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Modeling of Pocket Implant Effect on Drain Current Flicker Noise in High Performance Analog CMOS Devices

Jun-Wei Wu[1], J.C. Guo[2], Kai-Lin Chiu[1], Chih-Chang Cheng[1] , W.Y. Lien[2], G.W. Huang[3] and Tahui Wang[1]

[1]Dept. of Electronics Engineering, National Chiao-Tung University, Hsinchu, Taiwan
[2]Taiwan Semiconductor Manufacturing Company, No. 6 Li-Hsin Rd. 6, Science-Based Industrial Park, Hsinchu, Taiwan
[3]National Nano Device Laboratories, Hsinchu, Taiwan

Abstract

Pocket implant effect on drain current flicker noise in 0.13μm CMOS process based high performance analog nMOSFETs is investigated. Our result shows that pocket implantation will degrade device noise characteristics primarily due to enhanced non-uniform threshold voltage distribution along the channel. An analytical flicker noise model to take into account a pocket doping effect is proposed.

Introduction

Flicker noise has been considered as one of major concerns in analog CMOS devices because it will affect the signal-to-noise ratio (SNR) in operational amplifiers and in A/D and D/A converters. Phase noise of oscillators originating from flicker noise is another concern for RF applications [1]. Recent study has shown that pocket implantation in a CMOS device will degrade drain current flicker noise. Although some researchers attributed the increase of noise to additional oxide trap creation by pocket implant [2], the real cause of pocket implant induced noise degradation is still not clear.

In this work, we will investigate pocket implant effect on flicker noise in various gate length nMOSFETs. An analytical model based on a non-uniform V_t distribution is proposed to evaluate noise with different pocket implant doses. The devices under test have a gate length from 0.22μm to 1.2μm and a gate width of 10μm. All noise data are measured in the linear operation region and each data point represents an average of 6 to 11 devices. The normalized power spectral density (S_{id}/Id^2) is used as a monitor of drain current noise, which is considered to be a fair index because of normalization to the drain current. In addition, charge pumping measurement is performed to characterize oxide (interface) trap density in different pocket splits.

Results and Discussion

Fig. 1 shows the normalized noise power density in two nMOSFETs with a different pocket dose. The gate length is 1.2μm. The noise in the two devices is almost the same without regard to a considerably different pocket dose. As a comparison, Fig. 2 shows the noise in two 0.22μm devices with the same pocket implant split. Unlike the result in the 1.2μm devices (Fig. 1), the higher pocket dose device exhibits much worse noise behavior in the entire range of gate bias. Fig. 3 shows the channel length dependence of pocket implant effect on drain current noise. The pocket implant induced noise degradation is larger in a shorter gate length device. Further characterization by using a charge pumping technique shows that the oxide (interface) trap density of the two pocket splits is about the same (Fig. 4). The distinct noise degradation in the high pocket dose device in Fig. 2 therefore cannot be explained simply by implant caused oxide trap creation. Instead, pocket implant will result in a non-uniform V_t distribution along the channel. An analytical model [3] to explain non-uniform V_t enhanced noise degradation is given in Fig. 5.

Noise Modeling Including Pocket Implant

In our model, the channel is divided into three regions, as illustrated in Fig. 5. Regions 1 and 3 represent a pocket implant region, where the local V_t is increased due to pocket implant. Since the noise in Fig. 3 is measured at a relatively low gate bias, the flicker noise is dominated by number fluctuation [4]. Mobility fluctuation thus can be neglected in Eqs. (1) and (2). In long channel devices, the noise component arising from the pocket implant regions is relatively small. This argument can be verified by the result in Fig. 1 that the noise is nearly the same for different pocket splits. Thus, the noise in a long channel device can be modeled by Eq. (1) and the oxide trap density, $N_t(x)$ can be extracted from the measured noise directly. In short channel devices, the noise components in the three regions are modeled by Eq. (2). To obtain the effective length and local V_t in the pocket implant regions (i.e., regions 1 and 3), we use the method in [5] to extract them from the reverse short channel effects of the two devices (Fig. 6).

Fig. 7 shows the calculated result in the high pocket dose device. The noise can be well modeled for both long channel (1.2μm) and short channel (0.22μm) devices except for a high gate bias region where mobility fluctuation should be considered. It should be pointed out that in our calculation no fitting parameters are used. In the low pocket dose device (Fig. 8), our model result deviates from the measured data slightly. The possible reason is that a severe short channel effect exists in the low dose device.

Conclusion

Non-uniform threshold voltage distribution along the channel caused by pocket implant is found to be responsible for flicker noise degradation in a short channel device. This effect will become more significant as channel length is further reduced. A simple analytical model including pocket implant effect has been developed. Our calculation is in reasonably good agreement with the measured result for different gate lengths and pocket doses.

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Reference

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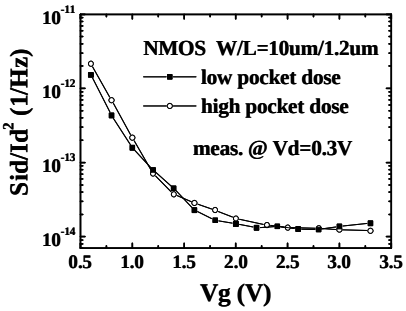


Fig. 1 Normalized noise power density versus measurement gate voltage for two different pocket doses. All data points are averaged from 6 devices. Gate length is 1.2μm.

