Temporal Noise Improvement Using the Selective Application of the Fluorine Implantation in the CMOS Image Sensor

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Abstract— **The selective application of the Fluorine Implantation for improving the Temporal Noise in CMOS Image Sensor is introduced. To improve the Pixel Temporal Noise, the Fluorine Implantation is applied for the Source Follower in pixel with some special process condition. In addition, to improve the Flickering Column Noise, the selective application of the Fluorine implantation to the 1st amplifier in CDS also is shown as an example of the availability of this process. From this process, especially, the # of blinking pixel is enormously improved and also the flickering column- induced dark image deviation is improved without any other degradation in pixel performance.**

Keywords- Fluorine implantation, Pixel Temporal Noise, Blinking Pixels, Flickering Column Noise

I. INTRODUCTION

The Temporal Noise in CMOS image sensor is the problem for a long time and so many improving methods have been suggested. The reason that the Temporal Noise and the blinking pixel performance are important is because this temporary varying noise cannot be removed perfectly by the circuit based removing architecture and also cannot be screened perfectly by the outgoing test and so this always makes the risk of the RMA (Return Merchandise Authorization) from the market.

This Temporal Noise results majorly from the Source Follower in the pixel, Fig.1, and basically, results from the RTS (Random Telegraph Signal) noise of this transistor [1]. Many trials have been reported to minimize the Temporal Noise by tuning of the Source Follower transistor size dependency [2]-[4]. Gate Oxide tuning process also be suggested and the conceptual explanation on this effect is explained by using Fig.3 [5]. Fig. 2 shows our own experiment result between NO-Gox and PNO-Gox process by using the Noise Histogram method. Thanks to the PNO-Gox process, the rms noise value and the blinking pixels are improved clearly.

[6] explained the dependency of the Temporal Noise on the Source Follower's threshold voltage and so the lower threshold voltage is better for the noise performance, especially, in the Blinking pixel suppression. Lower Vth means the lower voltage between the Drain and the Source and so the maximal electric-field in the channel is decreased. Thanks to this, the probability of the electron carrier trapping to the Oxide imperfection is decreased. As an extreme case, [7] reported the Native (~0V Vth) Source Follower transistor to minimize the Temporal Noise and the blinking pixel. And also the Buried Channel scheme is reported in Source Follower to minimize the NMOS's surface scattering [8]. PMOS based Pixel also is reported for same goal [9], [10].

In this paper, using the Fluorine implantation, especially, to apply selectively to the Source Follower and the 1st Amplifier in the CDS block, the pixel and column Temporal Noise are improved clearly. Especially, the blinking pixel and column Temporal Noise are improved without or minimizing the Vth shift from the original case. This is very important point because the noise performance can be improved by this selective action without the register setting change in the customer site.

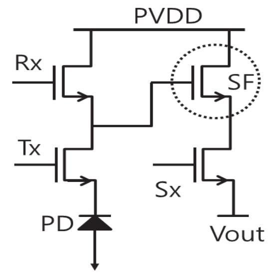

Fig.1. General 4Tr. Pinned APD Pixel Schematic with in-pixel Source Follower

II. EXPERIMETAL

A. *Plasma-Nitrided Oxide Gate Oxidation*

Fig.2 shows the Noise Performance of the Nitrided-Oxide Gate Oxide case (NO-Gox) and Plasma Nitrided-Oxide Gate Oxide case (PNO-Gox). It shows the clear improvement in the rms noise and the blinking pixels over some threshold level. The improvement by the PNO-Gox is explained by using Fig.3. The Nitrogen profile locates near the Gate oxide surface and so the defects induced by the Nitrogen locate remote from the Si-SiO2 interface. This means the activation energy for the electron to be trapped in this defect needs higher than NO-Gox case and, consequently, the electrons are not easy to obtain these energy from the channel flowing. That is, the probability of the trap occupation of PNO-Gox case is lower relatively than that of NO-Gox case.

But the problem in this result is that the tail in the histogram, that is, the blinking pixels in this PNO-Gox remains with considerable quantity. Therefore the technique to minimize the blinking pixels is necessary even now.

