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Oxygen Precipitate Density Control in CZ-Si Wafers by Hydrogen Annealing Process

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1. Introduction

This paper describes a new process which controls the oxygen precipitate density by hydrogen annealing for Czochralski grown silicon (CZ-Si) wafers.

One of the best of silicon wafers for ULSI is thought to have no defects in the device layer (10μm thick) and adequate oxygen precipitation in the bulk region. By using a denuded zone-intrinsic gettering (DZ-IG) technology, [1] the wafers were realized. Recently, it was reported that the wafers can be produced by hydrogen annealing at a high temperature. [2, 3] To ensure a high IG capability, the oxygen precipitate density in the bulk region must be carefully controlled. The oxygen precipitate density in the bulk region, however, depends primarily on the oxygen concentration of the as-grown crystal. We studied how to control the oxygen precipitate density in the bulk region and the denuded zone through the ramping-up process during hydrogen annealing.

2. Experimental

Wafers were 125-150 mm in diameter, P-doped CZ <100> silicon with a resistivity of 1-10-Ωcm and an oxygen concentration of $1.41\text{-}1.74\times10^{18}$ atoms/cm^3 (old ASTM). Silicon wafers were annealed at 1200°C for 1 hr in a hydrogen atmosphere in a cylindrical epitaxial reactor.

We made the following experiments on the ramping-up and ramping-down sequences: (A) Ramping-up and down sequences between 900°C and 1200°C were made up of a rapid rate (>30°C/min) process and/or a slow rate (3-4°C/min) one. (B) Ramping-up rates between 900°C and 1200°C were changed from 2°C/min to 40°C/min. After being annealed, the oxygen precipitate density was evaluated by infrared laser scattering tomography [4].

3. Results and Discussion

Figure 1 shows the dependence of the oxygen precipitate density on the ramping-up and down sequences. It is clearly found the oxygen precipitate density mainly depends on the ramping-up condition and is independent of the ramping-down sequence. Figure 2 shows that little oxygen precipitates in the crystal when the ramping-up rate is 30°C/min or above in the temperature-raising process from 900°C to 1200°C. Decreasing the temperature-raising rate increases the oxygen precipitate density exponentially. Defect densities in slow temperature-raising at 10°C/min between 900°C and 1000°C are about 10 times that in rapid temperature-raising at 30°C/min.

Oxygen precipitation nucleation depends clearly on the ramping-up sequence. A denuded zone is formed in every wafer in these experiments. Hence, no defects precipitate during the rapid ramping-up sequence. This is probably because radii of oxygen precipitate nuclei never exceed the critical radii for nucleation during the rapid temperature-raising process. Thus, most of the nuclei are annihilated in the rapid ramping-up sequence. [5]

We propose a process for controlling the oxygen precipitate density in the bulk region and the denuded zone. Furthermore, it is suggested that oxygen precipitates in the denuded zone would be decreased by adjusting the ramping-up sequence during the hydrogen annealing process.

References

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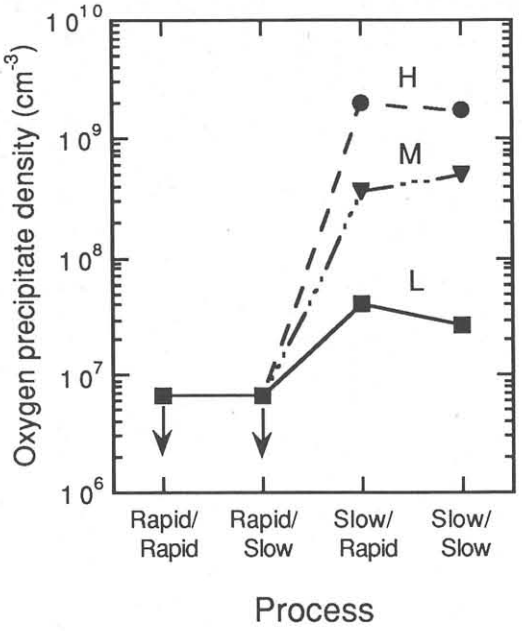

Fig.1 Dependence of oxygen precipitate density on the ramping-up and down process. The oxygen concentration [Oi] of H, M, and L are 1.72-1.74, 1.58-1.61, and 1.41-1.47x10^{18} atoms/cm^3, respectively

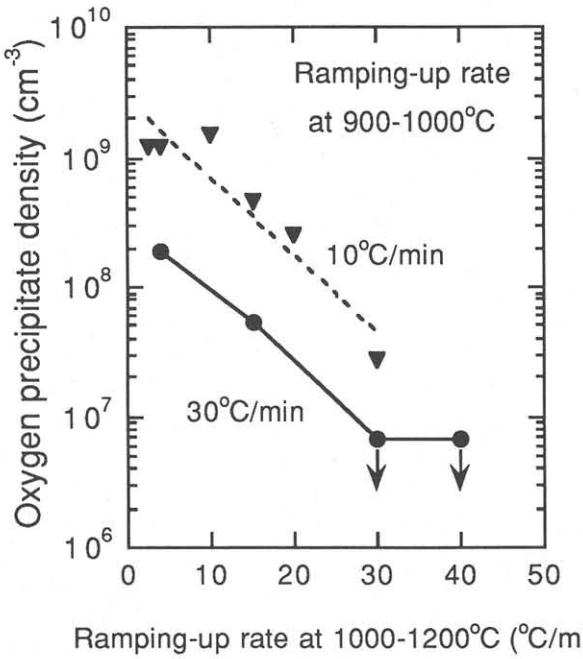

Fig.2 Effect of ramping-up rate between 1000°C and 1200°C on oxygen precipitate density in silicon crystal with [Oi]=1.61x10^{18} atoms/cm^3. The ramping-up rates between 900°C and 1000°C for closed circles and triangles are 30 and 10°C/min, respectively