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A Method of Hot Carrier Lifetime Prediction in Partially-Depleted Floating SOI NMOSFETs

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A method of accurately predicting the hot carrier lifetime in floating-body SOI MOSFETs was proposed, based on the nature that the ratio of hole current to drain current in a floating-body SOI MOSFET is approximately equal to the ratio of substrate current to drain current in body-tied one. In this lifetime prediction, floating SOI MOSFETs can be treated in the same way as bulk MOSFETs except the drain current increase due to the parasitic bipolar action.

1. INTRODUCTION

The hot carrier lifetime in floating-body SOI MOSFETs degrades abruptly when the parasitic bipolar transistor works[1]. In this case, the lifetime loses linear dependence on the drain electric field unlike the case of bulk MOSFETs. In addition, the convenient index for the hot carrier lifetime prediction in bulk MOSFETs, namely substrate currents[2,3] can not be used in floating SOI MOSFETs. Therefore, it has been difficult to estimate the hot carrier lifetime in floating SOI MOSFETs. In this paper, we indicate that the maximum electric filed in floating structure is almost the same as that in body-tied one, so that hole current in floating structure can be estimated using the substrate current in body-tied one and the drain current ratio of floating one to body-tied one. Based on this nature, we propose a method of hot carrier lifetime prediction in floating SOI MOSFETs.

2. EXPERIMENT

Partially depleted n-channel SOI MOSFETs were fabricated on SIMOX wafers. The thickness of the gate oxide, SOI and buried oxide layers are 7, 200 and 400nm, respectively. The gate length is 0.3μm. SOI MOSFETs with and without body-terminals were prepared for the hot carrier stress test so that substrate currents could be observed in the SOI MOSFETs with the body-terminal like in bulk MOSFETs. For the stress bias, 0.7V was chosen, because in floating SOI MOSFETs, the gate voltage around the threshold voltage was the most severe stress condition[4-6]. In this study, hot carrier lifetime was defined as the elapsed time by the 15% degradation in reverse-mode drain-current at saturation region.

3. RESULT and DISCUSSION

Figure 1 is the hot carrier lifetime in floating-body SOI MOSFETs and body-tied ones. This figure shows that the hot carrier lifetime in floating SOI MOSFETs is much smaller than that in body-tied ones, and that the lifetime in floating cases degrades abruptly at high stress drain bias region, while body-tied cases clearly indicate linear dependence on reciprocal of stress drain voltage. It is considered that in floating SOI MOSFETs, the parasitic bipolar transistors increase the drain current rapidly, thus degrading the hot carrier lifetime severely.

A hot carrier lifetime is determined by drain current and an electric field as conceptually shown in Fig.2. In body-tied SOI MOSFETs, we predict its hot carrier lifetime by observing substrate current, that is hole current from the high electric-field region, where the hot carriers generate[2,3]. On the other hand, in floating SOI

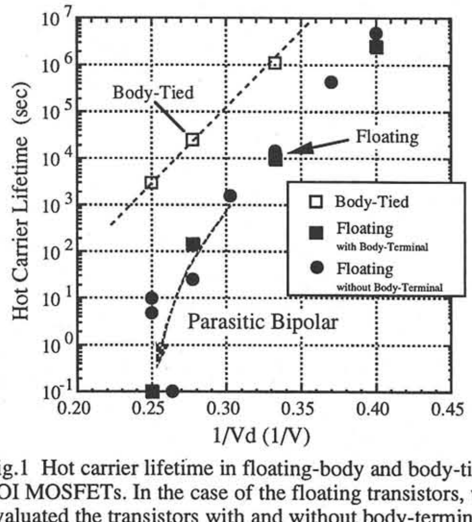

Fig.1 Hot carrier lifetime in floating-body and body-tied SOI MOSFETs. In the case of the floating transistors, we evaluated the transistors with and without body-terminal. The hot carrier lifetimes less than 0.1 second were plotted at the 0.1 second.

MOSFETs, the hole current causes parasitic bipolar action and increases the drain current. If we can estimate the hole current in floating cases, we can predict its lifetime.