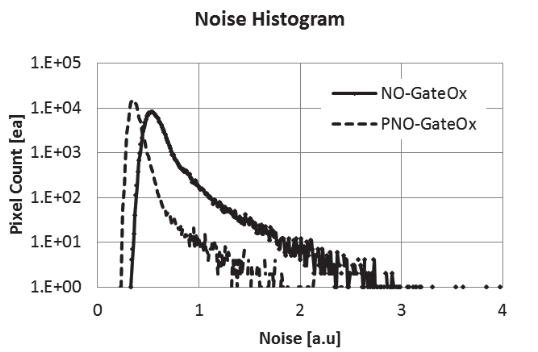

Fig.2. The Temporal Noise histogram from NO-Gox and PNO-Gox case (400x400 pixels). Vth of the Source Followers are same from 2 cases as 0.4V. (Product1: W/L=0.5/0.4um^2).

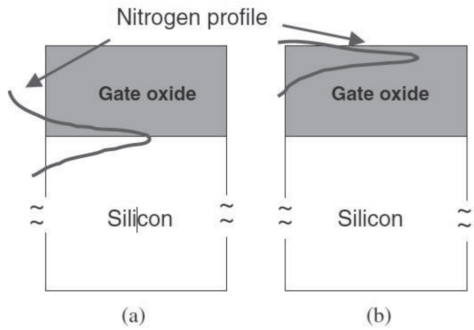

Fig.3. Schematic of nitrogen profile of (a) an NO gate and (b) a PNO gate [5].

B. Fluorine Implantation

The Effect of the Fluorine Implantation on the Transistor was reported in [11]. They evaluated the Fluorine implanted Transistors performance, especially, in 1/f noise and NBTI. From these evaluations, the Fluorine implantation contributes the improvement of the 1/f noise, Hot carrier, and NBTI performance. The mechanism is explained by using Fig.4 that the Fluorine atoms from the implanted layers in Polysilicon diffused to the SiO2 layer at following the Annealing process and, consequently, this F atoms passivated the dangling bonds in the Si-SiO2 interface and so the SiO2 imperfection is mitigated.

From the our own experiment, the 1/f noise performance is improved clearly from the baseline process and so from this result, it will be possible to improve the image sensor's noise performance by this process application. Fig.5 shows the 1/f noise result from the 10x0.6um^2 NMOS transistor in logic part. The threshold voltage of these 2 cases are same as 0.7V and same result with [11] case.

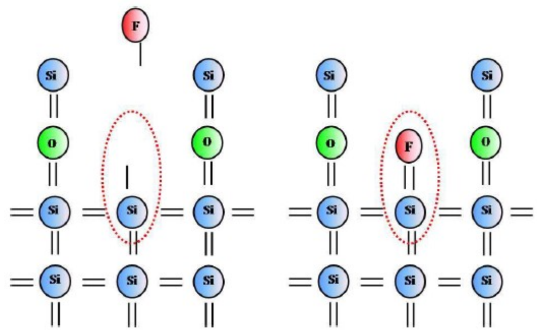

Fig.4 Passivation mechanism of dangling bonds at the interface between Si and SiO2 by Fluorine atoms [11].

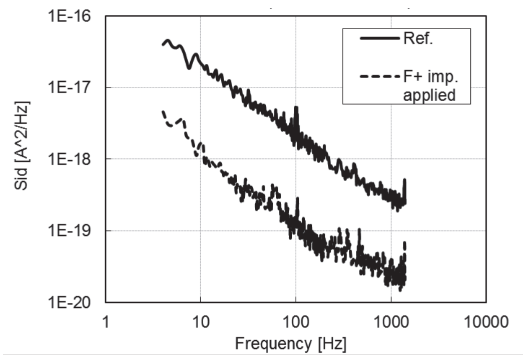

Fig.5 Flicker noise power spectral density in HV NMOS. 10x0.6um^2. F+ Implantation case showed improved Sid level.

