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Generation Current Reduction at LOCOS Isolation Edge by Low Temperature Hydrogen Annealing

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The generation current at the LOCOS isolation edge can be measured by the separation of the peripheral current generation and the surface and bulk current generation under the gate electrode. This method is accomplished by a C-t measurement of MOS capacitors with varying a gate area, and the effects of the generation current reduction at the LOCOS isolation edge by low temperature hydrogen annealing (LTHA) can be successfully investigated. As a result, it becomes clear that the generation current is strongly reduced by annealing at a temperature below 400℃, but at 450℃ the reduction is rather small.

1. Introduction

As the packing density of LSIs increases, peripheral length surrounding the active region per unit area becomes longer. And leakage phenomenon at the LOCOS isolation edge caused by the recombination and generation process has become a major issue to be discussed. Several studies on the phenomena and mechanisms of leakage current at the LOCOS peripheral have been carried out [1-3]. But little has been reported concerning the nature of the leakage current reduction at the LOCOS peripheral.

In the present work, we have modified a method to measure the generation current at the LOCOS isolation edge. With this method it is possible to investigate generation current reduction due to a low temperature hydrogen annealing.

2. Newly Developed Measurement Method

Two factors involved in the current generation in the depletion layer of a MOS capacitor are shown in Fig.1. They are the generation current at the LOCOS peripheral ($J_{gen,P}$) and the generation current at the surface and bulk under the gate area ($J_{gen,A}$). It has been difficult, however, to separate the $J_{gen,P}$ and the $J_{gen,A}$. With P the peripheral length at the LOCOS isolation edge and A the area of the active region, the total generation current (J_{gen}) can be expressed as follows :

$$J_{gen} = J_{gen,P} \times P/A + J_{gen,A} . \qquad (1)$$

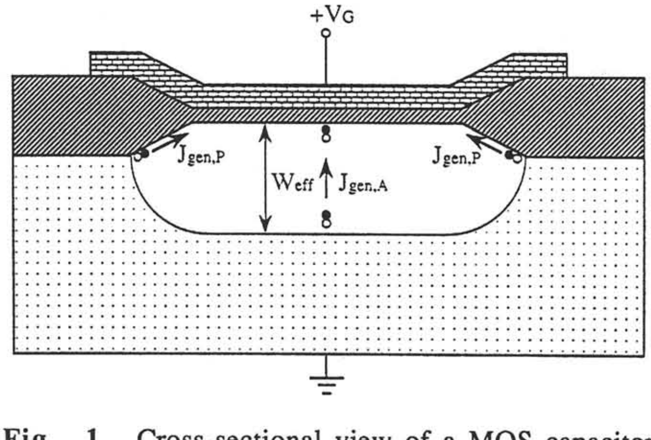

Fig. 1 Cross-sectional view of a MOS capacitor structure. Jgen,P and Jgen,A are the generation current sources in the depletion layer.

Figure 2 shows a typical Jgen vs. P/A plot corresponding with Eq.(1). $J_{gen,P}$ can be obtained from the slope, and $J_{gen,A}$ from the intercept on the Y-axis of the line.

Figure 3 shows a typical Zerbst plot, which is included a C-t characteristics to obtain a Zerbst plot. From Fig.3, a lifetime τ_g and a surface generation velocity S can be calculated [4]. However, the Zerbst plot given by a differential equation dose not always equals a straight line, and this makes it difficult to determine τ_g. Therefore we have calculated a mean lifetime τ_{gm} given by using Shroder's approximation [5] :

$$\tau_{gm} = n_i/8N_B \times C_F/C_O \times t_F \times (1 + C_i/C_F) . \quad (2)$$

According to Shroder's method, an unique value of the lifetime can be obtained without using the Zerbst analysis. Furthermore, if an effective depletion-layer width (Weff) spread out equally in the transversal direction and in the longitudinal direction, the J_{gen} defined by Eq.(1) is given by :

$$J_{gen} = qn_iW_{eff}/\tau_{gm} . \quad (3)$$

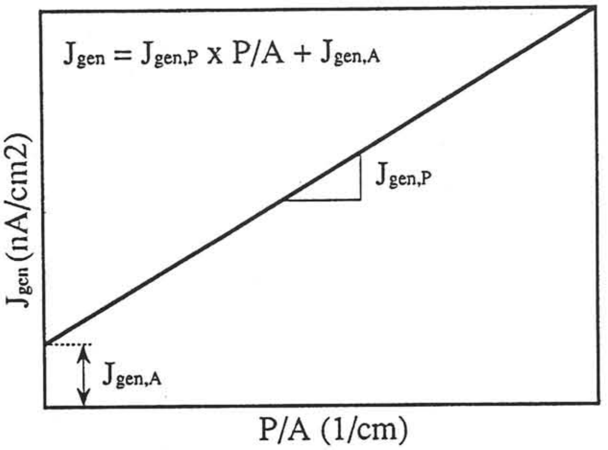

Fig. 2 Jgen vs. P/A plot with Jgen,P and Jgen,A equal to the slope and the interception on the Y-axis of the straight line, respectively.

