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Characteristics of HMCZ Silicon Single Crystals

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1. Introduction

Czochralski (CZ) grown Si wafer with a diameter of 200mm are increasing being utilized for ULSI devices such as 16M DRAM and 64MDRAM. Moreover, the investigation of Si wafer with a diameter of 300 mm has started for 1G DRAM fabrication.

A demand for CZ Si Single crystals with low interstitial oxygen concentration ([Oi]) is gradually increasing in such ULSI fabrication, since the device fabrication layer in the vicinity of the wafer surface should be free from oxygen related defects. In the conventional CZ method, it is difficult to grow Si single crystals with low [Oi] with such large diameter owing to the increase of Si melt convection.

On the other hand, the horizontal magnetic field applied CZ (HMCZ) method is effective to grow Silicon single crystals with low [Oi] [1]. Moreover large diameter crystals are expected to be easily grown in the stabilized melt convection by the applied magnetic field.

In this report, we study the quality of HMCZ crystals with a diameter of 200mm and of 300 mm. Then we discuss whether there are any problems in the use of HMCZ Si wafers for ULSI fabrication instead of conventional CZ wafers.

2. Experiment

We grew HMCZ Si single crystals in the direction of <100> with a diameter of 200 mm or of 300 mm in the magnetic field of 0.4 T generated by superconductive solenoid coils. We used quarts crucibles with a diameter of 600 mm. Boron or Phosphorus were doped as dopant impurity. We studied a distribution of dopant and [Oi], oxygen precipitation behavior and the flow-pattern defect (FPD)[2]. The relationship between FPD density and the passage time of the growing crystal from 1423 K to 1353 K [3] was also studied. The details are described in the published paper [4].

3. Results and Discussions

First we compared the quality of HMCZ crystals with that of CZ crystals for a diameter of 200 mm.

The axial fluctuation of the spreading resistance of a HMCZ crystal is less than that of the CZ one (Fig. 1). This result demonstrates the suppression effect of magnetic field on melt convection. On the radial [Oi] distribution profiles, lower [Oi] can be achieved for HMCZ crystals, while [Oi] of CZ crystals is limited to around $1x10^{18}$ atoms cm^{-3} (Fig. 2.). Axial [Oi] micro-distribution profiles of HMCZ crystals are almost same as those of CZ crystals for [Oi] higher than $10x10^{17}$ atoms cm^{-3} (Fig. 3.). However, the profiles become uniform for [Oi] below $6x10^{17}$ atoms cm^{-3}. Such uniform distribution and low [Oi] can be realized only by setting the CR low and applying a horizontal magnetic field. The change of the profile is considered to be due to the oxygen fluctuation in the melt. The relationship between the initial [Oi] and the precipitated [Oi] for HMCZ crystals exhibit the same as the CZ ones (Fig. 4.). This result supports that any new special thermal process is not necessary for HMCZ wafers during LSI fabrication processes. The FPD density of HMCZ crystals exhibit a dependency on the passage time from 1423 K to 1353 K as same as that of CZ crystals (Fig. 5.). This result shows that the suppression effect of magnetic field on the melt flow doesn't influence on the formation mechanism of grown-in defects. Moreover, FPD density doesn't depend on [Oi]. Therefore the FPD of HMCZ crystals exhibits the same level as the conventional CZ ones since the hot zone for HMCZ is same as one for conventional CZ. With regard to the gate oxide integrity, HMCZ wafers with lower [Oi] are superior to CZ ones since we can exclude oxygen-related defects that cause gate oxide integrity degradation.

Next we evaluated the quality of HMCZ crystals with a diameter of 300 mm. The level of [Oi] is realized to be adequate and its profiles are good (Fig. 6). Oxygen precipitation also exhibits same behavior as that of 200 mm (Fig. 3). The FPD density is less than 200 cm^{-2}. Such low FPD density is considered to be due to both low growth rate and long passage time over 100 min.

4. Conclusion

The quality of HMCZ crystals with a diameter of 200 mm and 300 mm are almost similar to those of conventional CZ ones. Therefore, we believe that HMCZ Si wafers can be used for LSI device fabrication in the same way as the usual CZ ones.

References

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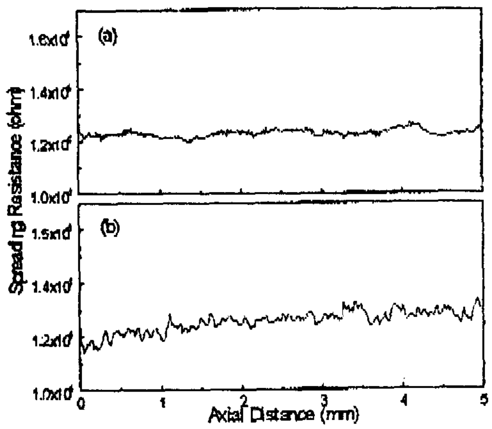

Fig. 1. Spreading resistance profiles along the growth direction, (a) HMCZ crystal and (b) CZ crystal with a diameter of 200 mm

