite adequately describe the phenomena under analysis and specific illustrations of the impurity distributions that are most often encountered in practice. An analysis of special features of these distributions makes it possible to gain insight into the mechanisms of impurity diffusion and

1063-7826/05/3903-0374$26.00

assess the role of the impurity–impurity and impurity–vacancy interactions in these diffusion processes.

With respect to the shortcomings of the book, we should note that, along with adsorption processes, the very important phenomena involving the interaction of impurity atoms with dislocations and other extended crystal-lattice defects are ignored in this book. Furthermore, when considering the behavior of gas-forming impurities (in particular, oxygen and hydrogen), Fistul' did not use the new data reported in original recent publications. Nor can we agree with all the concepts used by Fistul'. For example, Fistul' considers the subsystems of the lattice sites and interstices in a crystal as separate phases between which an exchange of particles (and energy) occurs. Each of the subsystems is understood in the form of an infinite cluster with a fractal (rather than planar) interphase boundary. From the standpoint of the concepts of classical physical chemistry, the above-described approach makes a treatment of the phase rule and the use of the mass action law when describing various quasi-chemical reactions rather problematic.

Finally, we feel that, in the next editions of the book, particular attention should be given to the special features of the behavior of impurities in low-dimensional nanocompositions.

Assessing the monograph as a whole, we can state that the semiconductor-concerned scientific community now has extremely valuable generalizing printed material at its disposal, whose active use will undoubtedly be conducive to further progress in the physics and technology of semiconductors. We should be grateful to Fistul' for taking so much trouble to prepare the book and to the Fizmatlit publishing house for printing such an excellent edition.

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