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RECONSTRUCTION OF MOBILITIES FOR ELECTRONS AND HOLES IN SEMICONDUCTORS

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Abstract From a simplified approximate semiconductor model, we develop a 1-D identification problem to recover the mobilities for electrons and holes in semiconductors based on the LBIC technique, and cast it as an optimization problem. Its solution is defined by the minimal point of some objective functional. On this argumentation, we derive the gradient operator of objective functional and the necessary condition for the solution of inverse problem. Our result provides a numerical approach to reconstruct the mobilities for electrons and holes in semiconductors.

Key Words LBIC technique; variational method; inversion.
Classification 35R30, 35J60.

1. Introduction

To detect the property of semiconductor devices, the determination of the parameters of semiconductors is an important topic. A new nondestructive optical testing technique called LBIC (laser-beam-induced current) has been developed recently (See [1]–[3]). The principle of LBIC technique can be found in [3]. The LBIC image contains the information about semiconductor structure, therefore it is possible to determine the parameters of semiconductor from the LBIC image.

In 1993, [4] first established a mathematical model for the LBIC technique and simplified the general model. [5] studies this model in detail and represents the LBIC image as a linear continuous functional of g, the intensity of laser beam. Under the assumption that other parameters are known, [6] discusses the problem of recovering doping profile $N(x)$ from the LBIC image according to the model in [5].

The property of semiconductor materials is described by many parameters. Doping profile $N(x)$ is only one of these parameters. The other parameters also include the lifetimes for electrons and holes (τ_n and τ_p), the mobilities for electrons and holes (μ_n and μ_p) and the electrical permitivity of the semiconductor material (ε). Just as pointed out in [4], the inverse problems for these parameters need "further investigation".

This paper aims at reconstructing the mobilities for electrons and holes (μ_n and μ_p) from the LBIC image. Comparing with [6], the parameters to be determined here are μ_n and μ_p, while the unknown parameter in [6] is $N(x)$. Such difference of parameters to be determined causes the inverse problem in this paper more ill-posed and more complex. This is because $N(x)$ is the free term in the Maxwell equation, while μ_n and μ_p are coefficients of differential terms in the drift-diffusion equations. This paper casts the inverse problem as an optimization problem. The solutions of the inverse problem, μ_n and μ_p, are defined by the minimal point of some objective functional subject to some constraint. By variational technique, we derive the necessary condition for the solution of the inverse problem and the gradient operator of the objective functional.

2. Inverse Problem Model

The schematic configuration of the LBIC technique is shown in Fig. 1. A focused laser beam g is directed at one position of the partial boundary Σ_N and the induced steady current flowing through two ohmic contacts Γ_1 and Γ_2 is measured. When the position of laser beam is different, all the corresponding current measurements, as a function of the laser beam position, form the LBIC image of a semiconductor sample. People attempt to seek the parameters of semiconductors from the LBIC image.

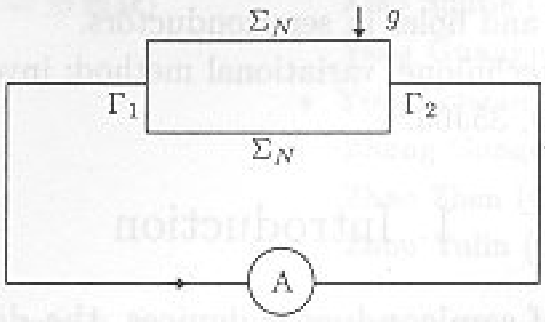

Fig.1 Schematic configuration of the LBIC technique

Derived from the stationary semiconductor equation, [4] establishes the following approximate LBIC technique inversion model for low-power laser beam by introducing new variables:

$$\nabla\cdot(\varepsilon\nabla u) = e^u - e^{-u} - N(x) \qquad \text{in } \Omega \tag{2.1}$$

$$\nabla\cdot(\mu_n e^u \nabla v) - Q(u)(v+w) + g = 0 \qquad \text{in } \Omega \tag{2.2}$$

$$\nabla\cdot(\mu_p e^{-u} \nabla w) - Q(u)(v+w) + g = 0 \qquad \text{in } \Omega \tag{2.3}$$

$$\frac{\partial u}{\partial\gamma} = \frac{\partial v}{\partial\gamma} = \frac{\partial w}{\partial\gamma} = 0 \qquad \text{on } \Sigma_N \tag{2.4}$$

$$u = \log\frac{N+\sqrt{N^2+4}}{2},\ v = w = 0 \qquad \text{on } \Sigma_D \tag{2.5}$$

where $Q(u)$ represents the Shockle-Read-Hall generation-recombination rate:

$$Q(u) = [\tau_n(e^u+1) + \tau_p(e^{-u}+1)]^{-1}(np - n_i^2)$$