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Characterization of Epitaxial Layer Defects in Silicon Wafers Using Focused Ion Beam and Transmission Electron Microscopy

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The increasing miniaturization and large-scale integration of advanced Si semiconductor device demand improved understanding of the crystalline defects in which play a vital role in the function of wafer.[1] In particular, it is becoming increasingly important to overcome detrimental effects caused by surface defects originating from Czochralski (CZ) grown in-defects or near-surface defects generated during the device thermal process.[2] Thus, it is important to understand the characteristics and formation mechanism of the epitaxial layer defects in epitaxial Si wafers.

Transmission electron microscopy (TEM) is a valuable technique which enables structural information on such defects to be ascertained on the nanometer scale.[3] In this study, we report on the microstructural characteristics of epitaxial layer defects in the Si epitaxial wafer. The formation mechanism of epitaxial layer defects is discussed mainly based on the results of TEM observations. The epitaxial layer defect structure was analyzed by TEM using a (110) cross-sectional sample fabricated by a dicing saw and a focused ion beam lift-cut system using the beam of focused 30 keV gallium ions over a sample.

Epitaxial layer defects on the wafers were observed within a wafer surface with an optical shallow defect analyzer (OSDA) and analyzed by a defect coordinate linkage system consisting of a scanning electron microscope (SEM) as illustrated in Figs. 1 (a) and (b), respectively. The stacking faults or voids in the epitaxial layers were observed by the coordinate-linked SEM. Fig. 1(b) shows typical top-view SEM images of the void defects in the epitaxial layer. Fig. 2 shows SEM image of the plan view of the final FIB cut prior to lift-out. An electron transparent cross sectional thin slice (9 μm x 12 μm x ~ 100 nm) is freed within the specimen trench. From the defect morphological characteristics, Fig. 3 shows diamond shaped octahedral void defects. The angle between its face and the Si surface is 55°, which indicates the face has (111) orientation. The characteristic faces of the side walls were identified as the (111) plane. Octahedral defects are basically void defects, in which the inner walls are covered with a 2-4 nm thick oxide. The thin layer completely covers the side-walls uniformly. Through consideration of the TEM and EDX experimental results, the generation mechanism of void defect is discussed.

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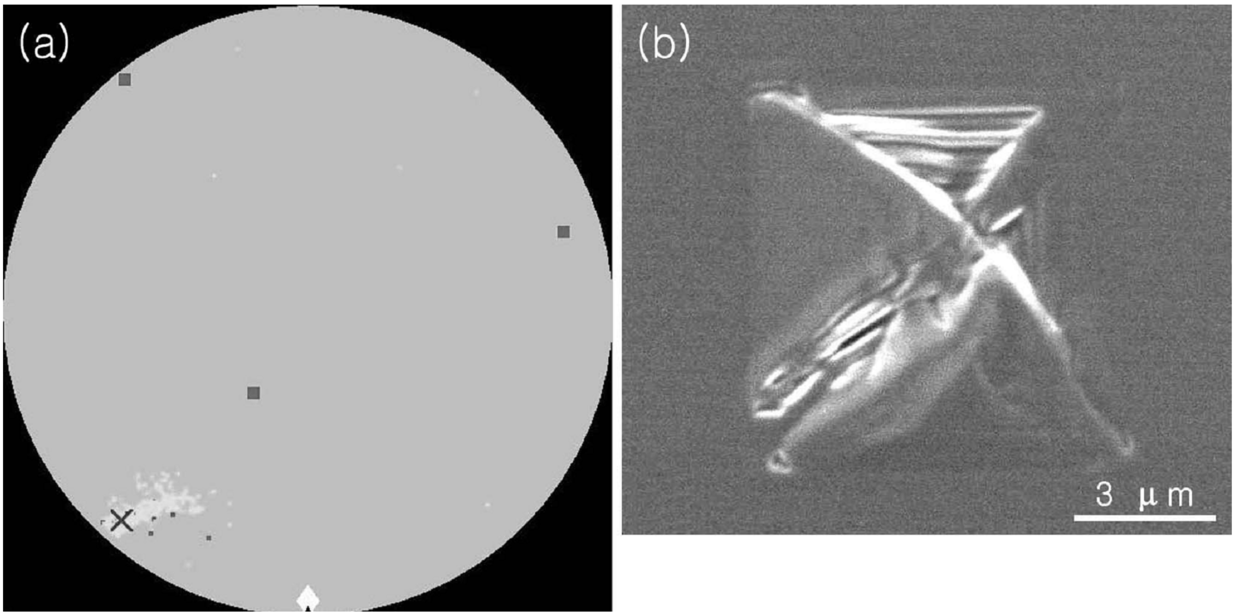

Fig. 1. (a) OSDA images observed for epitaxial 8-inch-diameter wafers. Position of epitaxial layer defects is indicated by X mark. (b) SEM image of epitaxial layer defect from X position shown in Fig. 1(a).

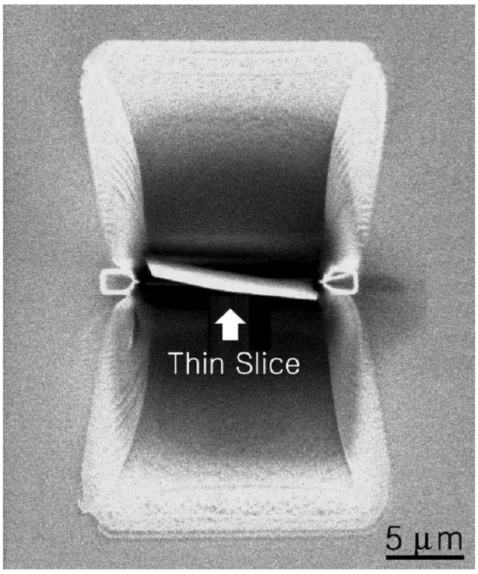

Fig. 2. SEM image of the plan view of the final FIB cut prior to lift-out. An electron transparent cross sectional thin slice (9 μm x 12 μm x ~ 100 nm) is freed within the specimen trench.

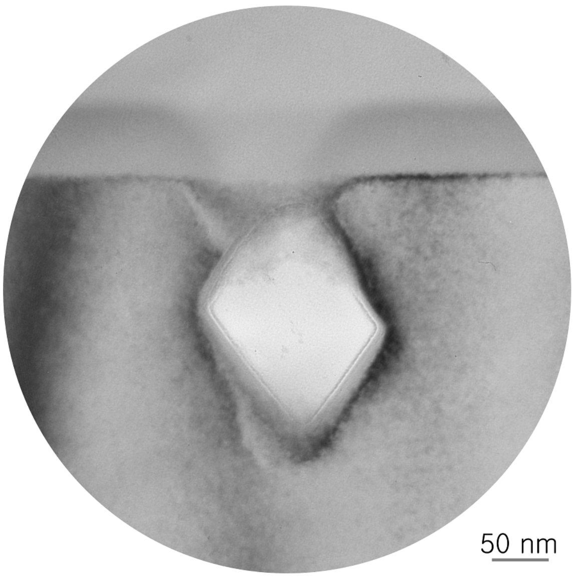

Fig. 3. TEM observation of the void defect on a CZ-Si surface.

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