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Suppression of Transient Enhanced Diffusion by LOCOS Induced Stress

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Abstract

We evaluated the phenomena of transient enhanced diffusion (TED) on different types of LOCOS structures. Boron profiles were measured by secondary ion mass spectroscopy (SIMS) on the backside of the wafers to eliminate any affects caused by uneven surfaces of the LOCOS structures. We found TED to be strongly correlated with mechanical stress in the active regions.

1. Introduction

The TED of boron is significant for controlling the threshold voltage (Vt) of deep-submicron n-MOSFETs, because it causes both a reverse short channel effect (RSCE) [1] and Vt fluctuations [2]. TED is promoted by the diffusion of excess interstitial Si. Interstitial Si can be influenced by many factors such as ion implantation, the thermal budget, and the isolation structure. In this paper, we investigated the effect of LOCOS induced stress on TED.

2. Experiment

Fig. 1 shows the sample preparation. We compared two types of LOCOS structures. One was ON-LOCOS using an oxynitride pad, and the other was conventional LOCOS using a SiO_2 pad. We made periodic island patterns (1 μm square) in each LOCOS structure to evaluate the boron profiles. Boron was implanted at 70 keV into each periodic island pattern. The resultant projection range (Rp) of boron was 0.2 μm, which is deeper than the bottom of LOCOS oxides. The samples were then annealed at 800°C for 30 min to activate the boron. After the activation of boron, Si was implanted at 33 keV to produce interstitial Si, and then annealed at 700°C for 10 min. This temperature does not cause normal thermal diffusion, but cause TED. The backside of the samples were polished, and then measured by SIMS. We also compared the characteristics of n-MOS transistors to evaluate TED on the surface area.

It is difficult to measure SIMS profiles with LOCOS directly. This is because the mixed signals from the Si area, the SiO_2 area, and the slant area, at the boundary of LOCOS act to broaden the SIMS profiles. Therefore, we measured SIMS profiles from the backside of the wafers to eliminate any affects caused by uneven surfaces on the LOCOS structures, as shown in Fig. 2. Using this method, we can obtain accurate profiles until the bottom surface of LOCOS is revealed by sputtering.

3. Results and Discussion

Fig. 3 shows boron profiles measured by SIMS from the backside of the LOCOS structures. A reference sample was fabricated without the 700°C annealing process. The profile at each depth was obtained to fit each peak position that is outside the LOCOS oxide. As explained previously, the profiles within the LOCOS area were scattered, but we can see clear differences in the Si bulk area. The TED of boron was observed in each LOCOS sample, but it was more remarkable in conventional LOCOS than in ON-LOCOS. The diffusion depth of ON-LOCOS at 10^{17} atoms/cm^3 was about 30 nm longer than that of conventional LOCOS.

We also evaluated the effect of TED in the active region by the Vt of n-MOS transistors. Fig. 4 shows the gate length dependence on Vt and σVt. RSCE was observed for conventional LOCOS, while no RSCE was observed in ON-LOCOS. The TED in the active region of ON-LOCOS was suppressed compared with that of conventional LOCOS, as was expected from the results of SIMS measurements. Note that the σVt of ON-LOCOS is larger than that of conventional LOCOS. This result differs from the report stating that the more TED that boron causes, the larger the Vt fluctuations will be [1].

Fig. 5 shows a cross-sectional SEM image of an ON-LOCOS structure. It seems that large amount of compressed stress was induced by field oxide that was grown under the nitride mask region. The depth of field oxide grown under the nitride mask (x in Fig. 5) increased with the field oxide thickness, as shown in Fig. 6. We suspected that the mechanical stress of LOCOS affects the TED. We evaluated the mechanical stress in the active area via microscopic Raman spectroscopy. Fig. 7 shows the average Raman shift in the active regions of the periodic LOCOS structures. As expected in Fig. 6, the Raman shift of ON-LOCOS increased with the field oxide thickness. The shift of ON-LOCOS was much larger than that of the conventional one. We also compared the surface concentrations by CV measurements. Fig. 8 shows that the surface concentration decreased with increases in the field oxide thickness. These results support our idea that LOCOS induced stress suppresses the TED of boron, and agree with the calculated report that compressive stress suppresses TED [3].

