

High Performance n/p Junction Characteristics Using High Temperature RTA in Conjunction with H₂ Treatment

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1. Introduction

Retention time degradation is becoming a serious problem in 64-Mbit DRAMs (Dynamic Random-Access Memories) and will be even more as a problem in future high-density DRAMs [1]. A generation current at the interface trapped state of the LOCOS (LOCAl Oxidation of Silicon)/Si is one of the majority origins of the retention time degradation [2][3]. Improvement of SiO₂/Si interfaces is one of the key issues for both 64-Mbit DRAMs with LOCOS isolation and future DRAMs with STI (Shallow Trench Isolation). It has been reported that hydrogen and fluoride are effective for the reduction of leakage currents, due to the decrease in the interface trapped state [3][4].

In this paper, we reveal that a new electrically active defects, with the exception of the interface trapped states, exists in the peripheral region and is reduced using RTA (Rapid Thermal Annealing) in conjunction with H₂ treatment. The mechanism of the leakage current reduction will also be discussed from the view points of electrically active defects introduced during the LOCOS formation and the interface trapped states at the LOCOS/Si interfaces.

2. Experimental

Figure 1 shows the schematic process flow of the sample fabrication. A p-type well and LOCOS were formed on an epitaxial wafer. Then, a channel stopping layer (guard ring boron) was fabricated just beneath the LOCOS. The n-type diffusion layer was formed by implanting phosphorous. RTA was performed at 1050°C for 30 sec in N₂ ambient after the electrode formation of the phosphorous-doped poly-Si. Finally, H₂ treatment (H₂ sintering) was carried out at a low temperature. Four types of samples (*H*, *HR*, *N*, and *R*) were made with the combination of RTA and H₂. To make the origin of the leakage current degradation clear, RTA was carried out at 1050°C and 1150°C for 30 sec just before the guard-ring boron implantation (Sample *B10* and *B11*).

We measured the current-voltage (*I-V*) and capacitance-voltage (*C-V*) characteristics under reverse-biased conditions. The measured area and perimeter were, respectively, 0.25 mm² and 200 mm.

3. Results and Discussion

Figure 2 shows reverse *I-V* characteristics for four samples (*H*, *HR*, *N*, and *R*), where the junction leakage current is mainly dominated by a perimeter component. The H₂ treatment (sample *H*, *HR*) is effective in reducing the leakage current. It has been reported that H₂ treatment plays a role in the passivation of the interface trapped state at the LOCOS/Si [4]. The result, thus, means that the leakage current for the sample without H₂ treatment is mainly due to

the LOCOS/Si interface trapped state.

The RTA reduces the leakage current for the sample with H₂ treatment. On the other hand, for the sample without H₂ treatment the leakage current increases. These results indicate that the effect of RTA on leakage currents is different for the samples with and without H₂ treatment.

Figure 3 shows n/p junction capacitance at a 3 V reverse-bias voltage, in addition to the junction leakage current at a 3 V reverse-bias voltage shown in Fig. 2. In this figure, the large 1/C value means there is a wide depletion layer width. The depletion layer width increases after RTA, but is not changed after H₂ treatment. The depletion layer width extended as a result that the redistribution of impurity such as guard ring boron and/or phosphorous in the junction peripheral region takes place after RTA.

In the case of the sample without H₂ treatment, the leakage current increases by RTA, as shown in Fig. 4 [11]. In this case, the dominant component of the leakage currents is the generation current of the LOCOS/Si interface trapped state. Therefore, the density of the interface trapped state is extremely increased by the extension of the depletion layer widths, and the junction leakage current increases.

In contrast, for the sample with H₂ treatment, the leakage current decreases after RTA in spite of the extension of the depletion layer width. This result reveals that the electrically active defect, which can not be passivated by H₂ treatment, exists in the peripheral regions and is reduced by RTA. The influence of the electrically active defect can be observed by reducing generation leakage currents (Fig. 4 [D1]) due to the interface trapped state. Thus, the leakage current is effectively reduced by RTA in conjunction with H₂ treatment (Fig. 4 [D2]).

To investigate the electrically active defect, RTA was carried out at 1050°C (sample *B10*) and 1150°C (sample *B11*) just before the guard-ring boron implantation. Figure 4 shows the junction leakage currents and junction capacitance. The leakage current decreases with the increase in RTA temperature, however, the depletion layer width, that is the impurity profile, is not changed. These results indicate that electrically active defects introduced during the LOCOS formation are annihilated by RTA, and that the leakage current subsequently reduced.

4. Conclusions

We demonstrated the existence of the electrically active defect induced during LOCOS formation and the reduction of this electrically active defect by RTA. The influence of the electrical active defect can be observed by reducing the leakage currents which are due to the decrease in the interface

trapped state by H₂ treatment. As a result, RTA by itself and RTA in conjunction with H₂ treatment effectively reduce the leakage current.