Fig. 6 showed the Temporal Noise when the Fluorine implantation is applied for the Source Follower in pixel selectively comparing with non-applied case. The remarkable result is the decrease of the blinking pixel even though its rms noise is nearly same with baseline. Higher rms noise than Fig.2 case results from the different product and different Source Follower size. The most important in this figure is the huge improvement of the blinking pixel by applying the Fluorine implantation to the Source Follower selectively without any other optical performance shift and setting change.

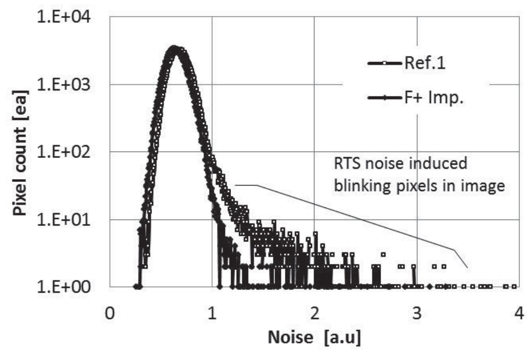

Fig.6. The Temporal Noise histogram from PNO-Gox and PNO-Gox with F+ implantation case (400x400 pixels). Vth of the Source Followers are same from 2 cases as 0.25V. (Product2: W/L=0.244/0.275um^2).

Another application of the Fluorine implantation is the suppression of the Flickering Column Noise. The Flickering Column Noise also have the same root cause like the pixel Temporal Noise, that is, the RTS noise from the 1st stage amplifier transistors. This noise generally shows 2 levels (Fig.7(a)) and different from the 3 levels fluctuation when the pixel Source Follower having the RTS noise [1], [3] because the column flicker noise is generated at the 1st Amp. stage which is after the signal sampling.

This Flickering Column Noise also can be suppressed by the additional selective application of the Fluorine implantation to the 1st Amp's Transistors. In general case, the active/poly/ contact and metal-1 layers revision is necessary to improve this noise based on the understanding of the 1/f noise's dependency on the transistor size [2]-[4]. This action needs so much time and the revision cost. And also this can need the fixing of the register setting. But the additional selective application of the Fluorine implantation to the 1st Amp's transistors just needs a 1 layer addition and the result can be obtained faster than revision case. Below Fig.7(b) shows the improvement of the Flickering Column Noise by the Fluorine implantation to the 1st Amp's transistors. The dark images code deviation become better than Ref. clearly thanks to the Flickering Column Noise Improvement.

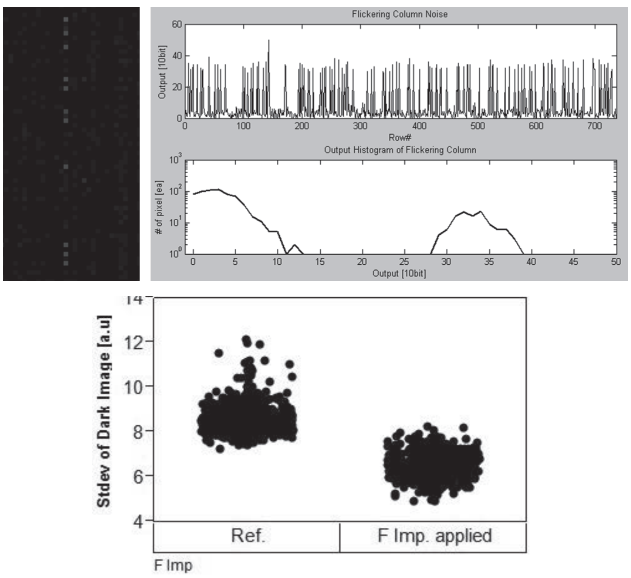

Fig. 7. (a) Output fluctuation in a column, (b) the suppression of the Flickering Column Noise which is confirmed by the Stdev of Dark Images.

III. Conclusion

In this report, through the selective application of the Fluorine implantation to the pixel Source Follower, the Blinking pixels are suppressed clearly thanks to the 1/f and RTS noise improvement. And also the Flickering Column Noise is improved when this process is applied to the CDS's 1st Amp. transistors selectively.

Because this process just needs 1step addition and not necessary to fix the setting, it is very economical when the blinking pixel performance should be improved during the mass production stage.

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