Two-Dimensional Transient Simulation of the Turn-On Behavior of a planar MOS-Transistor

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The properties of a special CMOS - Structure are mainly defined by the switching behavior of the components. We present results of a transient analysis of the behavior of a MOS-Transistor with 5V applied to the Drain, if the gate is pulsed from -0.3V to 7V within 50ps.
The Doping-Profile is given in Fig.1:
$L_{eff} = 0.6\mu m$, $d_{ox} = 250Å$, Channel Doping $= 1.10^{17}$, Substrate Doping $= 6.10^{15}$

The four selected points of time show how the inversion layer is built up from the source side because of the high inversion field under the oxide. The pinch off area at the drain side vanishes after gate voltage has reached the value of 5.8Volt (i.e.: drain voltage plus threshold voltage) (Fig.2-5).
We have found that the drain current first flows in negative direction (out of the device), according to the changes of space charge in the overlapping area, and changes sign after the delay time of 17ps. Bulk current shows a peak 10ps before the gate voltage reaches its maximum and then decreases slowly reaching its small steady-state value after 500ps (Fig.6).

We have particularly analyzed the dependence of the drain current delay time on the maximum of the gate voltage and the rise time, and the dependence of the steady-state bulk current on impact ionization. The results show that even small impact ionization causes a significantly higher steady-state level of the bulk current.

Our analyses have been done by applying the two-dimensional device simulator BAMBI which solves the three basic semiconductor equations discretized on a rectangular grid. It should be pointed out, that our results are based on a totally selfconsistent solution with impact ionization. From our experiences simple estimates with an ionization integral are not sufficiently accurate, since in particular the holes generated by impact ionization influence also qualitatively the space-charge distribution.

scaling of x-, and y-axes : μm

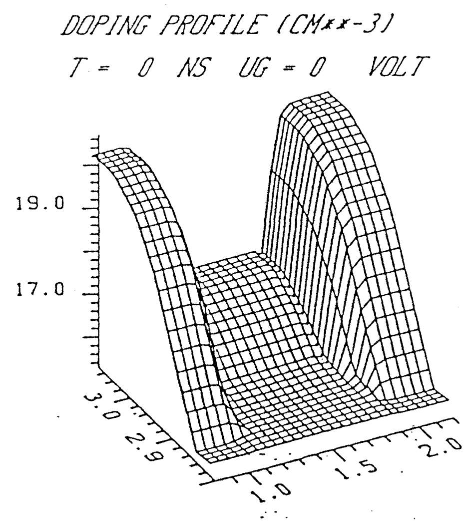

Fig.1: Doping profile of the channel region
drain is on the right side
source on the left side

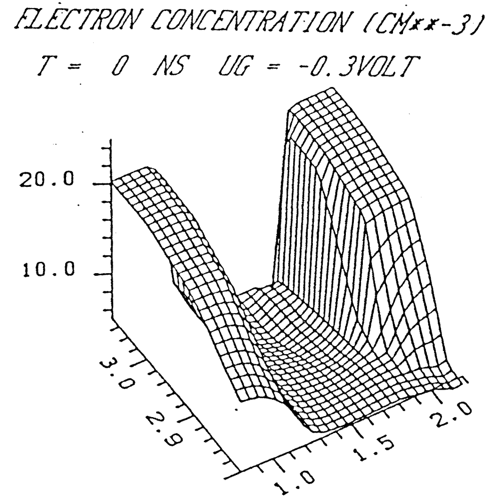

Fig.2: The steady-state electron concentration
in the channel region before
the switching process

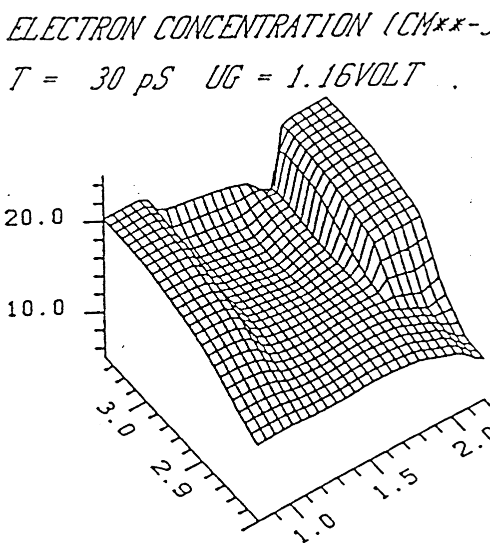

Fig.3: The electron channel with pinch-off
voltage ramp starts after 20ps

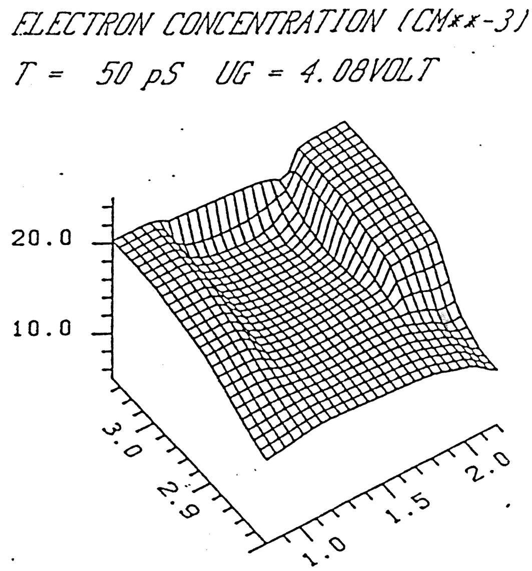

Fig.4: The electron channel with pinch-off

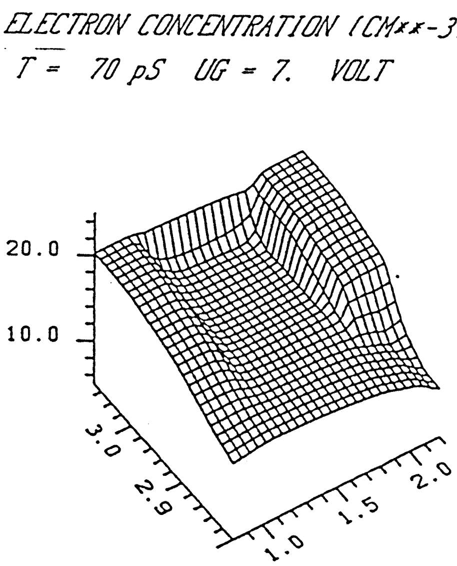

Fig.5: The steady-state electron concentration
in the channel region after

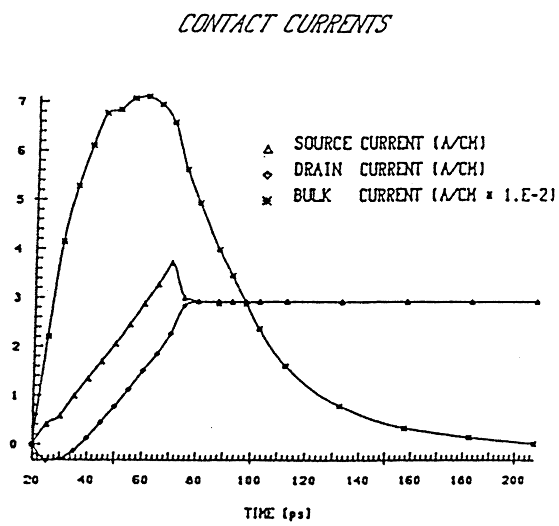

Fig.6: Drain-,Source-,Bulk Current
as a function of time