Study on the Characteristics of Strain according to the dark effect in 1.12u Pixel

Ho-Young Kwak, Jong-Eun Kim, Seong-Il Kim*, Do-Hwan Kim**, Jong-Chae Kim, Kang-Bong Seo

SK hynix, Future Innovation Technology Group, Icheon-si, Gyeonggi-do, Korea
* SK hynix, AT Group, Cheongju-si, Chungcheongbuk-do, Korea
** SK hynix, CIS Business, Icheon-si, Gyeonggi-do, Korea
E-mail : hoyoung.kwak@sk.com, mobile phone : 82-10-3445-9697

***Abstract*— We have investigated the strain according to the dark characteristic of 13M pixel using 90nm BSI (Backside Illumination) process. The change of dark characteristics according to the presence / absence of attack in the floating diffusion (FD) region was confirmed in WT(Wafer Test) and Electrical measurement, and the Si interface characteristic was qualitatively confirmed through HR-TEM. The results are compared quantitatively by Top spin analysis for objective characteristic differences because the qualitative confirmation depends on the point of view, it can be seen that the strain applied to Si changes from compressive to tensile when Si damage occurs. In addition, dark defects in WT increased from 110ppm to over 2000ppm by applying the FD region Ge imp.**

***Index Terms*— Local strain, CMOS image sensor, Hot pixel, Top spin**

I. Introduction

Image sensors in mobile phone cameras and digital cameras convert light received through lenses into electrical signals, and there are largely two types of image sensors: the CCD (Charge Coupled Device) and CIS (CMOS Image Sensor). The simple structure of CCD enables high density integration, low noise, and excellent image quality. It was widely used in comparison with CIS in the early days. But the low power characteristics have emerged due to the rapid spread of smartphones and IoT devices, CIS, which has high price competitiveness and easy peripherals and one chip using process, is commonly used than CCD[1]. Recently, dual or triple camera applications are being applied to smartphone to emphasize the state of the technology. As a high-pixel camera was applied to obtain a high resolution image even in a smartphone, the light absorption of the light-receiving part was maximized using a backside illumination (BSI) structure. BSI processes the back side of the wafer compared to the conventional front side illumination (FSI), so the metal wiring layers are located under the pixel, which prevents diffuse reflection by the wiring layer[2].

In addition, low light and dark characteristics are also important as many functions are added to the mobile phone camera to capture images in various environments. The dark characteristic is evaluated based on the output value during the accumulation time of PD (Photo diode) in the absence of light. The main evaluation and analysis indexes include dark current, hot pixel, dark shading, and temporal noise (TN). The dark current of image sensors is an unexpected signal according to the defects of typical pixel not due to the absorption of a photon. It can occur randomly in all pixels. This dark current limits the performance of the image sensors by creating false signals and noise. Dark noise increases due to electrons introduced into PD due to various defects that occur during process, and the main factors and effects that cause dark source are as shown in Equations (1) to (3).

$$I_{sur} = \frac{qn_i S_0}{2} = \frac{qn_i^2 S_0}{p} \quad (1)$$

$$I_{dep} = \frac{qn_i (x_d + t)}{2\tau_{g\_dep}} \quad (2)$$

$$I_{diff} = \frac{qD_n n_i^2}{N_A L_n} \quad (3)$$

Equation (1) represents the surface dark current generated at the Si / STI interface, Equation (2) represents Depletion dark current, and Equation (3) represents Diffusion dark current. Plasma process is a process that is essentially used for forming high resolution patterns, and is used for products that are completed using CMOS processes. When using the plasma etching processes, the physical damage caused by energetic ion bombardment of the Si substrate can be attributed to the Si recess [3,4]. This process of Si recess affects the deterioration of dark characteristics.

In this paper, we focused on the dark properties according to the Si interface state. The dark properties were analyzed through the electrical and physical properties analysis methods. In addition, the top spin method is used to quantify the physical change of Si interface due to the dark characteristics.

