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Channel dopant profile and Leff extraction of deep submicron MOSFETs by inverse modeling

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Introduction

For process modeling of deep submicron MOSFETs, information on dopant profile is very important to ensure a simulation accuracy. Although SIMS or C-V method is a reliable tool, we can measure 1D profile not on actual MOSFET but on special samples by these methods. An inverse modeling technique to determine the doping profile of MOSFETs from electrical measurements is a usefull tool and was reported by N. Khalil et al [1]. Their approach is significant since it can extract 2D MOSFET profiles. The drawback is their use of various C-V characteristics as fitting targets to determine the doping profile. However, capacitance measurements require large-area MOS capacitors or wide-gate MOSFETs. Thus, the extracted profile may be different from actual devices.

In this paper, we report a new method to extract channel dopant profile and an effective channel length(Leff) of actual device from measured I-V characteristics, and the accuracy of this method confirmed by simulation. In comparison to the capacitance values measureed in C-V method, measured current values are accurate even in conventional narrow width MOSFETs. No special devices are necessary in this method. Also noted is that only one device to be measured is necessary to extract its channel dopant profile and Leff, which contrasts other methods[2] to extract Leff by a series of MOSFETs with different channel lengths.

Method

Fig.1 shows the schematic approach to the extraction of MOSFET dopant profile. Depth profile of each impurity is represented by B-spline functions. Dopant profile at the channel region is assumed to be uniform along the channel direction. Lateral drain profile at drain edge is constructed by rotating the depth profile with a factor k to surface point at X0. In this study, depth profile at drain is fixed. Gate oxide thickness, work function difference, and gate poly length are also fixed. Thus, fitting parameters are coefficients of B-spline representation for channel dopant profile in the depth direction, a factor k and the point X0.

As for the targets of fitting, we chose threshold voltage(Vth) with its Vb and Vd dependence. Vb dependence is important to extract channel dopant profile. Fig.2 shows Vth vs. gate length(Lg) with the parameter of Vd. We can see that Vth is very sensitive to Vd with shorter Lg, which indicates that Leff with shorter Lg can be extracted accurately from Vth dependency on Vd.

Fig.3 shows the procedure to extract the profile. As the initial guess, we can assume abitrary dopant profiles or we can use process simulation results. First, Vth dependency on Vd is optimized with parameters k and X0. Second, Vtn dependency on Vb is optimized with B-spline parameters at the channel region. This procedure is iterated until sufficient convergence.

The accuracy of proposed method is studied by simulation. Simulated electrical characteristics of an 0.4µm nMOSFET with certain dopant profile(original profile) are the targets. Then, we assumed arbitrary initial dopant profile except at drain where the original depth profile is used as it is. We followed the procedure as shown in Fig.3. Fig.4(a) and (b) shows the extracted dopant profile at the channel region in the depth direction, and at the surface along the channel, respectively. In this case, drain profile is fixed to the original profile. We see extracted channel profile and Leff are in excellent agreement with the original profile.

It is often the case the depth profile of drain is not known. Fig.5 shows the results on Leff in such situation, where drain profile different from the original is assumed. The results of channel profile are not shown here since they are identical with Fig.4(a). The final results are more than satisfactory, which shows the effectiveness of the proposed method to extract channel profile and Leff.

Conclusion

A new method is proposed to extract dopant profile of actual MOSFET using inverse modeling. The proposed method is unique in the following two respects.

(1) Not special samples but actual device is used.

(2) Only one MOSFET is necessary.

Finally, the effectiveness of the proposed method is demonstrated through simulation study.

References

[1] N.Khalil et al, EDL, 16, p.17, 1995. [2] e.g., J.Ida et al, Proc. of ICMTS, p.117, 1990.

