ADAM - A Two-Dimensional, Two-Carrier IGFET Model Based on Generalized Stream Functions.

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ADAM (Advanced Device Analysis Model) has resulted from extensions and refinements to a preliminary model presented at NASECODE III. The model is based on a generalized stream function approach in which current densities are represented by

$$\vec{J}_n = \vec{\nabla} \times \vec{\Theta}_n + \vec{\nabla} \psi_n \quad \text{and} \quad \vec{J}_p = \vec{\nabla} \times \vec{\Theta}_p + \vec{\nabla} \psi_p$$

so that

$$\vec{\nabla} \cdot \vec{J}_n = \nabla^2 \psi_n \quad \text{and} \quad \vec{\nabla} \cdot \vec{J}_p = \nabla^2 \psi_p$$

where $\Theta_{n,p}$ are vector functions and $\psi_{n,p}$ are scalar functions. In the static case $(\partial/\partial t = 0)$, $\psi_p = -\psi_n$. This approach permits full two carrier transport to be treated using stream functions, and is an extension of the single carrier treatment due to Mock. The equations to be solved are Poisson's equation

$$\vec{\nabla} \cdot (\epsilon \vec{\nabla} \varphi) = N_A - N_D + n - p$$

the stream potential equation

$$\nabla^2 \psi_n = R - G$$

and the stream vector equations

$$\vec{\nabla} \times [e^{-\varphi} (\vec{\nabla} \times \vec{\Theta}_n + \vec{\nabla} \psi_n)/\mu_n] = 0 \quad \text{and} \quad \vec{\nabla} \times [e^{\varphi} (\vec{\nabla} \times \vec{\Theta}_p - \vec{\nabla} \psi_n)/\mu_p] = 0 .$$

These equations are solved sequentially using Newton's method to linearize Poisson's equation (Gummel's method). The discretized elliptical equations are solved using Stone's method. Carrier densities are calculated by integrating the equations

$$\vec{\nabla}(n e^{-\varphi}) = e^{-\varphi} \vec{J}_n / \mu_n$$

and

$$\vec{\nabla}(p e^{\varphi}) = -e^{\varphi} \vec{J}_p / \mu_p$$

along lines, as in Mock's treatment.

Figures 1, 2, and 3 show the stream potential, hole stream vector, and hole density for an n-channel MOSFET under high drain bias. The peak in the stream potential is due to impact ionization, and gives rise to the peak in the hole denstity in the same vicinity. The hole stream vector shows a depression located below the channel region, indicating a circulatory component in the hole current. However, the net hole current includes the gradient of the stream potential, which removes this circulation. Figure 4 shows the terminal current vs. number of iterations of the full two carrier system. The currents are seen to rapidly approach and remain within 5% of the final values well before the full system has converged. This illustrates the advantage of the stream function approach. The disadvantage is in the extra equations to be solved.

In its present form, ADAM is an IGFET simulator with extended source and drain and arbitrary gate electrode length. Impurity profiles can be input from SUPREM-3 and ROMANS (a Rockwell developed 2-D process simulator). A one carrier version of ADAM has been in regular use as an aid to process development for the last 3 years. A detailed description of the two carrier model and the generalized stream function implementation , plus simulation results including internal variable distributions, convergence behavior, and comparison between measured and predicted terminal currents will be presented.

References:
1) R.A.Williams and D.N.Pattanayak, Proc. NASECODE III Conf., J.H.Miller, Ed., Boole Press, Dublin, Ireland, 1983, p305.
2) D.N.Pattanayak, R.A.Williams, and J.G.Pokesheva, Appl. Phys. Lett. 41, 459 (1982). See also short course lecture notes by D.N.Pattanayak NASECODE III.
3) M.S.Mock, Solid-State Electronics 16, 601 (1973).

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Note: All results are for a 2-micron N-channel MOSFET with Vds=9, Vgs=1.2, Vbs=0.

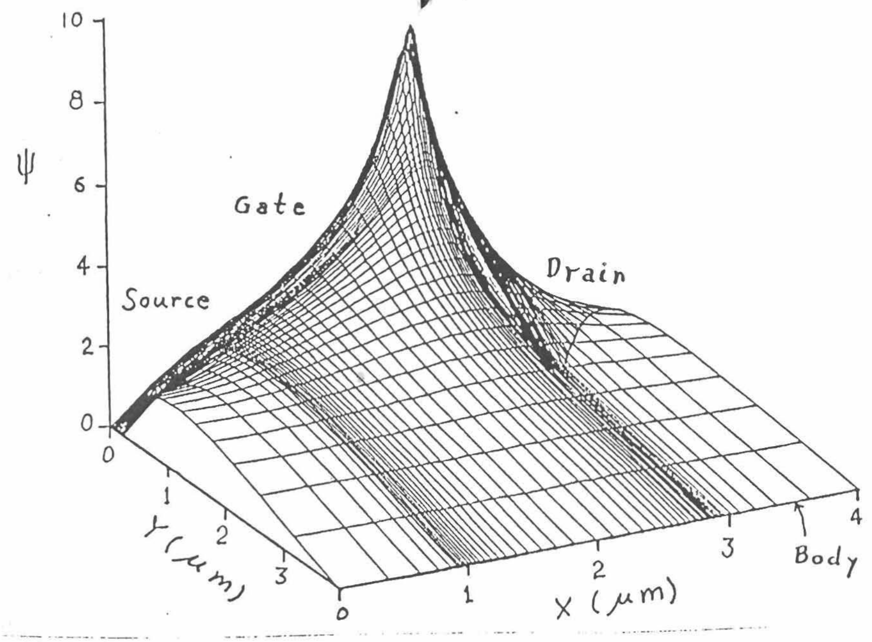

Figure 1: Stream Potential Distribution.

