Development of Simulator for Semiconductor Devices with Arbitrary Curved Surfaces Using High-Speed Algorithm on Voronoi Discretization Method

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Rapid advances of VLSI process technology have led to hundreds of thousands or even millions of transistors being integrated in single silicon chips. In such an integration, the individual device is not only miniaturized, but its structure becomes more and more complex. However, the great part of current device simulators cannot analyze complex semiconductor devices with curved boundaries, such as MOSFETs including LOCOS isolation, because they use finite-difference methods on a rectangular mesh. Hence, simulators are needed, which can analyze devices having arbitrary curved surfaces.

We have developed a device simulator using curvilinear coordinates as shown in Fig.1(a) and the Voronoi discretization method[1], in which control volumes are defined as the volume enclosed by the middle planes between the nearest grid lines as shown in Fig.1(b). In this method, it is easy to deal with boundary conditions on an arbitrary curved surface. But the Voronoi discretization method needs a CPU time 10 times larger than finite-difference methods on a rectangular mesh, because in this method the coefficient matrix becomes a 27-line regular matrix. (It becomes a 7-line regular matrix in the later method)

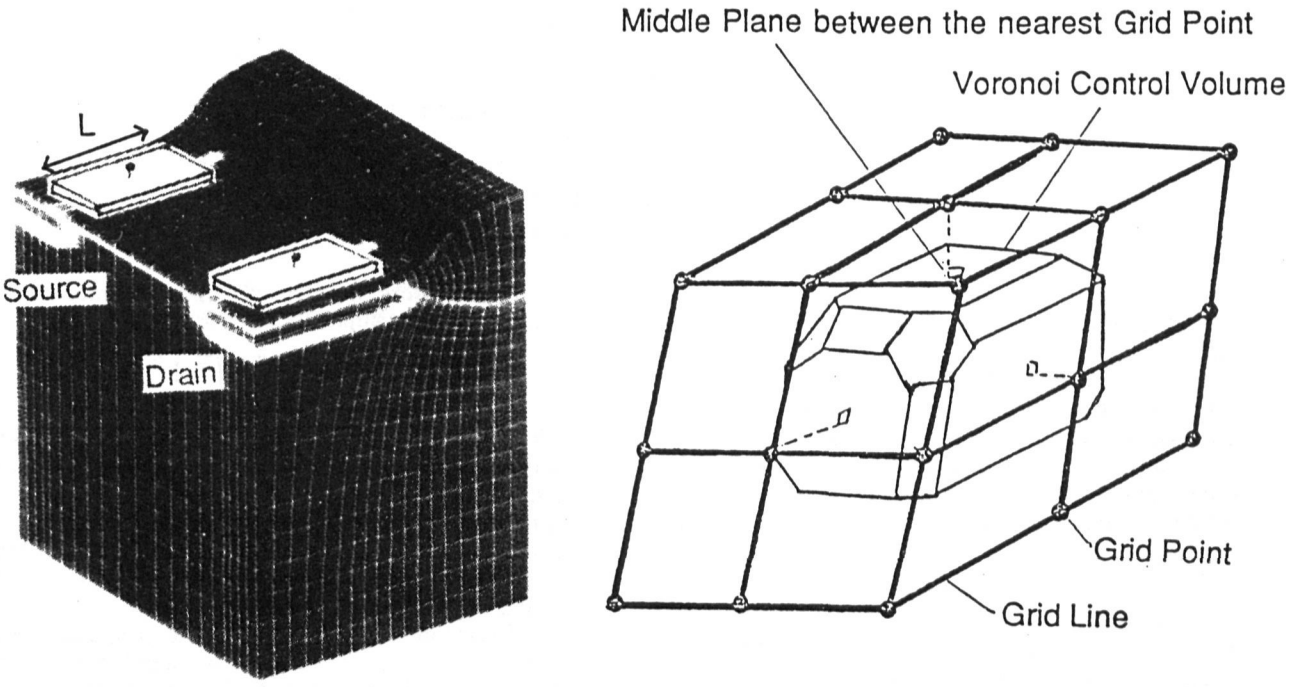
In this report, we show a new algorithm using an irregularly sparse coefficient matrix. The irregularly sparse matrix is obtained by taking away zero elements from the above 27-line regular matrix. These zero elements originate because in the matrix equation, the current term to one grid point form neighbor grid points vanishes, if there is no contact plane between the neighbor grid points (see Fig.2). Hence, positions of the zero matrix elements are previously known and the calculation effort can be economized by eliminating dealing with the non-contributed term. Furthermore, our matrix solver can regulate accuracy of the incomplete LU decomposition in a step, i.e. for a difficult problem, the solver can carry out the incomplete LU decomposition taking account of more fill-in's points around each grid point.

