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Deformation Mechanism Maps and Gettering Diagrams for Single-Crystal Silicon

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Equations for the plastic strain rate ($\dot{\varepsilon}$) are considered for the case of a single crystal and on the base of these equations the deformation mechanism maps (DMMs) for single-crystal silicon with different dislocation densities are constructed in the stress–temperature (σvs.T) coordinates. The DMMs are in good agreement with available experimental evidence. It is found that in the wide ranges of σ, T, and $\dot{\varepsilon}$ the flow stress is determined by the lattice resistance, and deformation with $\dot{\varepsilon} \geqq 10^{-7}\ s^{-1}$ can occur even at fairly low levels of T (500 to 700 K) and σ (0.01 to 1 GPa). By using the DMMs and the proposed criterion for nondecreasing $\dot{\varepsilon}$, gettering diagrams (GDs) are introduced which can be applied to estimate the efficiency of thermal methods of generating dislocations in the near-surface layer of the semiconductor containing stressed regions.

Рассмотрены уравнения скоростей ($\dot{\varepsilon}$) пластической деформации монокристалла, на основании которых в координатах напряжение–температура (σ–T) построены диаграммы механизмов пластической деформации (ДМД) монокристаллического кремния. ДМД удовлетворительно согласуются с известными экспериментальными данными. В широких диапазонах σ, T и $\dot{\varepsilon}$ напряжение течения определяется сопротивлением решетки, причем деформация с $\dot{\varepsilon} \geqq 10^{-7}\ s^{-1}$ может протекать даже при достаточно низких T (500 до 700 K) и σ (0,01 до 1,0 GPa). На основании ДМД, с помощью предложенного критерия неубывания $\dot{\varepsilon}$, введены и обсуждаются диаграммы геттерирования, пригодные для оценки эффективности термических методов генерации дислокаций в приповерхностном слое полупроводника, содержавшем напряженные области.

1. Introduction

Fabrication of silicon VLSIs and LSIs requires single-crystal silicon with low concentration of defects, in particular, dislocations. Very high dislocation densities (10^7 to $10^9\ m^{-2}$) can arise from relaxation of mechanical stress which is generated owing to the nonuniform temperature distribution in a silicon ingot during growth [1] or to high-temperature processing of wafers [2] in IC production. On the other hand, interaction of impurity atoms with dislocations is widely used for removing (gettering) point defects from active regions of semiconductor devices by means of intentional introduction of line defects into neighbouring regions of a single-crystal substrate.

The purpose of this paper is to study the mechanisms of generation of line defects in single-crystal silicon by using deformation mechanism maps (DMMs) [3, 4].

2. Plasticity Equation and Construction of the DMMs

Let us consider the equations for the rates of plastic deformation ($\dot{\varepsilon}$) that develops in accordance with different mechanisms such as dislocation glide, dislocation creep,

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