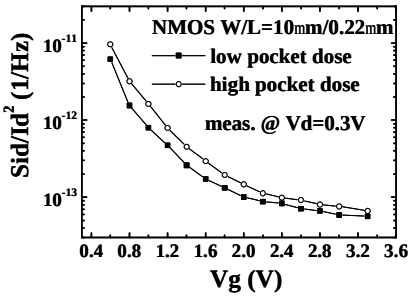


Fig. 2 Normalized noise power density versus measurement gate voltage for two different pocket doses. All data points are averaged from 11 devices. Gate length is 0.22μm.

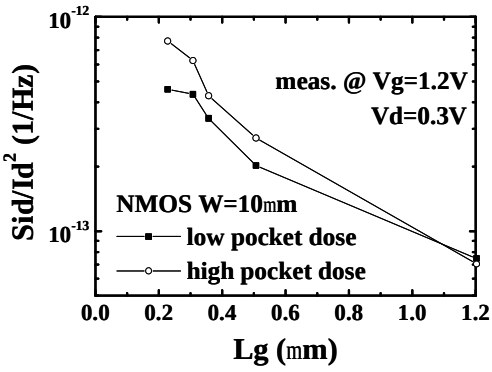


Fig. 3 Normalized noise power density versus gate length for two pocket doses.

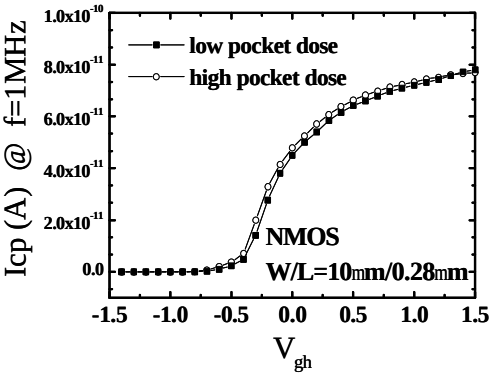
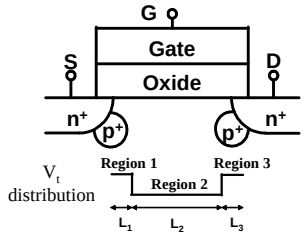


Fig. 4 Charge pumping current versus the high level of gate pulse (V_{gh}) in CP measurement for two pocket doses.



For long channel device :
(ignore pocket effect)

$$\frac{S_{Id}(f)}{Id^2} \propto \int_L N_t(x)\frac{1}{N^2(x)}dx \Rightarrow \quad extract\ N_t(x) \quad (1)$$

where N(x): channel carrier density
N_t(x): oxide trap density

For short channel device :
(consider pocket effect)

$$\frac{S_{Id}(f)}{Id^2} \propto \int_{L_1}\frac{1}{N_1^2(x)}dx + \int_{L_2}\frac{1}{N_2^2(x)}dx + \int_{L_3}\frac{1}{N_3^2(x)}dx \quad (2)$$

Fig. 5 Flicker noise model including pocket implant caused non-uniform threshold voltage distribution.

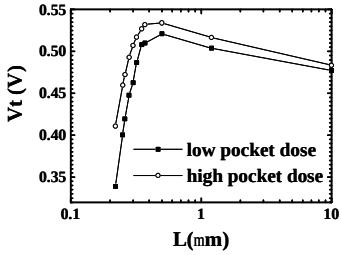
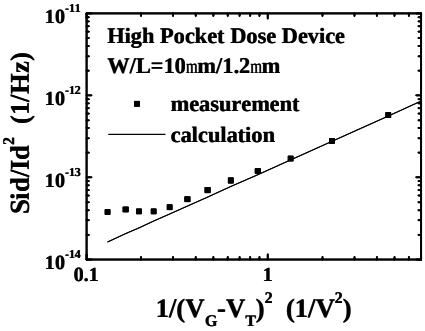
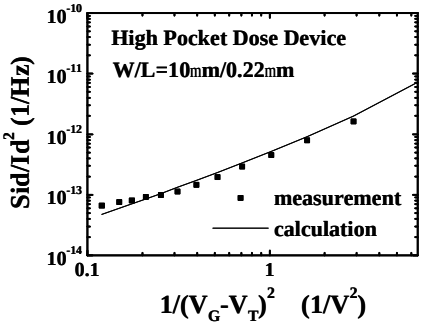


Fig. 6 Reverse short channel effect for two pocket doses. L_1=L_3=0.07μm, V_{t1}=V_{t3}=0.59V are extracted for the high pocket dose devices.



(a)



(b)

Fig. 7 Comparison of modeled and measurement results for high pocket dose. (a) L=1.2μm and (b) L=0.22μm.

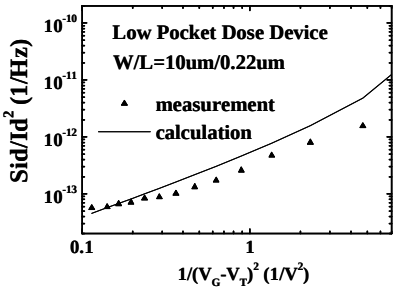


Fig. 8 Comparison of modeled and measurement results for low pocket dose.