Effects of Body Reverse Pulse Bias on Geometric Component of Charge Pumping Current in FD SOI MOSFETs

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Introduction: The geometry-dependent component in charge pumping current (Icp) is well-known as the undesirable factor causing the overestimated interface state density in FD SOI devices[1-3]. In this work, the effects of the body reverse pulse bias on the geometric component of Icp in FD SOI MOSFETs are described. The majority carries of the high resistive body region can be completely removed by the reverse pulse applied to the body. As a result, the geometry-dependent component is suppressed. This method also suppresses the reduction of effective channel length which takes place when using the DC reverse bias.

Device: The devices used in this study are FD SOI NMOSFETs fabricated on SIMOX wafers with n+ poly gate. Figure 1 shows the top view of the fabricated device with the thicknesses of the Si, gate oxide and buried oxide films of 100nm, 5nm and 98nm and the effective gate length and width of 5μm and 20μm, respectively. For source/drain and the main part of gate poly regions, phosphorus were implanted, while for the body contact, boron ions were used. It should be noted that boron ions were also implanted to the gate poly region near the body contact.

CP Current: The strong dependence of Icp on the rise/fall time (tr/tf) obtained from the variable amplitude CP method is shown in Fig 2. The measured CP current at the long rise and fall time tr,f=1μs is considered as the reference data where the minimum distribution of the geometric component is adjusted. The two stepwise increases in the CP current are observed, being similar to the results reported by Tseng et al. [4] and attributted to the edge interface states [4]. However, in our data, from the ratio of the magnitudes of the CP currents and the difference of the gate voltages V_{GH} at which these currents start to increase, the second stepwise increase can be concluded as the effect of the p+ poly. The influence of this p+ poly region does not affect the results being discussed here.

Geometric Component and DC Reverse Method: The CP current at the rise and fall time tr=1μs, tf=0.1μs does not have much difference compared to the reference data. However, as the rise time decreases to tr=0.1μs, the CP current increases dramatically due to the inefficiency of the body contact to collect carriers. To control this unfavorable component, the DC reverse method[3] has been proposed as shown in Fig.3. The geometric component significantly decreases with an increase in the DC reverse bias. However, as the applied body bias continues to increase, the CP current still decreases due to the shortening effect of the effective channel length resulting from an expansion of the depletion regions. Therefore, to determine a suitable reverse voltage in the DC body is extremely difficult.

New Reverse Pulse Method: Since the geometric component is caused by the holes not having enough time to flow back to the body contact only during the rise time of the gate voltage, the reverse pulse bias is applied on the body contact only at the rise time to improve situations in the proposed reverse pulse method. The waveform of the pulse voltages applied to the gate and the body contacts is shown in the insert of Fig.4. The body pulse bias is ON only at the rise edge of the gate pulse and OFF at all the rest of it, therefore, it does not cause any influence on the device during the time when the gate surface is accumulated and inverted. As can be seen from Fig.4 where the body pulse top level Vp dependence of the CP current is displayed, an increase in Vp leads to an expressively marked decline in the geometric current. The result with Vp = -0.6V shows the same effect in restraining the geometric component as when using the DC reverse bias at Vbody=-0.5V. In addition, even when increasing the top level to Vp = -0.8V, the CP current does not decrease, remaining nearly constant as in the case of the reference data. It is obvious that the reverse pulse bias does not affect the effective channel length. The comparison of both methods is illustrated in Fig.5 where the recombined Icp is plotted as a function of Vbody and Vp. When Vbody and Vp are smaller than -0.5V, both methods have the same effective role in suppressing the geometric component. However, as Vbody and Vp become larger than -0.5V, the measured CP current using the DC reverse method decreases sharply while that of the proposed reverse pulse method levels off. The results in Fig.5 reveal that by using the reverse pulse method, one can not only suppress the geometric component in the CP current, but also avoid the shortening effect of the channel length.

Conclusions: The proposed reverse pulse method shows the advantage over the DC reverse method in that it does not cause an undesirable shortening effect of the channel length. Therefore, the precise measured CP current and consequently the accurate evaluated interface state density of the devices can be obtained. This new method is also expected to be more powerful in the scaled MOS devices where a slight reduction in the effective channel may lead to a significant decrease in the charge pumping current. The reverse pulse method can be also used in the similar manner by applying the reverse pulse bias to the source and drain contacts of the devices where mobile minority carriers (electrons for NMOS) play a major cause of the parasitic geometric current.

