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A practical model for the determination of transport parameters in semiconductors

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Abstract In this paper a new and practical model for the determination of transport parameters of crystalline semiconductors, by means of the photoacoustic technique is reported. The model is based on the calculation of the photoacoustic signal for the so-called heat transmission configuration, and considers that the thermal response to periodical heating, due to light absorption, in semiconductor materials has mainly two contributions: (a) the vibrations of the crystal lattice (phonon contribution) and (b) the diffusion and recombination (bulk and superficial) of the photogenerated charge carriers. Considering these contributions as the heat sources, and using unmixed Dirichlet and Neumann boundary conditions, the solution of the heat diffusion equation, necessary for the calculation of the photoacoustic signal is obtained. In addition, an expression—describing a particular transport regime—that can be used as practical fitting function, for the more available experimental conditions, is developed. Finally, values of transport parameters for silicon wafers are obtained by fitting this model to the experimental data, showing a good agreement with the values quoted in literature.

Introduction

Since the presentation of the PA technique for studying condensed matter samples by Rosencwaig and Gersho [1], numerous works have been written with the aim of providing a more complete theory that explains the experimental results in this and other related techniques. In the case of semiconductor samples, several authors have proposed different models that include the effect of the diffusion and recombination of the photogenerated charge carriers. These extra contributions lead to the inclusion of "slow" heat sources, in the sense that they appear after the "fast" heating generated by the periodical light excitation. In this direction, the earliest papers [2] have considered the bulk and surface recombination of carriers as the origin of the slow heat source, but maintaining front (illuminated surface) and rear surface recombination velocities equal. In subsequent works, this later mechanism was included, but only on the illuminated surface, for the mirage detection approach by Fournier et al. [3] and for the study of nonlinear piezoelectric PA effect by Cheng et al. [4] For the PA technique the superficial recombination in both (rear and front) surfaces has been already taken into account considering the Beer light absorption model [5–7] and the inclusion of other effects such as the thermoelastic and electronic strain contributions, among others [8, 9]. For a review of these and other major works in the field, the reader can be referred to the recent published work by Marín et al. [10].

The main difficulty in the use of the reported models, is that their implementation requires a multi parametric nonlinear fitting procedure to the experimental data (PA signal vs. modulation frequency), leading to a lack of reliability in the calculations. Thus, in this work, a photoacoustic model is proposed in which the carrier superficial recombination effect is introduced into the heat diffusion equation directly as a superficial heat source. By means of an approximation, valid for the more available experimental conditions, a special case is defined in which the general solution

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