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Residual Defects in Low-dose Arsenic Implanted Si after High-temperature Rapid Thermal Annealing: Their Behavior and Influence on CCD Image Sensors

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Abstract

The behavior of the residual defects in low-dose (10^{13} cm^{-2}) arsenic implanted Si after high-temperature (1100 °C) annealing and their influence on the properties of CCD image sensors have been investigated. The presence of residual damage was shown when using rapid thermal process as heat treatment. This damage was identified as vacancy-type defects (V_4), and transformed to be oxygen-related defects (C_iO_i, V_mO_n) combined with oxygen introduced in annealing chamber. These defects made a critical impact on the transfer efficiency and white defects of CCD image sensors.

1. Introduction

Along with the development of Si industries, numerous studies have been attempted to the defects remains after ion-implantation process [1]. Nevertheless, little attention has been paid to the defects in 'low-dose (~10^{13} cm^{-2})' implanted Si after 'high-temperature (>1000 °C)' annealing due to a lack of characterization technique and awareness of the risk of device degradation. In this study, we have shown the presence of residual defects in low-dose arsenic (As) implanted Si when using rapid thermal annealing (RTA) system as heat treatment. Cathodoluminescence (CL) and positron annihilation spectroscopy (PAS) technique were selected for characterizing the defects. The behavior of the defects and their influence on the properties of CCD image sensors were also evaluated and discussed.

2. Experiment

Figure 1 shows the making-flow of the samples. The dose amount of As^+ ions were small; $1.0\times10^{13}cm^{-2}$. The top temperature of RTA was sufficiently high for activation; 1100 ˚C. Note that O_2 gas was introduced to the annealing chamber with various proportions. The behavior of the defects was characterized and analyzed using CL and PAS techniques. CCD devices are also prepared in order to confirm the influence of the defects on device performance.

3. Results and Discussion

Figure 2 shows the CL spectra. When O_2 gas was introduced to the annealing chamber, C-line was detected in addition to band-to-band transitions (TO, TO+O^{Γ}-line). C-line is originated from interstitial carbon and oxygen complex (C_iO_i), and it is known to be vanished at relatively low temperature around 600°C in equilibrium conditions [2]. Therefore, this defect can be concluded to be created by non-equilibrium reaction during RTA.

The *S* parameters and its depth distributions obtained PAS analysis are shown in Fig. 3. The *S* value of the samples after RTA was higher than that of reference sample in surface region (~300nm). This indicates that the vacancy-type defects remain after RTA.

Figure 4 shows the *S*-*W* relationships. The *S* and *W* value didn't approach to the reference's value even with increasing O_2 content in the annealing chamber. And the positron lifetime listed in the same figure was shorter. This implies that the residual defects was changed their features combined with oxygen. It is considered to be transformed from tetra-vacancy (V_4) to vacancy-oxygen complex (V_mO_n) refer to the literature [3].

The sheet resistance (R_s) was compared with the variation of all results in Fig. 5. R_s was shown to be reduced with O_2 content due to the creation of oxygen-related defects. It was confirmed from Fig. 6 that these defects made a crucial influence on the VCCD potential, i.e., transfer efficiency and white defects of CCD image sensors.

4. Conclusions

Residual defects in low-dose ($10^{13}cm^{-2}$) As implanted Si after high-temperature (1100°C) RTA in O_2 ambient were characterized and identified. These defects led to vary the transfer efficiency and white defects of CCD devices.

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References

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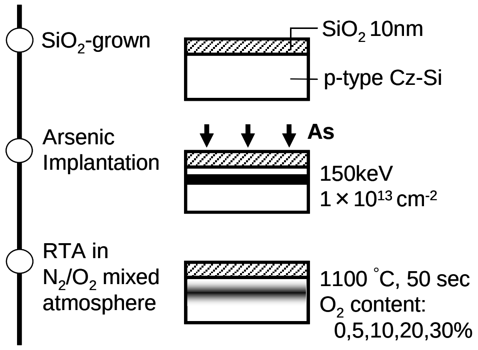


Fig. 1 Fabrication of the samples used in this investigation.

