Quality of silicon substrate and point defects (3) On the Precipitate Engineering

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シリコン結晶基板の品質と点欠陥(3)Precipitate Engineeringについて

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Silicon crystal growth and its technique are one of most successful industry and technology in Japan. We summarized their history into 4 periods and showed that "the defect engineering" provided the success as shown in the table [1]. In the present paper we examine the Precipitate Engineering (PE) which was the beginning and the biggest success (OSF-free and intrinsic gettering, IG) of the defect engineering.

Period	Device	Defect	Defect Engineering
I, 1965-	Tr, IC	Dislocation, anom. diffusion.	Diffusion modeling [2]
II, 1975-	LSI	OSF (IG)	Precipitate [3,4, 5]
III, 1995-	SOC	Void, Dislocation loop	Microdefect [6]
IV, 2005-	Power	C_iO_i complex	Complex [7, 8]

<u>1 Contents and tools of Precipitate Engineering</u> Precipitate engineering is a total system from understanding to application. In each field original and unique tools were developed and the fruit of the former field was used as a tool. The first breakthrough was provided by "the precise and volume defect density measurement" which enabled thermodynamic analysis in contrast to the areal density (etch pit /cm^2), and "the quasi-in-situ observation" techniques by TEM. The system is summarized as follows.

Fields	Objects and contents	Tools originally developed and provided breakthrough
Measurement	Oxygen conc., Precipitate density and size	Accurate volume defect density by TEM
Observation	Nucleation and growth behavior of precipitate	Semi-in-situ observation by HVTEM
Understanding	Nucleation rate, growth rate, mechanism	2-step annealing, classical nucleation theory
Finding	Grown-in micro- and large- precipitates	Critical radius, simulation
Defect control	Size and density of precipitate	Nucleation and diffusion-limited growth model
Application	(IG), OSF formation mechanism and suppression	Large precipitate suppression

<u>2 Related works</u> Homogeneous nucleation of oxide precipitate was firstly proposed by Freeland [9], however the reported increase rate due to the annealing was too low. We developed their 2-step annealing and the classical nucleation theory analysis and used further. Quasi-in situ observation of the octahedral precipitate growth and diffusion limited growth model were reported by Schwuttke [10]. Square plate is the principal shape which we analyzed and practically used. Heterogeneous nucleation by carbon was proposed by Kishino [11]. To the contrary we clarified that precipitate density did not depend on the carbon concentration, and there was no need to measure carbon concentration, supporting our result. OSF (oxidation induced stacking fault) ring was named by Hasebe [12] because the OSFs were formed in the periphery of the Si wafer. This is the result of our findings that the large oxide precipitates were formed in the periphery and SF was nucleated at the edge of some size of precipitate, as confirmed by the work later [13]. Also OSFs are present in the V-rich region [6] where oxide precipitation is enhanced as described next.

<u>3 Second generation PE</u> With the severe demand to control precipitation for IG, deviation from homogeneous nucleation was recognized. Hu pointed out it and proposed that vacancy enhances the precipitation [14]. It is the turnover of his previous result that precipitation emits the interstitial (which forms the stacking fault). This model was examined by many authors and the gettering using rapid thermal annealing (RTA) which quenching in the excess vacancies was developed [15].

The cooperation by E. Arai, M. Itsumi, K. Tanahashi, K. Hoshikawa and K. Wada is greatly appreciated.

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