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Human Body Model ESD Simulation Including Self Heating Effect

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INTRODUCTION

Electrostatic discharge (ESD) is an important issue in LSI design and fabrication. One category of ESD pulses is known as the human body model (HBM) which represents a charged human discharging into an integrated circuit. In this paper we present transient characteristics simulation of NMOSFETs for which ESD pulses of HBM are applied. The temperature rise owing to the self heating effect is included in the simulation, which is naturally an important aspect in high current phenomenon such as ESD.

MODELING

A setup for HBM ESD simulation is shown in Fig.1. A capacitance *C* of 100pF is charged by high voltage V_0 of several hundreds Volt closing a switch a, and then the capacitance is connected with a resistance *R* of 1.5kOhm [1] and a MOSFET opening the switch a and closing the switch b. In the actual transient simulation V_1 is raised from zero to a high voltage equal to V_0 in a very short time (0.1ps) , and then *C* is connected with *R*. The charge on *C* is discharged through *R* and the MOSFET. The temperature rise ΔT in time Δt is given by (1),

$$\Delta T = \frac{I_D V_D}{c\rho V_a}\Delta t \qquad (1)$$

where *c* is the specific heat of Si (0.7J/gK), ρ the density (2.33g/cm^3) and V_a is the volume of the device. The conduction of heat is ignored in driving (1) considering that the phenomenon is slow compared with ESD process. It takes microseconds for heat to diffuse in Si by ten micrometers much larger than the device size.

The temperature dependent models of carrier mobility and impact-ionization coefficients which are measured in [2] are included in the simulation. Robustness of the convergence computation is attained by including Jacobian of the impact-ionization coefficients.

RESULTS AND DISCUSSION

First, DC *Id-Vd* curves having snapback characteristics are shown in Fig2 for temperatures 300K-900K. Transient *Id-Vd* trajectories in HBM ESD with self heating effect are shown in Fig.3 for initial voltages on *C*, V_0 of 100V-500V. On the *Id-Vd* trajectory for 500V, several time points are shown by symbols, which shows that the time scale of ESD is of the order of *RC* time constant (=0.15 μs). Drain current changes in time are shown in Fig.4. The drain current in the early stage is equal to V_0/R. The changes of internal drain voltage and the voltage on *C*, V_1 in time are shown in Fig.5. The internal drain voltage changes largely in the time range of 100ps, while V_1 is constant and equal to V_0 up to 1ns and decreases to zero in 1μs. Finally the temperature rises vs. time are shown in Fig.6(left). For V_0 of 500V, temperature rises to 1100K. At such a high temperature *Id* is high as seen in Fig.3. Maximum temperatures Tmax caused by ESD pulses are shown in Fig.6(right). It should be noted that the results are obtained for the case of the channel width, *W*=100μm, and the wider the channel, the lower *Tmax* is.

CONCLUSIONS

HBM ESD transient simulation is successfully carried out including self heating effect. Transient *Id-Vd* trajectories and temperature rise in time can be obtained for various high voltages on discharging *C*.

REFERENCES

[1] S. Dabral and T. J. Maloney, Basic ESD and I/O Design, John Wiley & Sons, Inc.1998.
[2] S.Reggiani, E.Gnani, M.Rudan, G.Baccarani, C.Corvasce, D.Barlini, M.Ciappa, W.Fichtner, M.Denison, N.Jensen, G.Groos, and M.Stechrer, IEEE Trans. Electron Devices **52**, 2290 (2005).

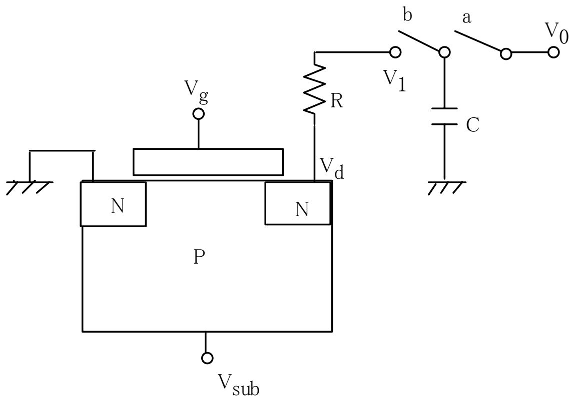

Fig. 1. A setup for HBM ESD simulation. C=100pF, R=1.5kOhm.