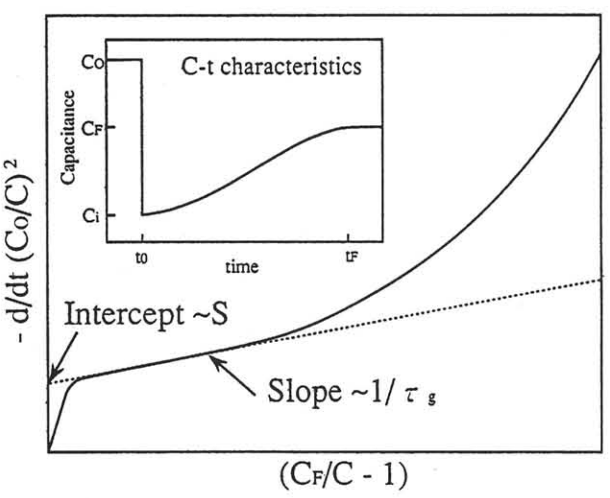

Fig. 3 Typical Zerbst plot with corresponding C-t characteristics; used for measuring a conventional lifetime in reciprocal proportion to the slope.

3. Application of the Method to Investigate Low Temperature Hydrogen Annealing (LTHA) Effect

MOS capacitors with LOCOS are processed in such a way that Weff in the transversal direction almost equals Weff in the longitudinal direction, by avoiding the surface channel-cut layer. Thereby, net generation current at the LOCOS isolation edge can be obtained. Also LTHA was performed as post-metalization annealing (PMA) for 30 min at 350℃, 400℃ and 450℃ to investigate the generation current reduction at the LOCOS isolation edge. Several MOS capacitors with various P/A are fabricated on the same wafer to estimate $J_{gen,P}$. Similar capacitors but without LOCOS are also prepared to compare with the characteristics of the LOCOS samples.

Figure 4 shows the interface density of states of the sample without LTHA (further reffered to as NOPMA) and the LTHA samples both without LOCOS. In contradiction to the work of other researchers [6,7], we do not observe a remarkable reduction of the interface trap generation in the active region observed in Fig.4. Probably this is due to a detailed optimization of our oxidation process. It can be verified that the generation of interface states in the lower-half of the Si band gap is reduced but the generation of interface states in the upper-half is increased by means of the LTHA.

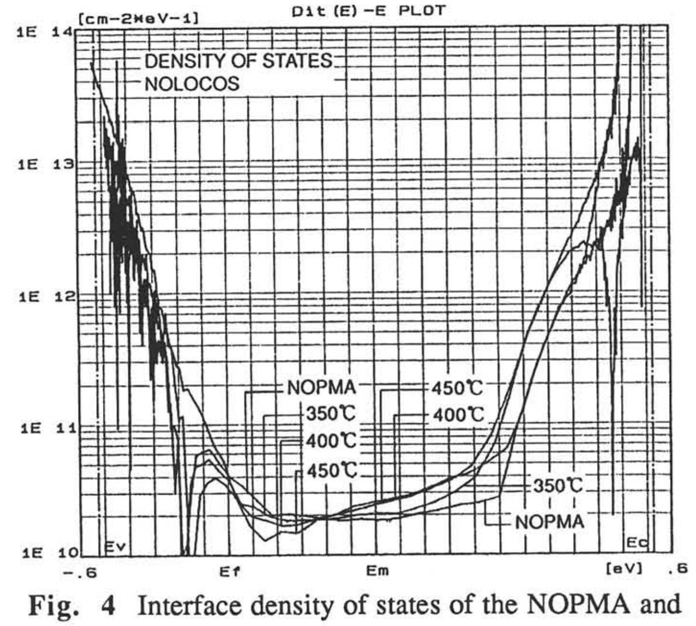

Fig. 4 Interface density of states of the NOPMA and the LTHA as a parameter both without LOCOS.

Figure 5 shows the C-t characteristics for the NOPMA samples with P/A as a parameter. It is obvious that the C-t characteristics depend on P/A. With increasing P/A, the lifetime obtained from Eq.(2) decreases and the generation current obtained from Eq.(3) will increase.

Figure 6 shows the LTHA dependence of C-t characteristics with P/A equal to 30.5 /cm. For a LTHA treatment at 400℃ the lifetime obtained from Fig.6

increases stlongly. But in case of a LTHA treatment at 450℃ the lifetime will decrease, in contradiction with the behavior shown in Fig.4. This means that the longer lifetime indicates the saturation of Si dangling bonds with hydrogen, and the shorter lifetime for 450℃ indicates the release of hydrogen, at the Si/SiO_2 interface of the LOCOS isolation edge as well as the plane surface as reported in the previous studies [6-8].