References

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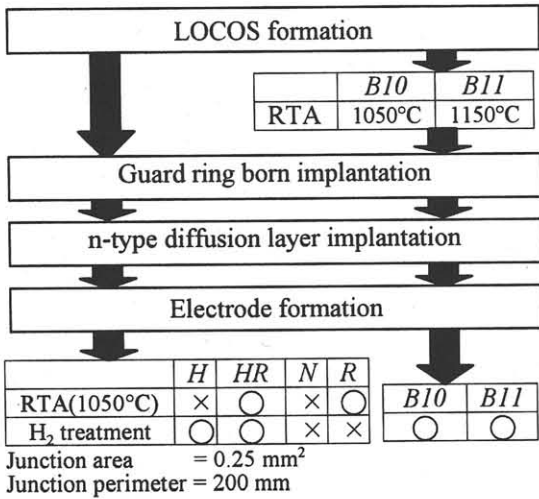


Fig. 1. The schematic process flow.

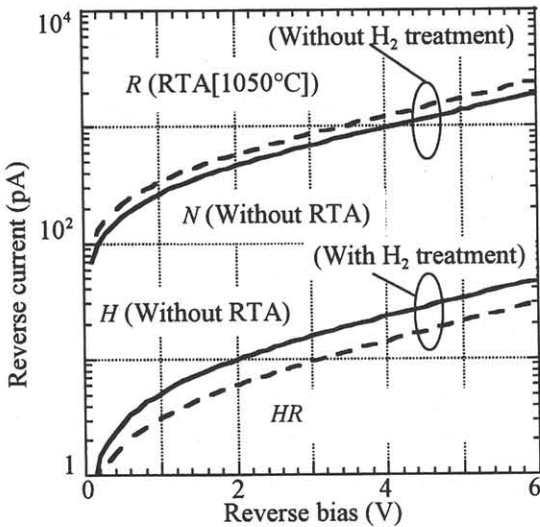


Fig. 2. Reverse I-V characteristics for H, HR, N, and R.

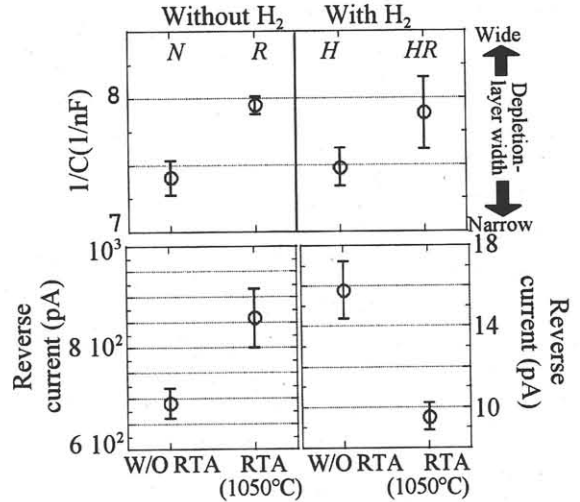


Fig. 3. Reverse leakage currents and capacitance at reverse bias of 3 V for four samples.

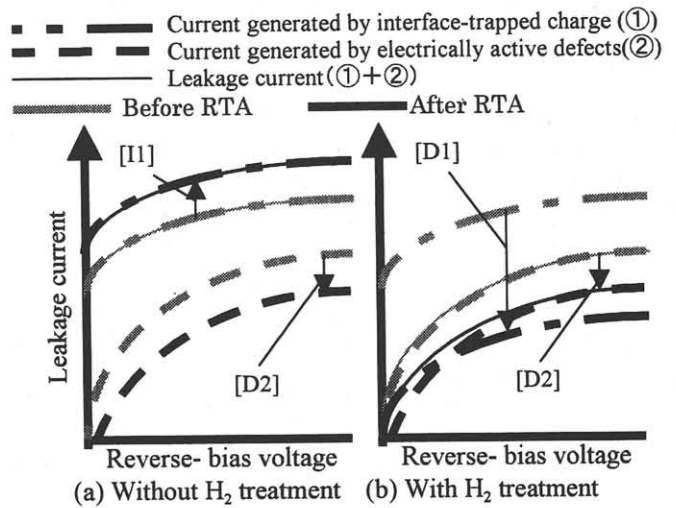


Fig. 4. The schematic I-V characteristics of reduction in the leakage current by RTA and H₂ treatment. [I1]:Leakage current increment by extension of the depletion layer width. [D1]:Generation current reduction using H₂ treatment. [D2]:Generation current reduction using RTA.

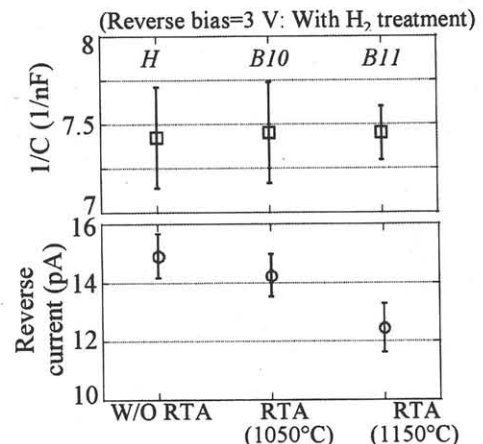


Fig. 5. Reverse leakage currents and capacitance for the samples with H₂ treatment. RTA at 1050°C and 1150°C was carried out just before the guard ring boron implantation.