Electrothermal Modelling of SOI MOSFETs

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Fig.1 shows the structure of a normal SOI MOSFET. The device is built in a silicon island. Except the contacts the silicon island is surrounded by silicon dioxide, thus the device is insulated electrically. Just such insulation results in the possibility of very high packing density. At the same time it is also thermally insulated owing to the poor thermal conductivity of silicon dioxide. Therefore there is a rather large thermal resistance in SOI MOSFETs[1,2]. This thermal resistance leads to the fact that the channel temperature is higher than that of surroundings; namely the channel area will be heated. The channel temperature increase will greatly change device electrical properties, and conversely the electrical property change will also alter the temperature increase. At the stationary state therefore the device has a certain increased temperature and dissipated power which are coupled together and influenced by each other. Thus the electrical properties of SOI MOSFETs are not only determined by device electrical parameters but also by device thermal parameters, and the modelling of device is no longer only an electrical process but should also be a electrothermal coupling process.

We use the following equations as physically basic modelling principle:

$$I_{DS} - I_{DS}(T_c, V_{gf}, V_{gb}, V_{DS}) \qquad (1)$$

$$T_c = T_c(I_{DS}, V_{DS}) \qquad (2)$$

Where I_{DS} is drain-source current; T_c is channel temperature; and V_{gf}, V_{gb} and V_{DS} are forth gate voltage, back gate voltage and drain-souce voltage respectively.

These two equations are coupled together and must be solved at the same time. Owing to the complicated dependence of electrical parameters on temperature it is almost impossible to get an analytical solution. We have used an iteration method to solve these two coupled equations. As an example in Fig.2 the calculated result for a SOI MOSFET with W/L=40/4, $t_{si} = 0.15$, $t_{ox} = 0.025$, $t_{box} = 0.3$ and $N_A = 2 \times 10^{17}$ has been given. For contrast the result which is only based on simple electrical modelling of equation (1) has been given in Fig. 2 at the same time. Other device parameters, transconductance for example must be calculated from the coupled equations (1) and (2). Fig. 3 shows the transconductances of our SOI MOSFET with and without considering the electrothermal coupling.

References

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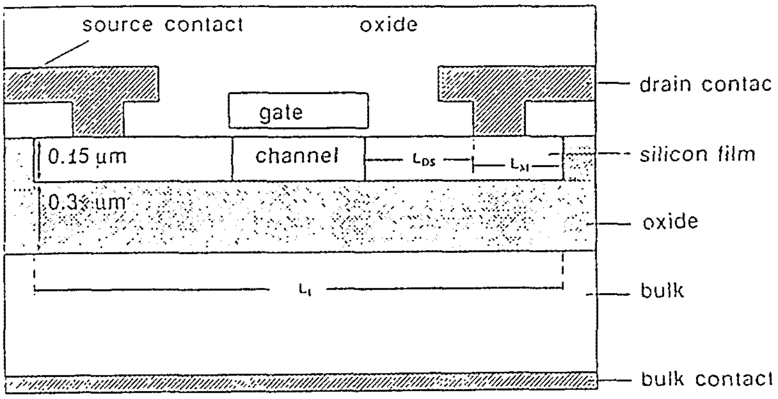

Fig.1. The cross section of a typical SOI MOSFET

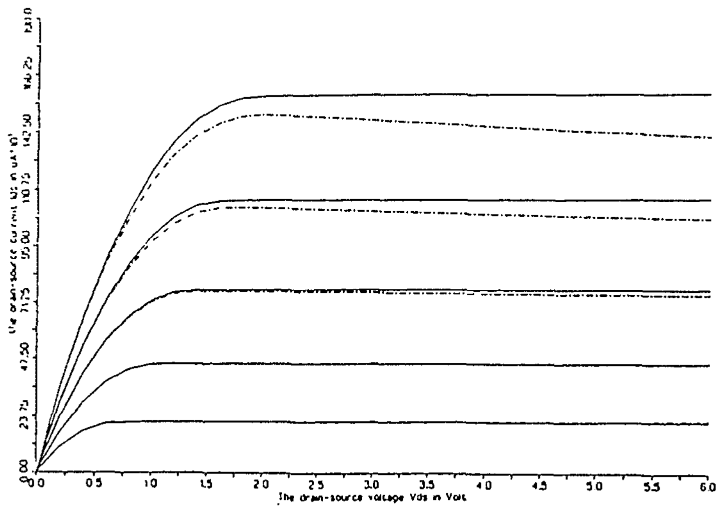

Fig.2. The current-voltage characteristics of ETM(- - -) and SEM(—) at the back surface accumulation

ETM: Electrothermal Modelling

SEM: Simple Electrical Modelling

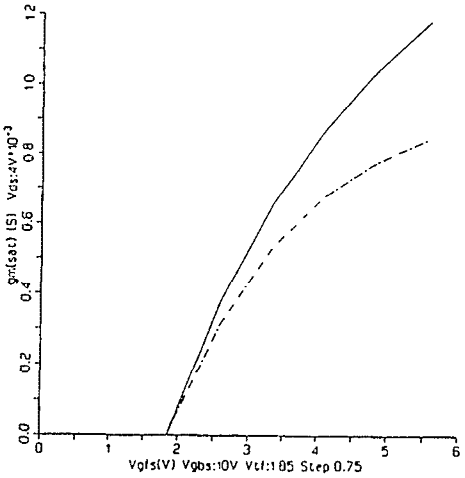

Fig.3. The transconductance of ETM(- - -) and SEM(—) at the back surface depletion