PHYSICS OF SEMICONDUCTORS AND DIELECTRICS

THE MECHANISM OF FORMATION AND PROPERTIES OF STRATIFIED-INHOMOGENEITY DEFECTS IN SILICON

O. A. Kulinich

The mechanism of formation and properties of stratified-inhomogeneity defects in single-crystal and epitaxial silicon wafers are studied using currently available investigation methods. The mechanism of formation of these defects is found to be due to the layered structure of silicon wafers. The type of defects and conditions of impurity precipitation are determined.

Further microminiaturization of the elemental base of electronics imposes heavy demands on the purity of initial semiconductor materials and on the technology of intermediate and complete products. The defects in initial semiconductor materials have been studied in a number of papers (see, e.g., [1–3]), however, some types of defects are either poor understood or the mechanisms of their formation are still elusive. In this work, one type of defects commonly occurring in silicon is considered. This is a defect of stratified inhomogeneity which is a concentric circle with structural defects at the center. The purpose of this work is to study the mechanism of formation and properties of these defects.

SUBJECTS AND METHODS OF INVESTIGATION

Single-crystal silicon wafers with various specific resistances grown by the Czochralski method and the KEB-4.5 (111) and KDB-10 (100) epitaxial-silicon wafers are investigated.

The surfaces of the samples were treated by selective Sirtle ((111)-surface) [4] and Secco ((100) surface) [5] etchants to reveal the defects. The etching rate was about 2–3 µm/min. The samples were also subjected to pretreatment in the Caro- and ammoniacal-peroxide solutions [6]. This pretreatment improved the revealing properties of the selective etchants.

The following techniques and equipment were used for examination of silicon surface upon chemical treatment:

– scanning electron microscopy (SEM) (a Cam Scan-4D scanning electron microscope-analyzer with a Link-860 energy dispersion analyzer system (mass sensitivity of the device 0.01% and the beam diameter between 5·10⁻⁹ and 1·10⁻⁶ m, according to a «Zaf» program code) [7],
– Auger electron spectroscopy (AES), a “Riber” LAS-3000 spectrometer (spatial resolution 3 µm, analyzer energy resolution 0.3%) [8],
– optical methods using an MMR-2R metallograph.

RESULTS AND DISCUSSION

To reveal the defects with complex and fine structures in silicon, special methods are required. The use of selective chemical etching in combination with conventional optical methods alone gives no way of revealing either the mechanism of formation or fine structure of the defects.
The complexity of the problem depends on the fact that it is difficult to completely determine the mechanism of defect formation because there can be several mechanisms, and they may complement each other.

The investigation technique for stratified-inhomogeneity defect formation proposed in this work can be also applied to investigation of other defects not only in silicon but also in other semiconductor materials.

We examined the surfaces of silicon wafers using an electron microscope upon pretreatment in the Caro- and ammoniacal-peroxide solutions followed by treatment in selective Sirtle and Secco etchants. The major defects in the majority of wafers were the $60^\circ$- dislocations (Fig. 1), slip lines (Fig. 2), and dendritic clusters (Fig. 3). The defects of stratified inhomogeneity were observed on the surfaces of several wafers of epitaxial and single-crystal silicon (Fig. 4). In some cases, structural defects and impurity precipitates (mainly potassium and oxygen or their salts (KCl) or/and

Fig. 1. A typical Cam Scan image of dislocation distribution over the (111) surface of a single-crystal silicon wafer upon selective etching in the Sirtle-etchant for 5 minutes («Cam Scan», $\times500$).

Fig. 2. A Cam Scan image of slip lines on the (100) surface of single-crystal silicon ($\times2300$).

Fig. 3. A Cam Scan image of dendrites in single-crystal (a) and epitaxial (b) silicon ($\times2300$).