II. Experiment

The device used in this study was fabricated using SK hynix 90nm CIS BSI process with 1.12um 13M Pixel. A color filter array was constructed for spectral characteristics and in order to apply half shield PDAF (Phase Defect Auto Focus), DTI (Deep Trench Isolation) process is applied to PDAF area. The AR (Anti Reflection) stack of Al2O3 / HfO2 layer is applied to improve flare characteristics.

FD is an important area in the dark characteristics. The processes that can affect FD include NGS(Gate Spacer) Etch and PP2 (FD LDD) IMP step. In the case of 90nm CIS process, the Silicon of FD region is recessed during NGS etching, so the dark characteristics may change according to process issues such as equipment PM and variation of condition, and so on. In addition, the dark characteristics are affected by the implant conditions of the FD region. The process integration flow of the FSI section for the experiment is shown in Figure 1.

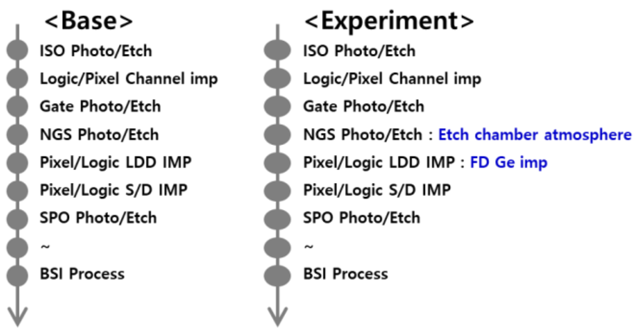

Fig. 1. Process Flow for Experiment

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III. Results and Discussion

Dark characteristics of Pixel according to chamber of progress after PM of NGS Etch equipment are shown in Figure 2. In the dark category, 37 hot pixels of C chamber materials were increased, DBPC 200 characteristics were degraded by more than 35%, and 2nd and 3rd peaks on the dark histogram were

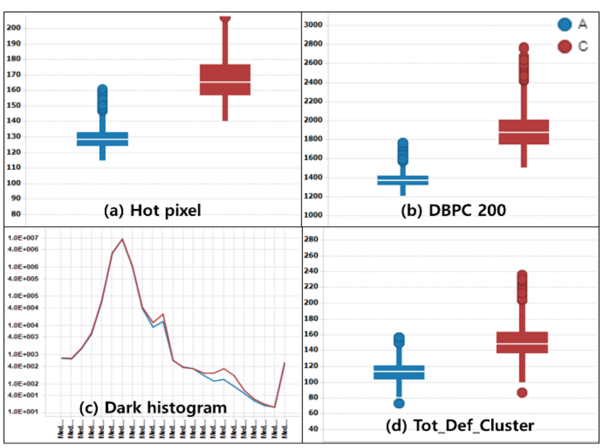

Fig. 2. WT data according to the Chamber of NGS Etch

also degraded. Because 80 ~ 90 OTPs are basically used to correct defect DPC of the pixels around PDAF equipped with AF function (4.5% portion of total pixels). Yield loss in Tot_Def_Cluster item gets worse due to lack of OTP when Dark property deteriorates. The area that is open during NGS etching is the FD area between TXs. Si lattice damage and point defects caused by plasma damage during etching cause local Si strain and band gap shrinkage to affect dark characteristics [5]. This can be confirmed that 2nd peak and 3rd peak are improved when applying NGS low power as shown in Fig. 3 (a). Also, as shown in Fig. 3 (b), if Ge imp is applied to FD region, 2nd peak(100~200 code range) and 3rd peak(deteriorate due to Si-interface trap deterioration in Tx gate-edge depletion region) were degraded.

