Extended Abstracts of the 1992 International Conference on Solid State Devices and Materials, Tsukuba, 1992, pp. 420-421

Raman Study of Stresses Caused by Intrinsic Getters Distribution in Device Structures

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A problem of material's purity with scaling down of elements size in VLSI and ULSI technologies become very important. This importance explains a great interest to questions of formation of impurity and defect getters and oxygen precipitates as one of its. Precipitation of oxygen in silicon was intensively investigated in past years. In particular role of mechanical stresses in gettering and precipitation processes was widely discussed [1]. In present paper we study stress distribution in device structures with nonuniform distributed oxygen precipitates and stress influence on precipitation and gettering.

In experiment we controlled depth distribution of defects and stresses on prepared low angle wedges. Raman spectroscopy was used to measure the stress distributions with focused laser beam scanning on wedges surface. The stress value were obtained from silicon LO phonon line shift by computer fitting of the line shape. Depth distributions of stacking faults, dislocation loops and oxygen precipitates were controlled by microscopy. Anti-thermodonors (690^{0}C), middle temperature (450^{0}C-800^{0}C) and high temperature (1000^{0}C-1100^{0}C) thermal treatments were used to introduce oxygen precipitates and to form nonuniform distributions of its. During of high temperature treatments denuded zone of oxygen was formed with small concentration of controlled defects.

Obtained results show that processes of oxygen precipitation are followed by arising of average tensile mechanical stresses up to 0.6 kbar. Strong correlation of stacking faults and dislocation loops concentration with oxygen contents in silicon was observed. The precipitation was supposed to stimulate formation of interstitial defects formation eliminating deformation energy of precipitates. There are in literature data confirming this suggestion by observing stacking faults formation near dilatation centers. Emission of interstitial atoms to the periphery of precipitate creates supersaturation of ones during precipitation process and stimulates formation of the defects. The stresses approach 0.47 kbar value at 1.3 10^6 cm^{-2} of concentration of the precipitates. The more small precipitates was assumed to cause more significant stresses because of its structure and absence of satellite stacking faults and dislocation loops. Measurements of the stresses in samples with low contents of the large size precipitates show correlation of distributions of the stresses and the precipitates (Fig.1). The concentration of the large precipitates increased the stresses fall down in the bulk. The effect is supposed to be due to small size precipitates formation in oxygen denuded zone, providing appearance of more large stresses in crystal. To analyze this suggestion we have theoretically considered stresses distribution in a case of nonuniform distribution of dilatation centers in a framework of thin plate approximation, corresponding to usually used silicon structures. As a result of evaluation expression of curvature radius R was obtained depending on centroid of dilatation centers distribution α :

$$R=\frac{2}{3}\frac{h}{\alpha\Omega_o}; \qquad \alpha=\frac{4}{h^2}\int_{-h/2}^{h/2} N^{def}(z)\,z\,dz;$$

,where h-plate thickness, $\Omega_0\,\delta_{ik}$ - average strain tensor of the dilatation centers. Ω_0 was found for large size precipitates to be 4.3 10^{-13} cm^3. Also stress distribution depending on dilatation centers distribution was obtained.

In a basis of the theory a concept of strain tensor of dilatation center was introduced. And this approach allows to explain of the measured stresses value and to estimate deformational mechanism of defects and impurities interaction in the processes of precipitation and gettering.

1. C.Claeys, J.Vanhellemont, Solid State Phenomena 6,7,21(1989).

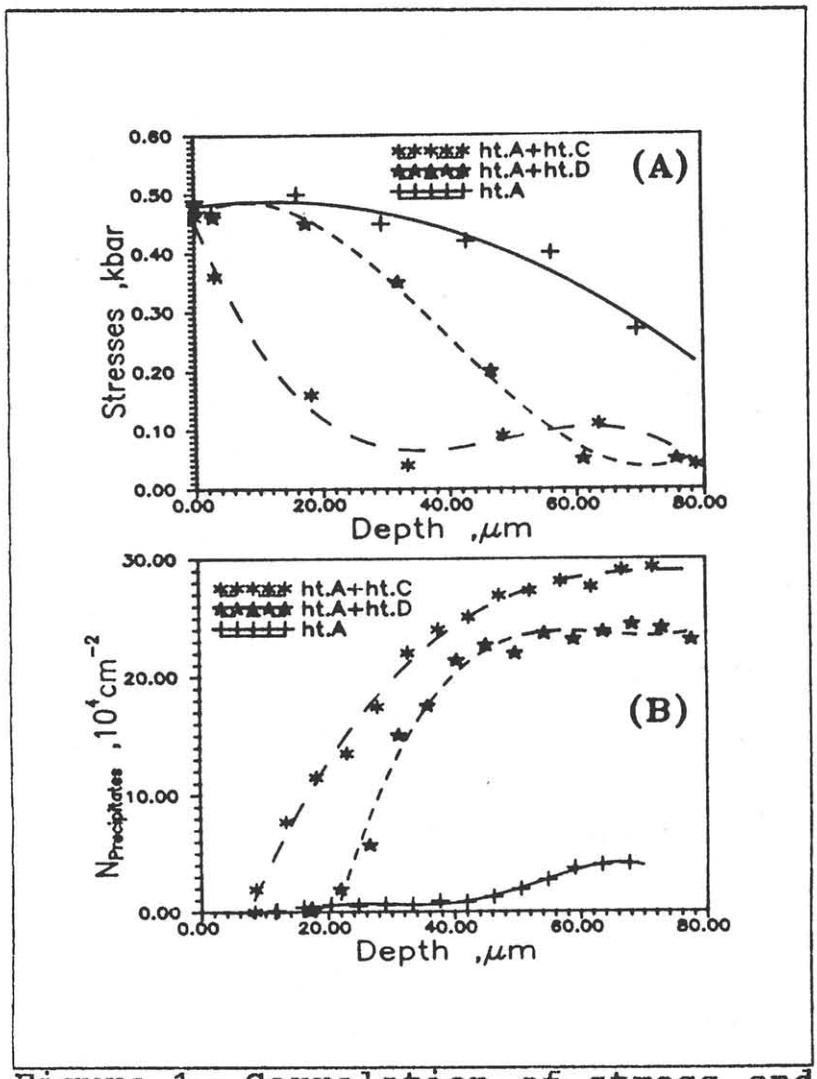

Figure 1. Correlation of stress and oxygen precipitates distributions after thermal treatments.