Figure 3 is the simulated maximum electric field in a floating-body SOI MOSFET and a body-tied one. This figure indicates that the maximum electric filed in floating SOI MOSFETs is almost the same as that in body-tied ones at the high drain voltage region. This means that we have only to consider currents for the lifetime prediction. By the way, the maximum electric filed is obtained at the surface of the SOI layer. We verified that the electric field in floating structure is lower than that in body-tied one at the deeper portion.

Figure 4 shows the simulated drain current and hole current density in floating and body-tied structures. The ratio of the currents in each structure is calculated in Fig.5. It is found that the ratio of the hole current (Ihf) to the drain current (Idf) in a floating case is approximately equal to the ratio of the substrate current (Isub) to the drain current (Idt) in a body-tied case, near the front surface, where most of the current is confined, that is,

$$Ihf / Idf \sim Isub / Idt \ . \qquad (1)$$

Figure 6 is the correlation between the lifetime τt, drain current and substrate current in a body-tied case[3].

$$\tau t \bullet Idt / Weff = A \bullet (Isub / Idt)^{-B} \ , \qquad (2)$$

where the A and B are constant, and the Weff means effective channel width. Figure 7 shows measured drain currents. Using the equations 1 and 2, and the drain current in Fig.7, we can predict the hot carrier lifetime τf in floating

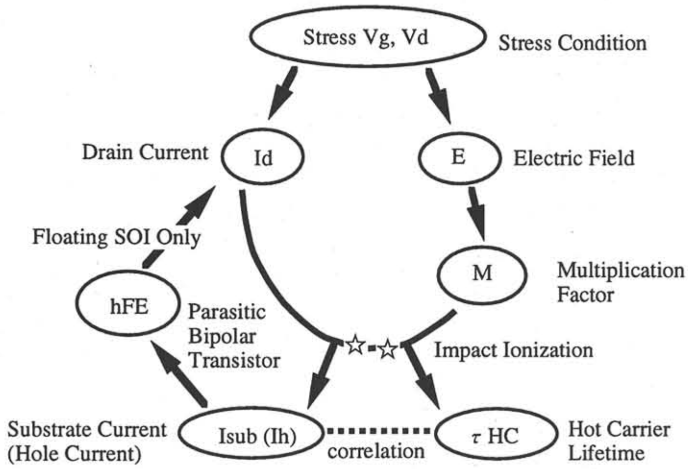

Fig.2 Conceptual view of the hot carier lifetime prediction

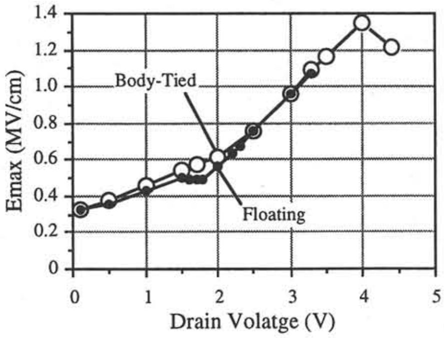

Fig.3 Simulated maximum elctric field near the drain edge in SOI film. The gate volatge (Vg) is 0.7V.

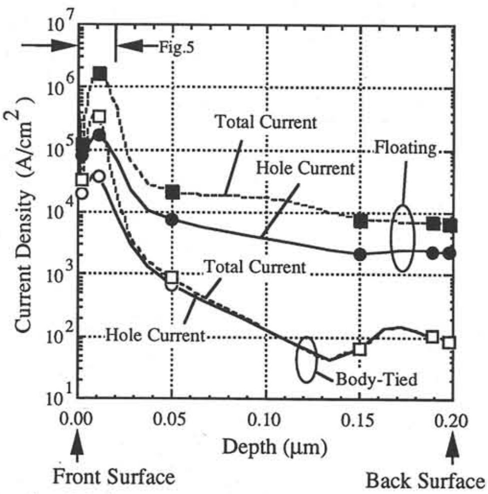

Fig.4 Simulated drain current and hole current density in floating and body-tied SOI MOSFETs under high field region near the drain edge at Vg=0.7V, Vd=3.0V. The ratios of the hole current to the drain current near the front surface are plotted in Fig.5.