References: [1] J.S. Brugler and P.G.A. Jespers, IEEE Trans. Electron Devices, 16, 297 (1969). [2] G. Groeseneken, et al., IEEE Trans. Electron Devices, 31, 42 (1984). [3] Y. Li and T.P. Ma, Int. Symp. on VLSI Tech., Syst. and Appl., p.144, (1995). [4]Y.C Tseng, et al., Proc. 1996 IEEE Int. SOI Conf., p.90 (1996).

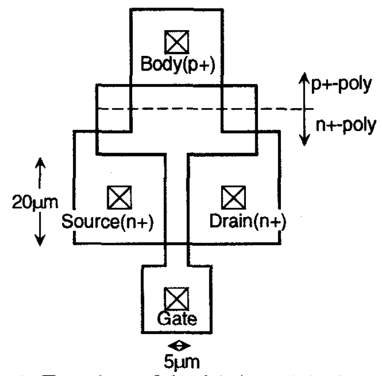

Figure 1: Top view of the fabricated devices.

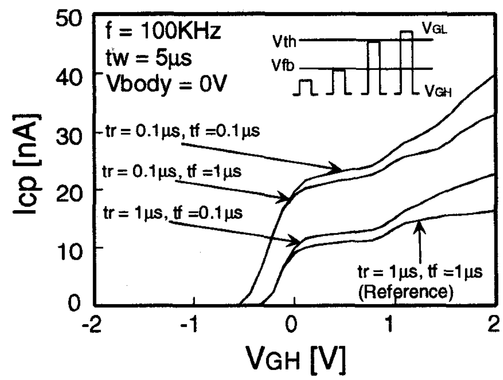

Figure 2: CP current as a function of the top level of the gate pulse, using the variable amplitude CP method as shown in the insert. The rise and fall times are also changed. The reference data do not have any geometric component.

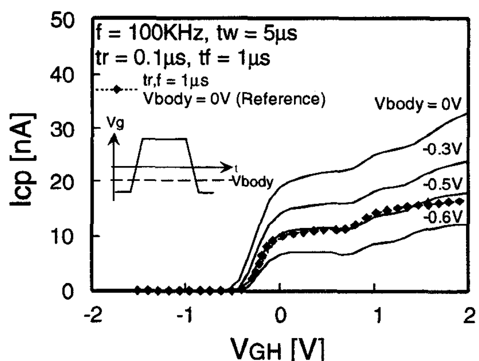

Figure 3: DC body bias dependence of the charge Pumping current.

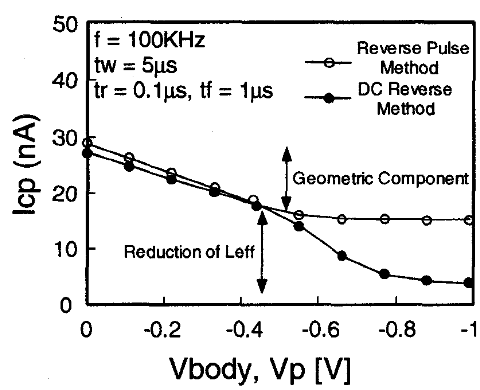

Figure 5: CP current as a function of DC body bias Vbody and pulse top level Vp. The horizontal axis is Vbody for the DC method and Vp for the reverse pulse method.

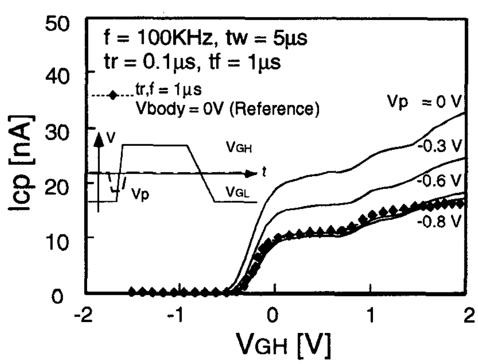

Figure 4: Body pulse top level dependence of the charge pumping current. The insert shows the waveform used in the reverse pulse method.