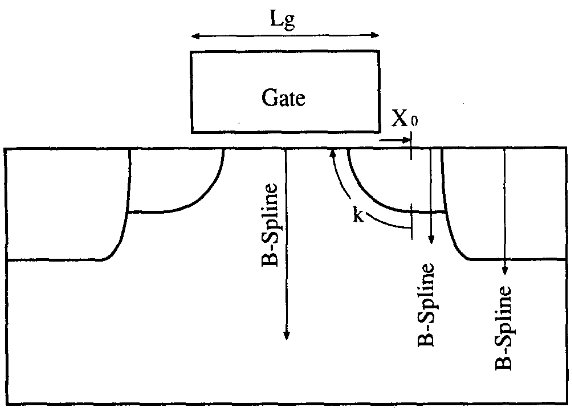

Fig.1 Schematic approach to the extraction of MOSFET

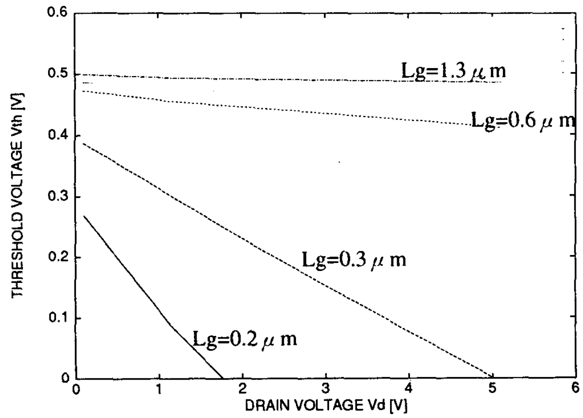

Fig.2 Vth vs. Vd with a parameter of Lg

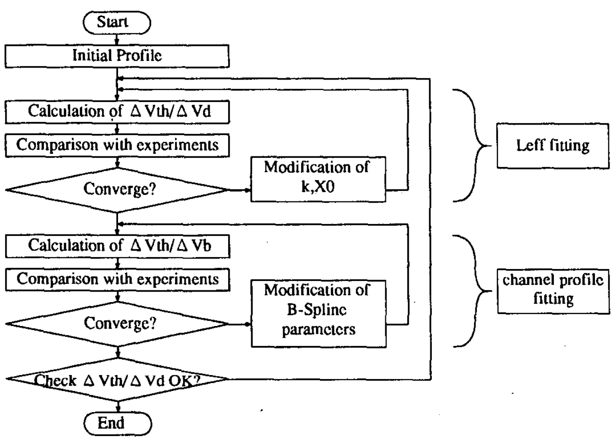

Fig.3 Procedure to extract channel profile and Leff

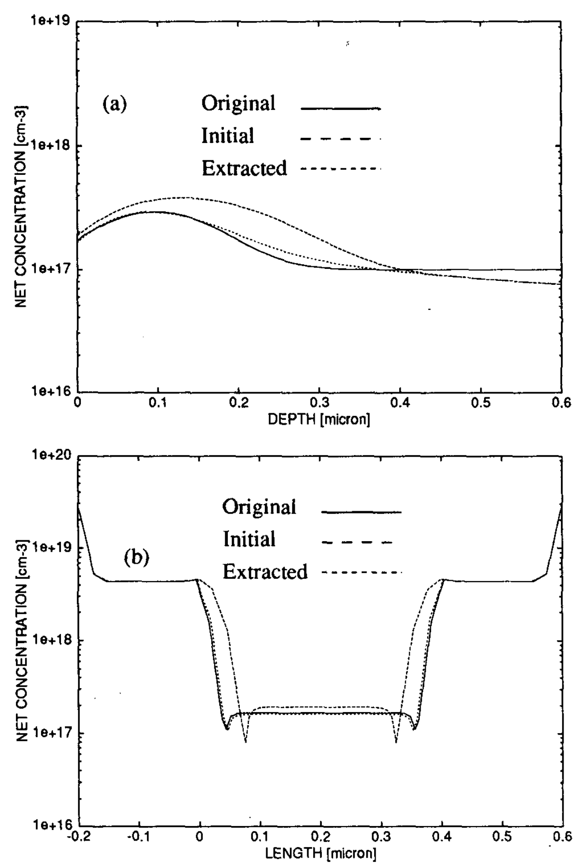

Fig.4 Extracted profile (a) at channel region, and (b) at surface along the channel. The same drain depth profile at drain is assumed.

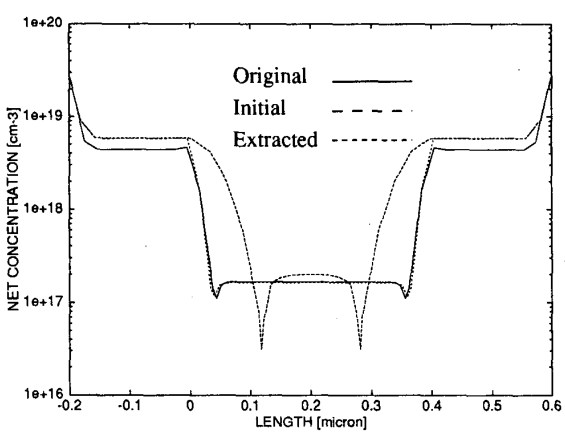

Fig.5 Extracted profile at surface along the channel. A different drain profile is assumed.