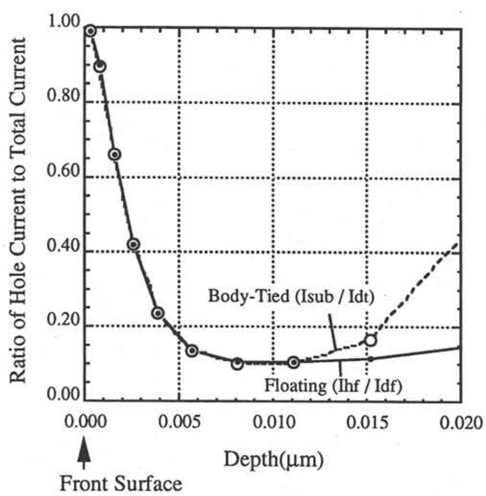

Fig.5 Ratio of the simulated hole current density to the drain current density in floating and body-tied SOI MOSFETs.

SOI MOSFETs by

$$\tau f \bullet Idf / Weff = A \bullet (Isub / Idt)^{-B} . \quad (3)$$

Figure 8 indicates excellent agreement between the prediction and the experiment. This means that only the drain current difference between floating and body-tied structures results in the lifetime difference.

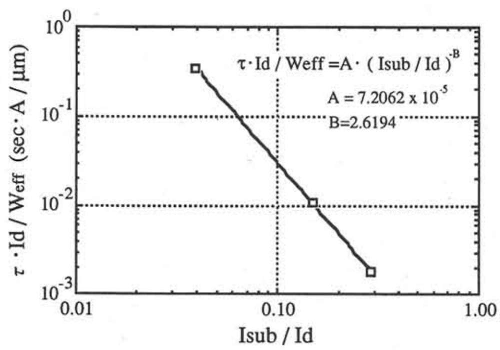

Fig.6 Correlation between a measured lifetime (τ), drain current (Id) and substrate current (Isub) in a body-tied structure.

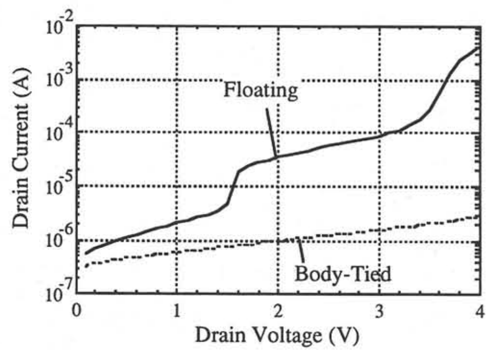

Fig.7 Measured drain current in floating and body-tied cases at gate voltage Vg=0.7V.

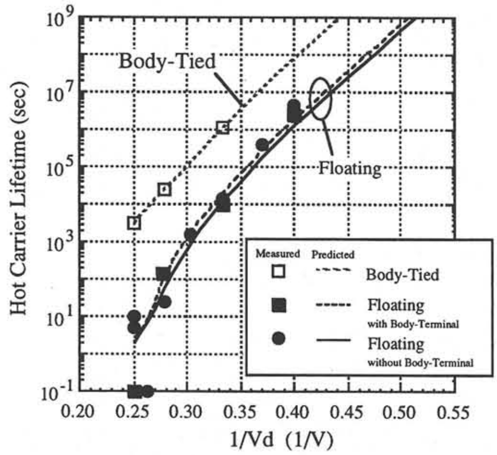

Fig.8 Predicted and measured lifetime. Marks indicate the measured lifetime. Lines indicate the predicted ones.

4. CONCLUSION

We found that the ratio of the hole current to the drain current in floating-body SOI MOSFET is approximately equal to the ratio of the substrate current to the drain current in body-tied one. Based on this nature, we proposed a method of accurately predicting the hot carrier lifetime in floating-body SOI MOSFETs. In this lifetime prediction, we can treat floating SOI MOSFETs in the same way as bulk MOSFETs except the drain current increase due to the parasitic bipolar action.

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