FORMATION MECHANISM OF VOIDS AND OXIDE PRECIPITATES IN SILICON CRYSTALS

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As IC devices become smaller, the grown-in defects in silicon crystals are having a more pronounced effect on their performance. The typical grown-in defects are voids formed by the vacancy aggregation. Therefore, it is necessary to precisely understand the formation mechanism of void defect in silicon crystal. The formation of void defect in silicon crystals was generally explained by the homogeneous nucleation model [1]. The homogeneous nucleation models with some parameter-adjustment have described the behaviors of void formation very well. However, there were three phenomena that cannot be explained by the homogeneous nucleation mechanism.

1) Switch of the defect mode from voids to oxygen precipitates by the increasing of cooling rate of crystal [2]
2) Fluctuation of void density synchronized with the striation of oxygen along the crystal axis [3].
3) Double voids structure in the morphology of voids [4].

Voronkov [1,5] proposed two types of scenario of vacancy agglomeration and oxygen precipitation during crystal growth process. The parallel model assumes independent homogeneous nucleation of two kinds of micro-defects. The sequential model assumes homogeneous nucleation of only oxygen precipitates and subsequent transformation of some (larger) precipitates into voids, by cavitation induced by a high vacancy-controlled negative pressure in oxide. In this paper, we discuss about the parallel and sequential model, using experiments and numerical calculations by these models.

First, we examined the relation between density of voids and cooling rate of crystal (Fig.1). Second, we examined the relation between the fluctuation of void density and cooling rate in the crystals with the oxygen-striation that was intentionally incorporated. Fig.2 shows the formation process of defect striation in the sequential model. Parallel model (homogeneous nucleation model for void) could not explain the formation of defect striation. Fig. 3 shows the dependency of void density on the cooling rate in the area of high and low oxygen concentration in the crystal with oxygen-striation. The sequential model well describes the switch of the defect mode by the cooling rate 1) and the defect striation 2). From these results, we support the sequential model for void formation.

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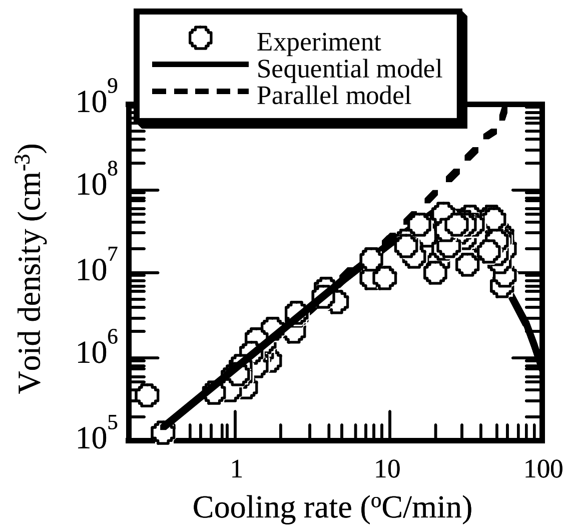

Fig.1 Relationship between the density of voids and cooling rate of crystals. Solid and dotted line denote the calculation results by the sequential and parallel model, respectively

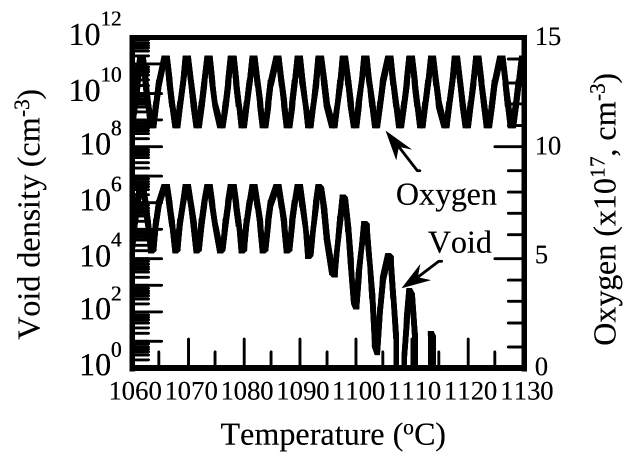

Fig.2 Formation behavior of void defect in the crystal with oxygen striation in the sequential model. Horizontal axis denotes the temperature of crystal. Striation interval : 2 mm.

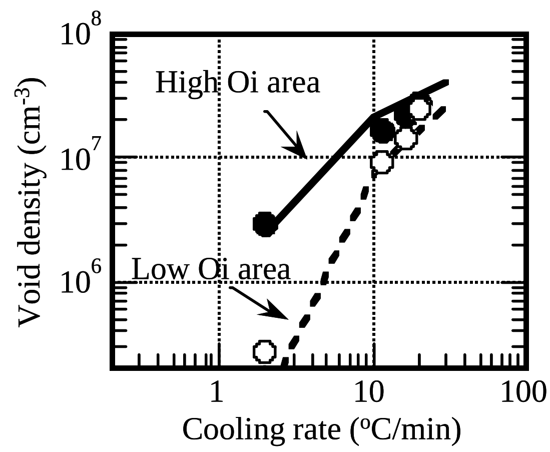

Fig.3 Relation between the cooling rate and defect density in the crystals with oxygen striation. Filled and open circles denote the defect density in high and low oxygen concentration region, respectively. Solid and dotted line are the calculated results by the sequential model.