4. Conclusion

We have demonstrated that LOCOS induced stress suppresses the TED of boron. In future devices, other isolation structures such as shallow trench isolations (STI) utilized. However, the mechanical stress issues will still remain. To control the concentration of surface impurities, we must consider the affect of stress from isolation.

Acknowledgments

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References

[1] C. S. Rafferty et al., IEDM 311, (1993).
[2] A. Ono et.al., IEDM, 755, (1996).
[3] Inoue et al., Extended Abstract of Japan Society of Applied Physics, 806, (Spring Meeting,1998).

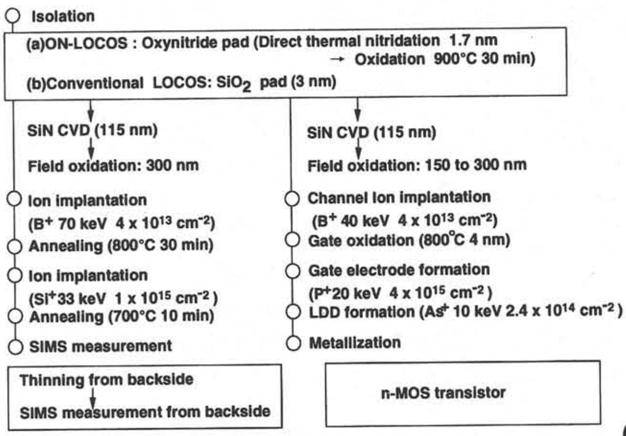

Fig. 1. Sample preparation.

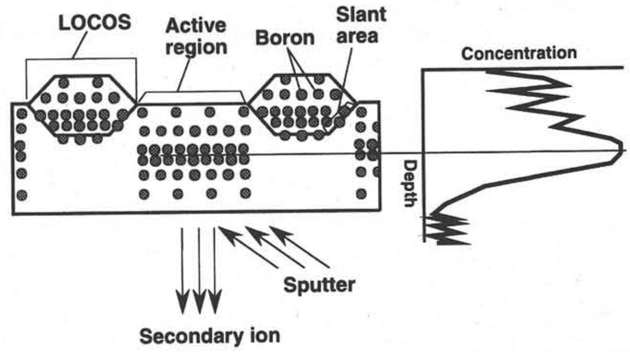

Fig. 2. Sample preparation for SIMS measurement from backside.

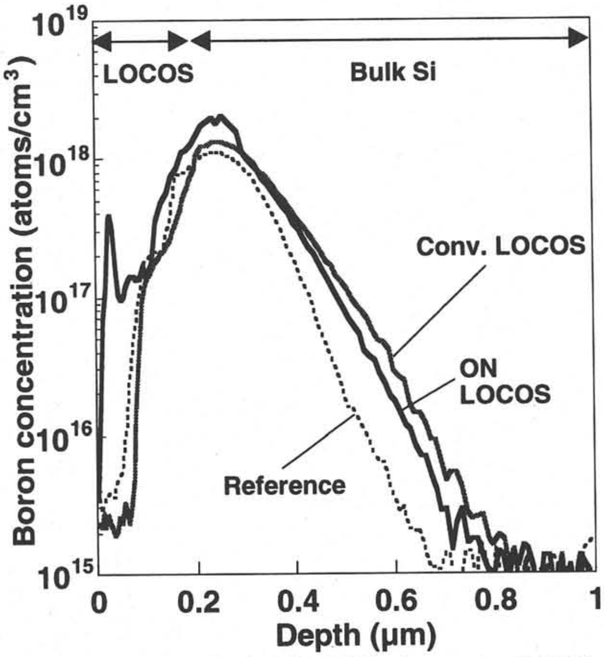

Fig. 3. SIMS profiles for ON-LOCOS and conventional LOCOS.

