FORMATION AND CONTROL OF DEFECTS IN NITROGEN DOPED SILICON CRYSTALS

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INTRODUCTION

Crystal-originated particles (COPs) or void defects are well-known for deteriorating gate oxide integrity [Ref. 1, 2]. In (001) Czochralski grown Si void defects have an octahedral shape and are covered with a thin oxide layer. Pull rate and thermal gradient are parameters to control size and density of grown-in voids. Furthermore, nitrogen doping for Si crystals has attracted much attention in recent years. For medium nitrogen doping level $N = 5 \cdot 10^{14}$ at/cm^3 a platelet triclinic void shape was observed and for high nitrogen doping in the range 10^{15} at/cm^3 oxygen precipitates are the prevailing defect species [Ref. 3].

In this paper floating zone (FZ) wafers are chosen to study experimentally the nitrogen impact onto void annihilation. High cooling rates favor FZ wafers as an excellent candidate for tiny void defects without oxide layer. In addition, a model is proposed explaining void formation in Si crystals.

EXPERIMENTAL

The samples were (001)-oriented floating zone wafers with a nitrogen doping level N varying from zero to $2 \cdot 10^{14}$ at/cm^3. The nitrogen doping level was confirmed by FTIR measurements on 10 mm thick wafers.

Flow pattern defect (FPD) density was evaluated after Secco etching by automated counting the flaws with etch pits. In addition, time zero dependent breakdown (TZDB) measurements were performed on MOS capacitors.

RESULTS

Nitrogen concentration was nearly linearly varied within one Si crystal as shown in Fig. 2. The FPD density pattern for a wafer without nitrogen doping is depicted in Fig. 1. FPDs are observed within around 0.64·R (R = wafer radius). As shown in Fig. 2 the radius of the FPDs can be controlled well in the low nitrogen doping level. The FPD pattern disappears for $N > 6 \cdot 10^{13}$ at/cm^3. Gate oxide integrity measurements showed a similar behavior with higher C-mode yield (> 8 MV/cm) for higher N concentration.

A model is proposed showing that nitrogen reacts with vacancy and interstitial defects. The reaction equations demonstrate that nitrogen doping reduces vacancy agglomeration temperature. As a consequence smaller void defects exist less harmful for gate oxide integrity [4].

REFERENCES

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FIGURES

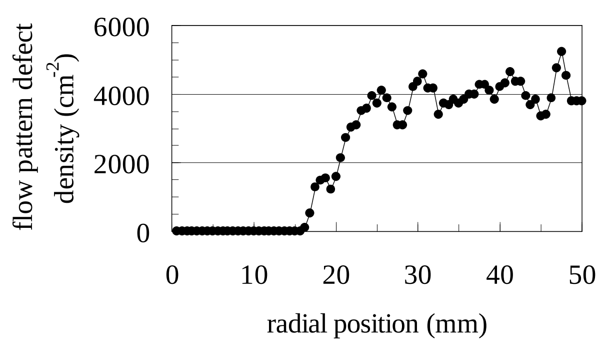

Fig. 1: flow pattern defect density versus radial position (0 mm = edge, 50 mm = center) for FZ without nitrogen doping.

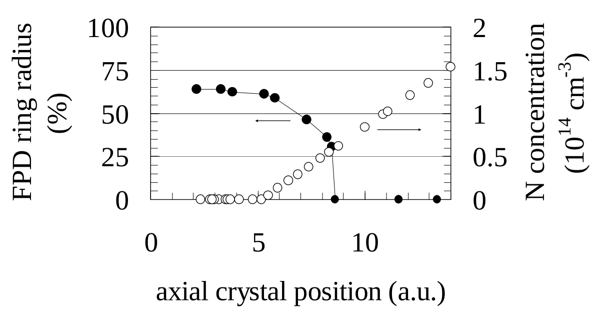

Fig. 2: flow pattern defect ring radius as a function of axial crystal position. The corresponding N doping concentration is indicated.