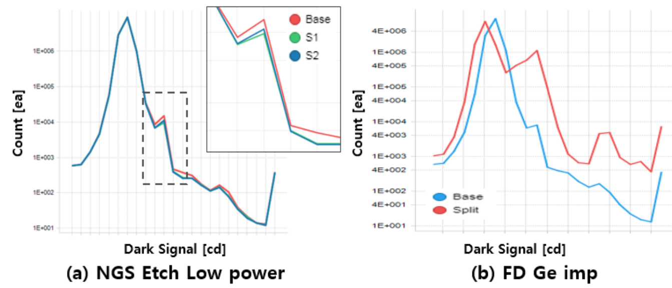

Fig. 3. Dark histogram according to Experiment

The electrical characteristics were confirmed by measuring the FD cap in Fig.4. A 1 / C2 difference in depletion state was observed in both good and bad materials. There are two factors of the defects. The defects between surface and intersection affects the capacitance. If both dopants(N_D) and defects contribute to capacitance, the slope of 1/C2 becomes gentler than reference. The damage(n_{dam}) is estimated form the slope of the 1/C2. The n_{dam} is the volume density of residual defects in the damaged layer[6]. It can be seen that 1 / C2 is shifted in hot pixel deterioration material and that it is good from bottom to top, which is the basic influence of part unit of chamber.

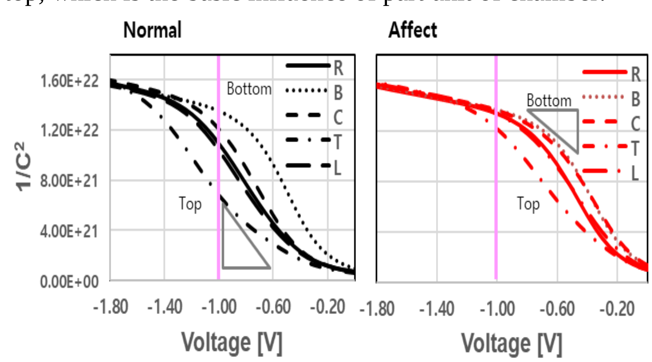

Fig. 4. C-V data of FD according to the chamber of NGS Etch

HR-TEM analysis was performed to confirm the physical properties of the Si interface. In order to confirm the change according to the opening of the FD region, Poly remained so that the pattern of Si not open and the pattern of Si open during NGS Etch were checked together. As shown in Fig. 5, there is no difference in Si / SiO2 interface regardless of chamber in case of pattern without Si recess. However, in the case of the pattern where the Si recess occurs due to the FD region being opened, the Si lattice was damaged due to the local strain occurring at the Si / SiO2 interface in the sample conducted in the C chamber compared to the A chamber. Qualitative differences can be identified qualitatively in HR TEM analysis.

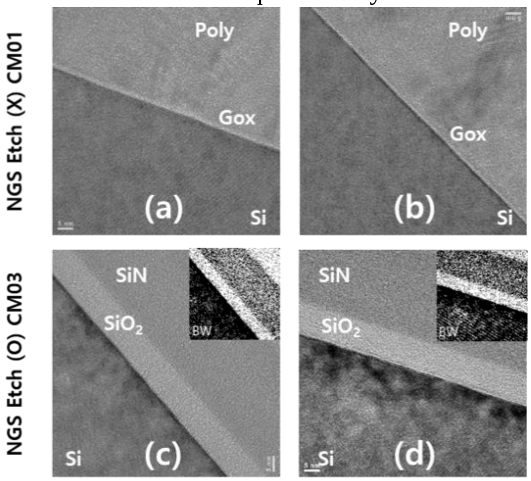

Fig. 5. Image of HR-TEM according to NGS Etch chamber (a)/(c): A chamber, (b)/(d): C chamber

Top spin method was considered to quantitatively identify strain effects. Top spin means the type and amount of stain by using a diffraction pattern to shift peaks or change the shape of a strain during occurrence of strain. The related equation is shown in equation (4)[7].

$$\varepsilon_{str} = \frac{\beta_{\varepsilon}}{C \tan \theta} \tag{4}$$

β_{ε} is strain broadening, C is constant (4 or 5), and θ is Bragg angle. As shown in Fig. 6, Strain was analyzed by Nano Precession Electron Diffraction method by setting Si / SiO2 interface region. The strain present in the interface was confirmed by the 2-D strain map and profile with 0.1% (0.001) resolution.