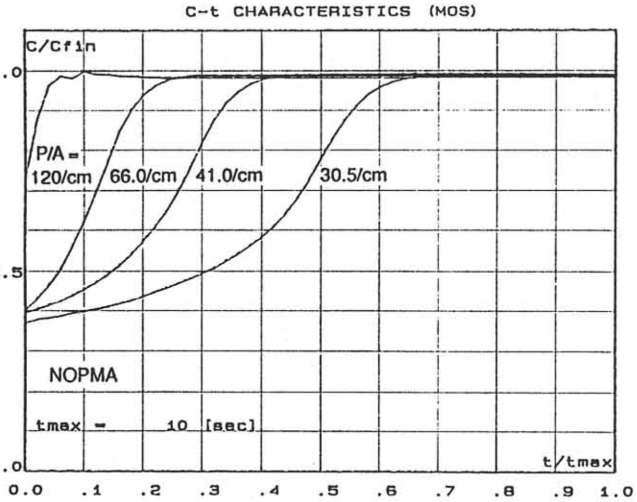

Fig. 5 C-t characteristics with P/A as a parameter without LTHA.

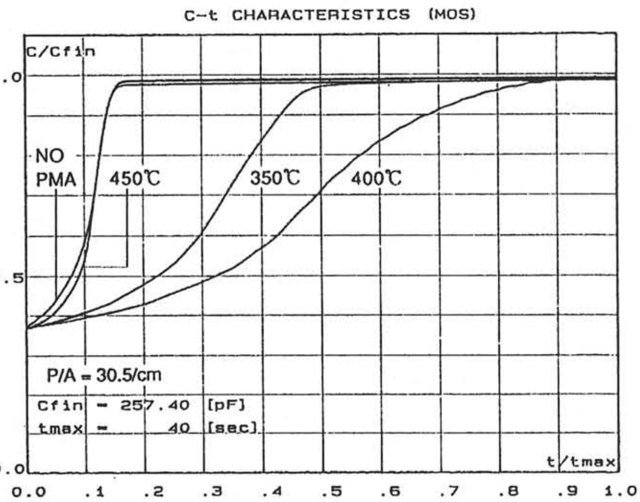

Fig. 6 C-t characteritics of the NOPMA and the LTHA as a parameter with P/A equals 30.5 /cm.

Carrying out the same experiments using various P/A, the Jgen vs. P/A plot can be calculated, as shown in Fig.7. The net generation current at the LOCOS isolation edge $J_{gen,P}$'s are given by the slopes of each line, so it is confirmed that the generation current at the LOCOS isolation edge is substantially affected by the temperature of LTHA. As a result, it becomes clear that the generation current at the LOCOS isolation edge is reduced by LTHA treatments up to 400℃ but becomes high again at 450℃.

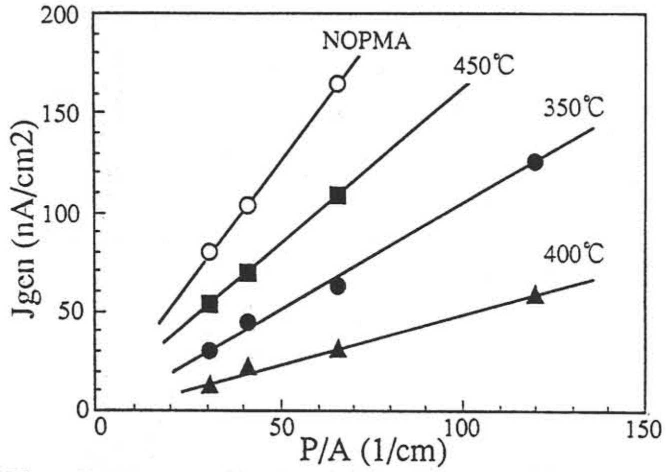

Fig. 7 Jgen vs. P/A plot of the NOPMA and the LTHA as a parameter.

4. Conclusions

We have measured the generation current by using the C-t method based on the mean lifetime measurement with varying a gate area size of MOS capacitors by Shroder's approximation avoided the use of Zerbst analysis. It is observed that the generation current at the LOCOS isolation edge is remarkably reduced due to the annealing in hydrogen ambient at 400℃ but hardly reduced at 450℃. TDS (thermal desorption spectroscopy) studies indicate that hydrogen is desorbed from the Si surface at about 400℃ [8]. Our experimental results suggest the desorption of hydrogen should also occur at the Si/SiO2 interface of the LOCOS isolation edge when the LTHA is higher than about 450℃.

References

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