

A Decoupled Iteration Method for
the Basic Semiconductor Device Equations

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Abstract

An iterative method for the solution of the basic semiconductor equations is presented. It is shown that, while the computational effort per iteration step is comparable to Gummel's method, its convergence properties are significantly superior for unipolar devices. A numerical comparison between the presented approach and Gummel's method is performed.

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Extended Abstract

In this talk an iterative method for the solution of the basic semiconductor equations in the steady state is presented. The method is based on decoupling the equations and therefore the amount of work required per iteration step is comparable to the one required by Gummel's method. The convergence properties however are distinctively superior to those of Gummel's method if one of the current densities can be assumed to be small as it is the case for most MOSFET's. The underlying idea of the method is the following:

Given the basic semiconductor equations (in a scaled form):

$$(1) \quad -\Delta\psi + e^{\psi}u - e^{-\psi}v - C(x) = 0 (=f_1)$$

$$(2) \quad \operatorname{div}[\mu_n e^{\psi} \nabla u] - R(\nabla\psi, u, v) = 0 (=f_2)$$

$$(3) \quad \operatorname{div}[\mu_p e^{-\psi} \nabla v] - R(\nabla\psi, u, v) = 0 (=f_3)$$

and an iterate (ψ_k, u_k, v_k) one first solves

$$(4) \quad \frac{\partial f_3}{\partial v}(\psi_k, u_k, v_k) dv = -f_3(\psi_k, u_k, v_k)$$

$$v_{k+1} := v_k + dv.$$

In the next step the equation

$$(5) \quad \frac{\partial f_2}{\partial \psi} (\psi_k, u_k, v_{k+1}) d\tilde{\psi} + \frac{\partial f_2}{\partial u} (\psi_k, u_k, v_{k+1}) du = -f_2(\psi_k, u_k, v_{k+1})$$

$$u_{k+1} = u_k + du$$

is solved.

Here $d\tilde{\psi}$ is the linearized zero space charge approximation of Poisson's equation:

$$(6) \quad [\exp(\psi_k)u_k + \exp(-\psi_k)v_{k+1}] d\tilde{\psi} + \exp(\psi_k)du = -f_1(\psi_k, u_k, v_{k+1})$$

$d\tilde{\psi}$ is expressed in terms of du from (6) and inserted into (5). This results in a single equation for du . Finally Poisson's equation

$$(7) \quad -\Delta\psi + e^{\psi}u_{k+1} - e^{-\psi}v_{k+1} - C = 0$$

is either solved or a finite number of Newton iterations are performed on (7).

The main difference to Gummel's method is the inclusion of the term $\frac{\partial f_2}{\partial \psi} d\tilde{\psi}$ in (5), (Here we have assumed that the hole current densities are small.) In this talk local convergence results based on singular perturbation theory are presented. A numerical comparison between the described approach, Gummel's method and Newton's method is presented.