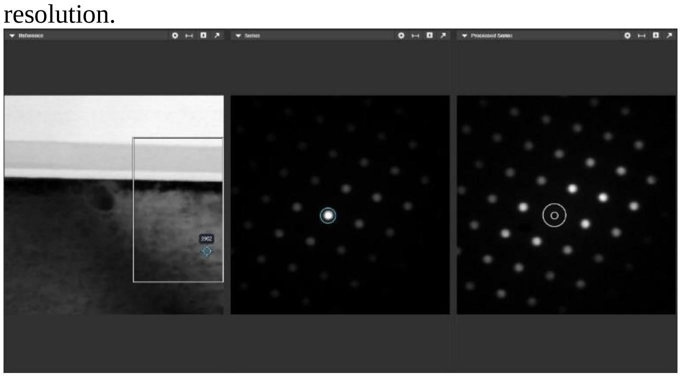

Fig. 6. NBD for analysis of strain

The reference value was set in Si and 2-D strain map was extracted according to the crystal direction, and the strain type and degree of XX direction (Channel direction) and YY direction (Si sub direction) were checked as shown in Fig. 7. In the 2-D map and histogram, positive values (+) indicate tensile strain and negative values (-) indicate compressive strain. The histogram in Fig. 7. shows that the peaks near the Si interface and the tensile strain is concentrated to the Si surface for both XX and YY directions of the C chamber.

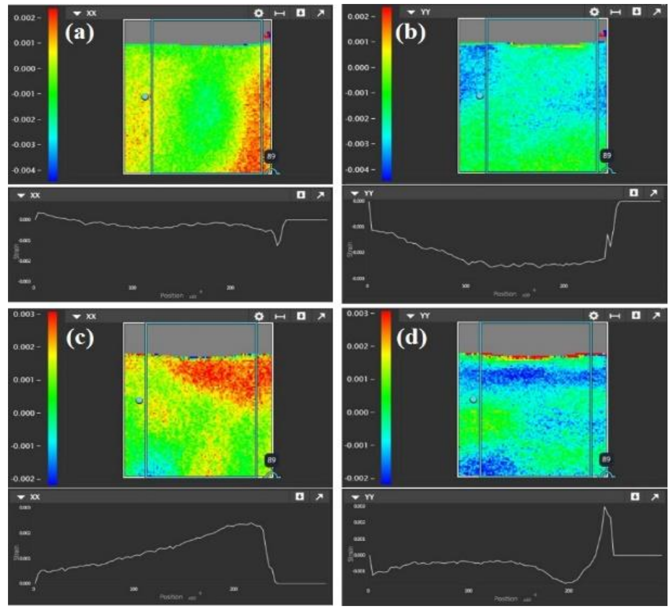

Fig. 7. 2-D strain map and histogram of Top spin (a)/(b): A chamber, (c)/(d): C chamber

IV. Conclusion

In this study, the dark properties of 13M Pixels with PDAF structure using 90nm BSI process were analyzed. Differences were confirmed through analysis of electrical properties and physical properties of changes in the Dark properties according to the state of the Si interface. Also, a top spin method for dark characteristic analysis was proposed. The HR-TEM can only be qualitatively evaluated through images, but it is possible to quantitatively confirm the strain by applying the Top Spin method. As a result of analyzing the strain according to the Dark property at the Si interface of the manufactured pixel, it can be seen that the strain is concentrated at the Si interface and the Tensile Strain is greatly affected when the Dark property is deteriorated.

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