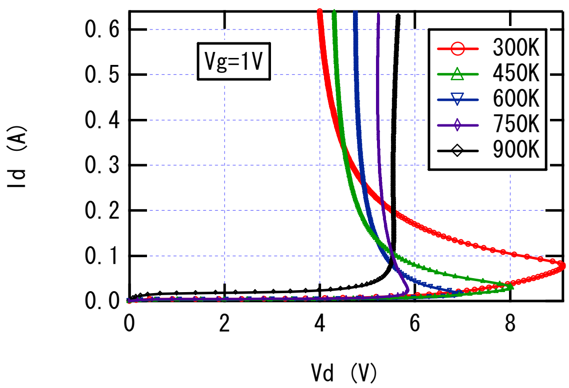

Fig. 2. DC drain current characteristics for various temperatures. Channel length, 1μm, and width, 100μm.

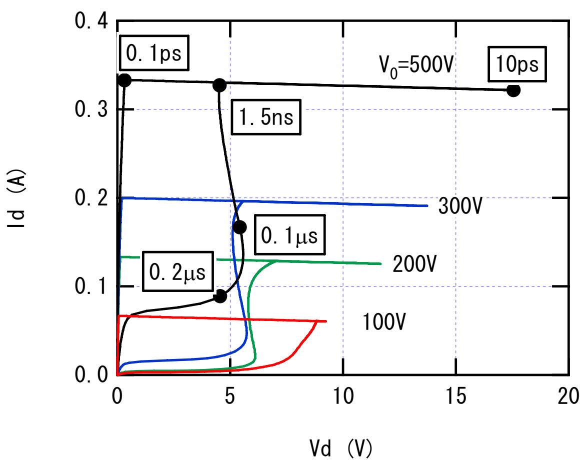

Fig. 3. Transient drain current characteristics with self heating effect.

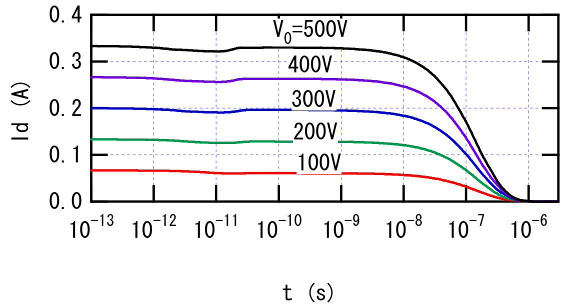

Fig. 4. Drain current vs. time. for V_0 0f 100V-500V.

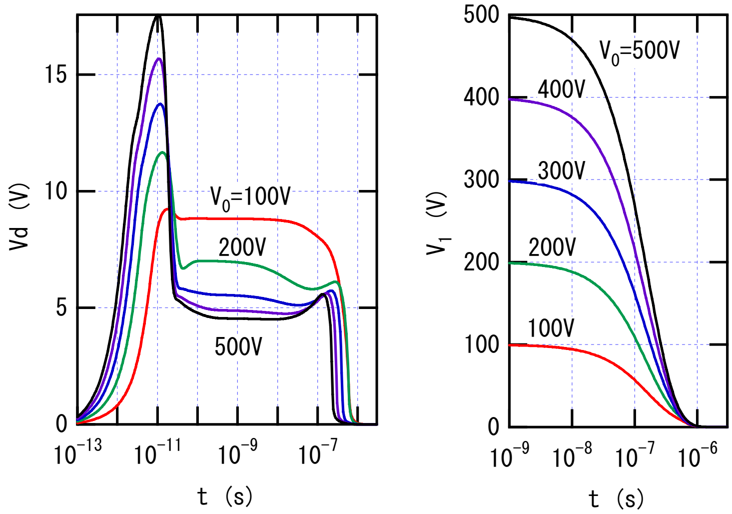

Fig. 5. Internal drain voltage Vd vs. time, and V_1 vs. time.

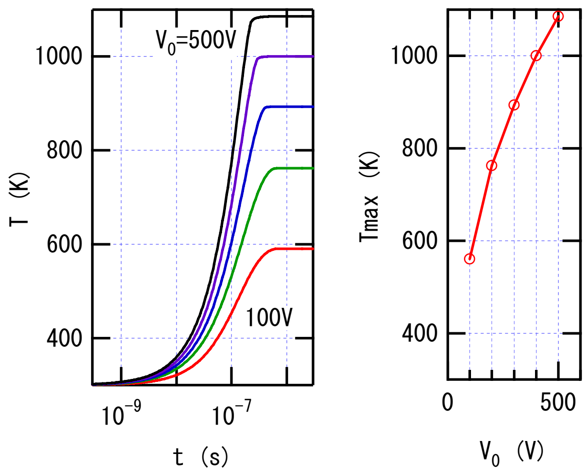

Fig. 6. Temperature vs. time(left) and Tmax vs V_0.(right)