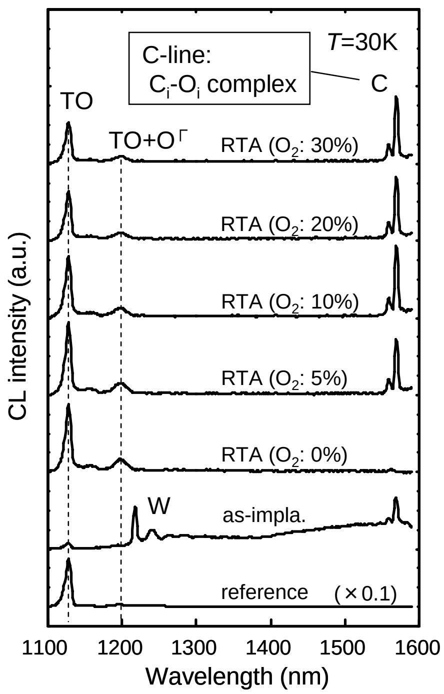


Fig. 2 CL spectra of all samples

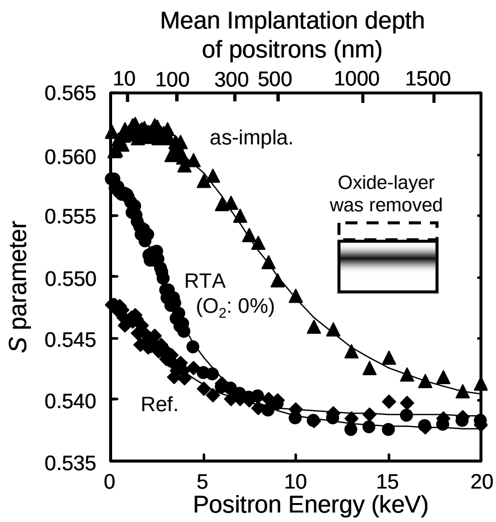
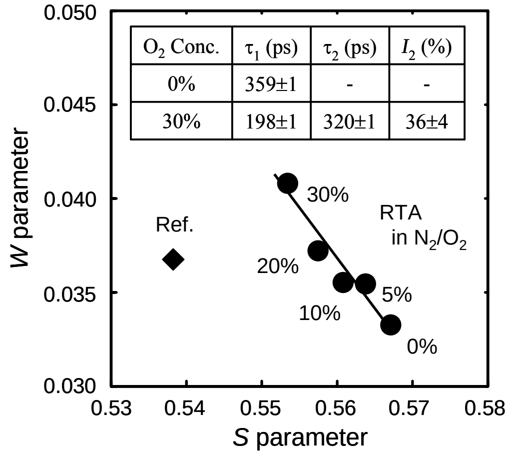


Fig. 3 S parameters as a function of incident positron energy E. Mean implantation depth of positrons are described upper x-axis.



O$_2$ Conc.	τ_1 (ps)	τ_2 (ps)	I_2 (%)
0%	359±1	-	-
30%	198±1	320±1	36±4

Fig. 4 S-W relationships and positron lifetimes (insert table).

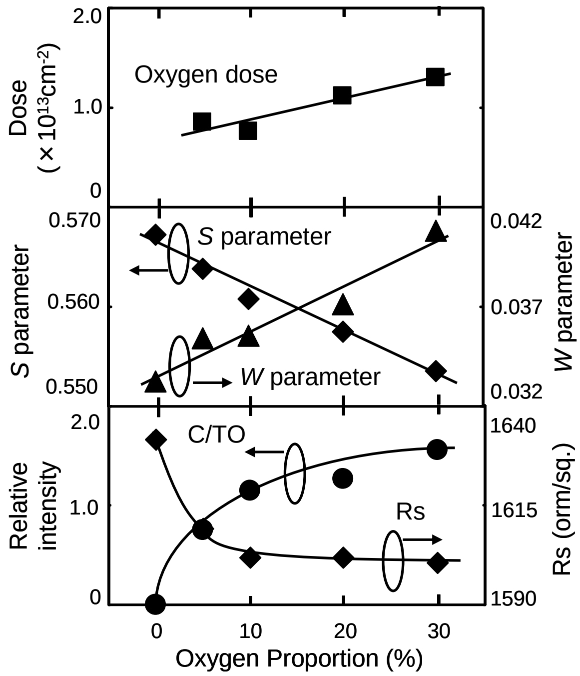


Fig. 5 Variation of the defects' levels and sheet resistance

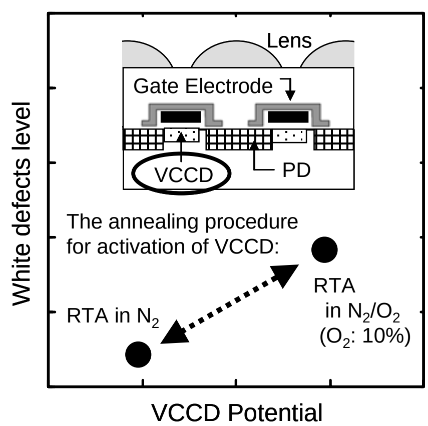


Fig. 6 Variation of white defects' level and VCCD potential corresponding to O$_2$ content in the annealing chamber during RTA.