For some non-rectangular mesh problem, our device simulator can solve matrix equations within about 2~3 times more CPU time than a simulator using the finite-difference methods solves for a rectangular mesh problem. For devices of partial curved surfaces structures i.e. curved boundaries localized in a small part of the devices, large part of meshes can be made rectangular. So the matrix equations can be solved in as nearly small a CPU time as in the case of a rectangular mesh system.

As an example of curved surfaces system, we calculated I-V curves (Fig.3) for MOSFET and LOCOS isolation system in Fig.1. Drain currents I_d are plotted as a function of gate voltage V_g for some channel lengths L.

REFERENCE

(1) K.Tago. Elc. and Com. in Jap. Part 2, Vol.71, No.7, pp. 65-76 (1988); Translated from Denshi Joho Tsushin Gakkai Ronbunshi, Vol.70-C, No.8, pp. 1132-1140 (1987).



(a) Curvilinear coordinates system of MOSFET with a LOCOS isolation

(b) Voronoi control volume

Fig.1 Voronoi discretization method

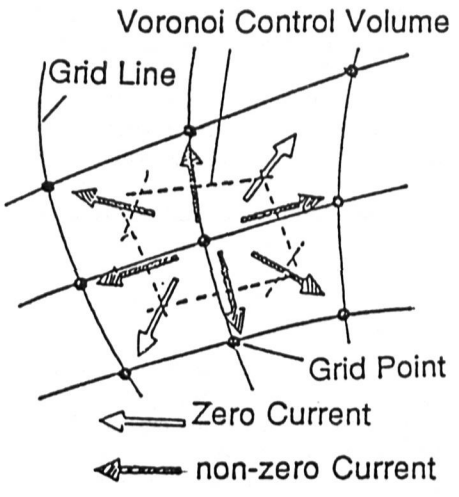


Fig.2 Current flux and contact planes in two-dimensional grids

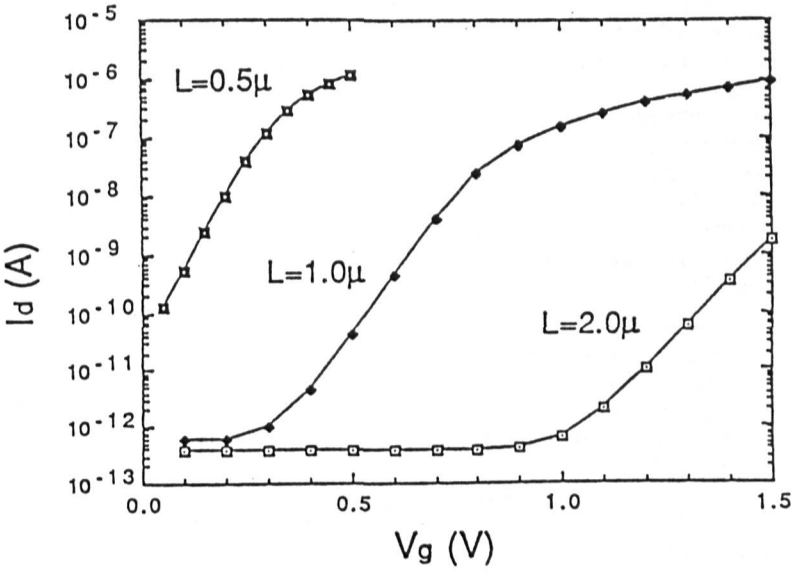


Fig.3 I-V curves for a MOSFET with a LOCOS isolation

(V_g : Gate Voltege Id : Drain Current L : Channel Length)