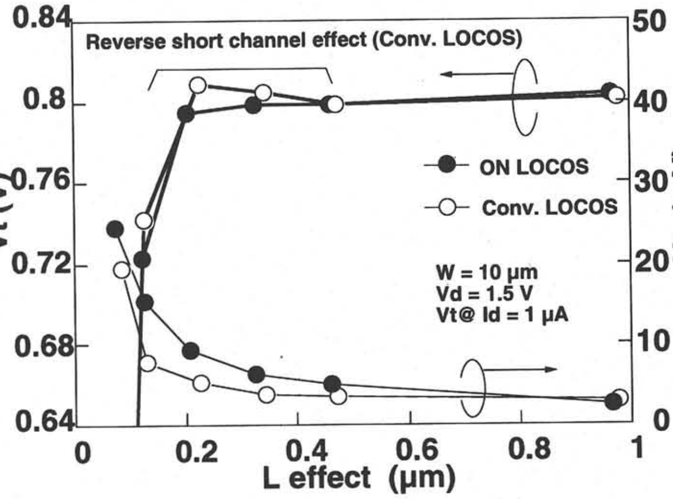

Fig. 4. Gate length dependence on Vt and standard deviation.

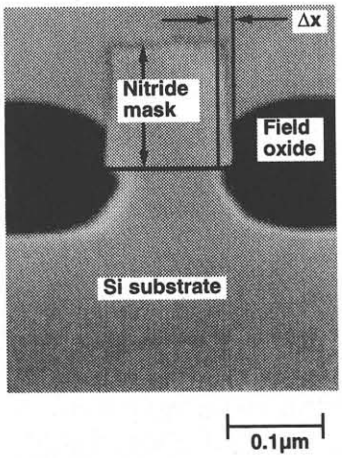

Fig. 5. Cross-section SEM image of ON-LOCOS.

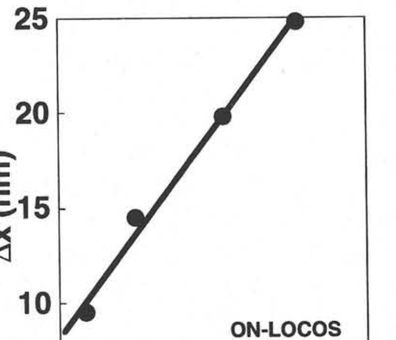

Fig. 6. The invasion length of field oxide under the nitride mask

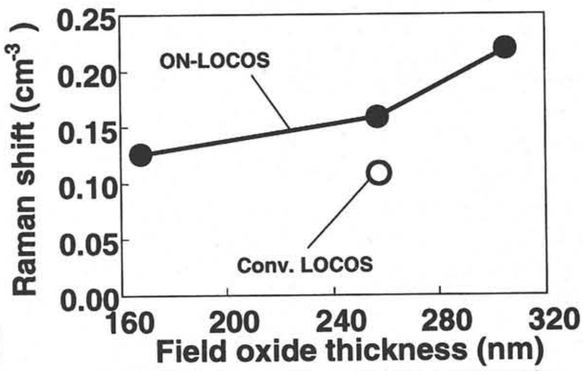

Fig. 7. Raman sfift of active region of LOCOSs.

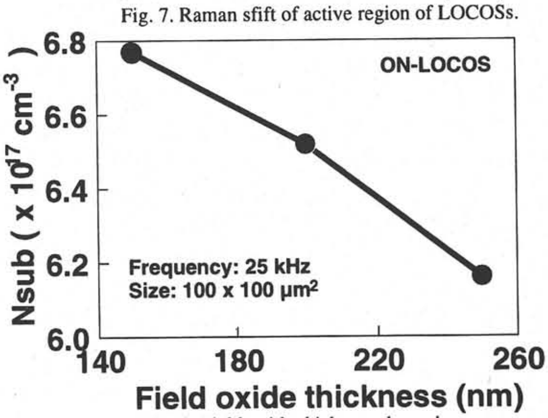

Fig. 8. Field oxide thickness dependence on surface concentration.