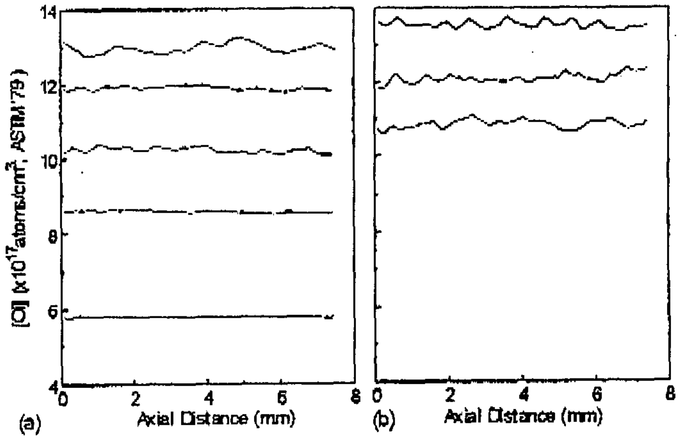

Fig. 3. [Oi] micro-distribution profiles of (a)HMCZ crystals and (b) CZ crystals with a diameter of 200 mm grown by setting the SR at –15rpm.

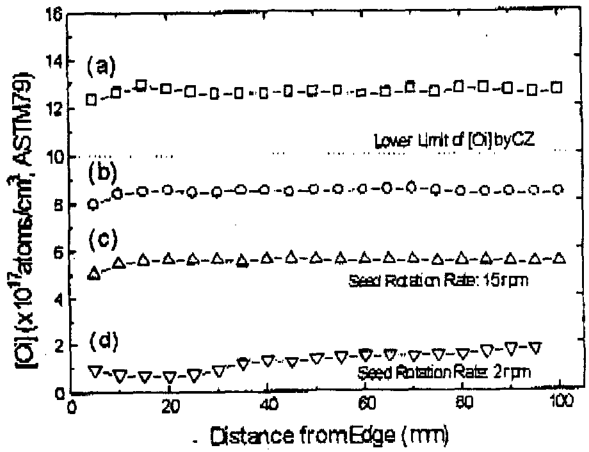

Fig. 2. Radial [Oi] profiles of HMCZ crystals with a diameter of 200 mm. SR was set at –15rpm for (a), (b) and (c) and at –2 rpm for (d). Dotted line shows the lower limit of [Oi] by CZ.

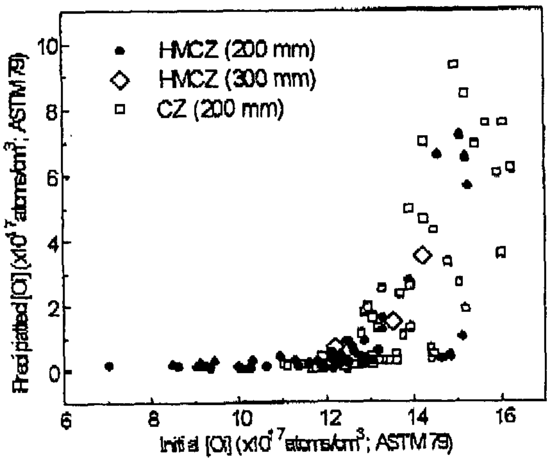

Fig. 4. Oxygen precipitation behavior of HMCZ and CZ crystals.

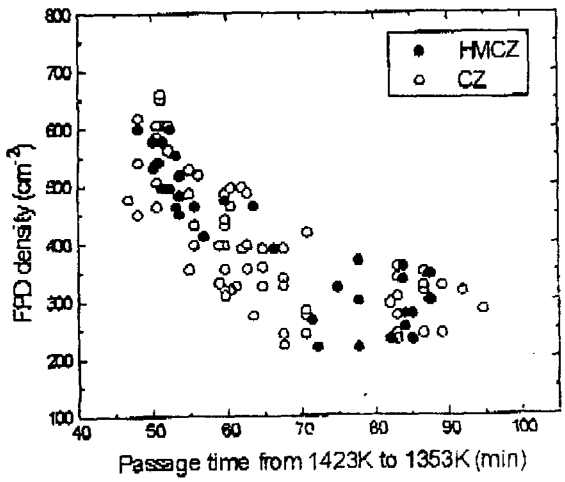

Fig. 5. Relationship between FPD density and passage time during growth from 1423 K to 1353 K.

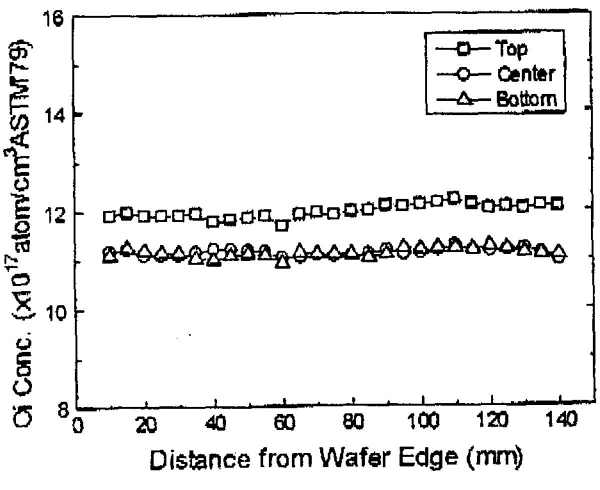

Fig. 6. Radial [Oi] profiles of HMCZ crystals with a diameter of 300 mm.