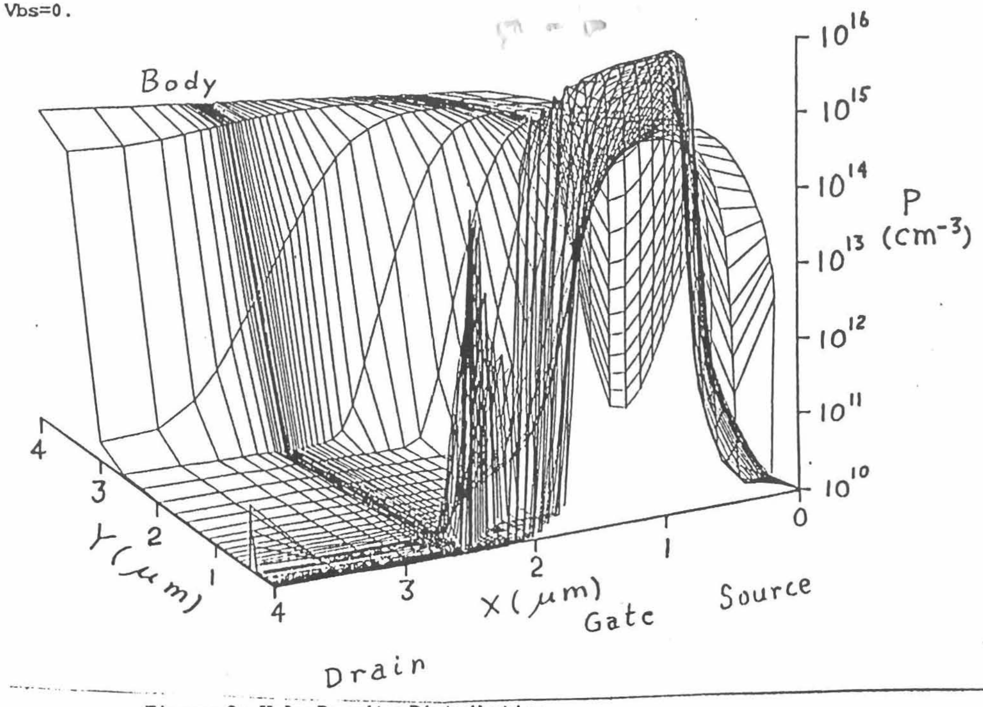

Figure 3: Hole Density Distribution.

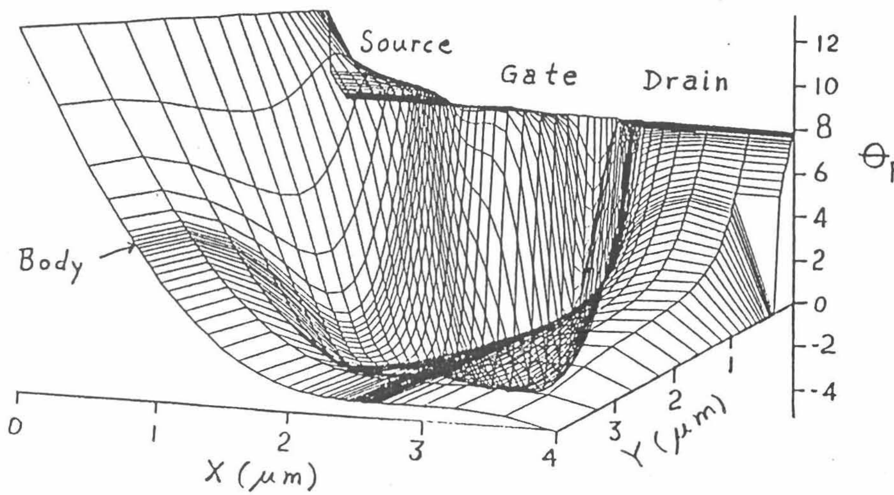

Figure 2: Hole Stream Vector Distribution.

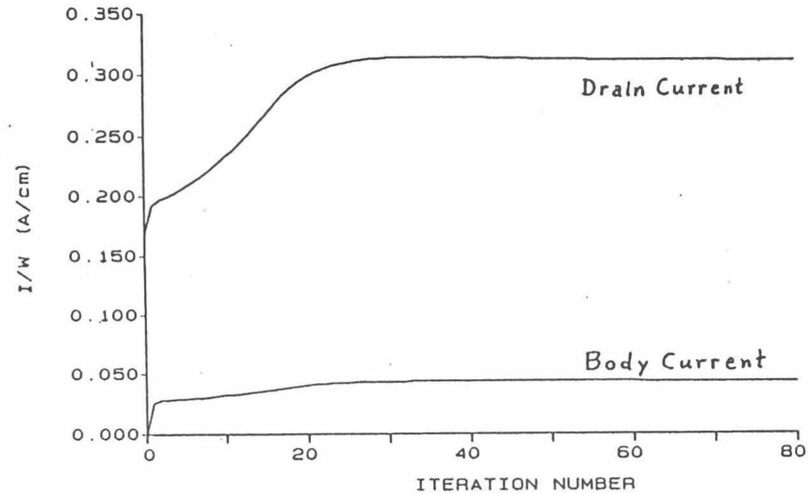

Figure 4: Convergence of Terminal Currents
Starting from 1-Carrier Solution.