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FIB Bit Marking Technique for XTEM Analysis of Megabit Memory Failures

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TEM(Transmission Electron Microscope) observation for the device failure analysis is strongly demanded to achieve high production yield and high reliability of VLSI memories with a high bit density and a complicated structure. We have developed a new XTEM(cross sectional TEM) sample preparation technique using FIB(Focused Ion Beam) marking [1], which makes it possible to observe a specified point on VLSI chips. Applying this technique to the analysis of retention-time-failure bits in a DRAM with trench cells, it was found that the oxygen precipitate exists near the trench bottom of the failure bit with excess node-to-substrate leakage current.

After a retention failure bit on a chip is specified with IC tester, V-shape and I-shape patterns are grooved by using the FIB, as shown in Fig.1. The V-shape pattern is used for a position monitoring during the sample thinning, while the I-shape pattern defines the location of the failure bit cell after the sample preparation is completed. Monitoring the specified cell by SIM(Secondary Ion Microscope) image in FIB machine, V and I patterns were formed in the positions 2-3μm apart from the failure cell. The cell-to-mark distance of 2-3μm is necessary to avoid FIB induced damages.

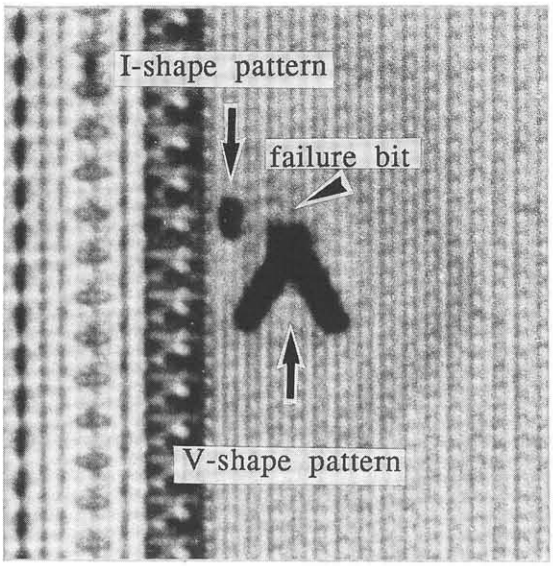
Figures 2 and 3 show XTEM photograph of two types of retention failure cell-A and B. Defects are observed at or near the bottom of the trenches in the both cells.

XTEM observation clearly indicates that these defects have octahedral structure, as shown in Fig.4. It is known that the octahedral structure is the morphology which is characteristic to oxygen precipitates in Si at high temperatures more than 1100 °C [2]. These precipitates are presumably generated during the high temperature well formation process. No conspicuous surface defects, however, have been recognized by etch-pit observation. These results suggest that the oxygen precipitation in the device region is the cause of retention failure. Therefore, it is significantly necessary to avoid the occurrence of oxygen precipitation in the surface layer of silicon substrate during megabit DRAM fabrication.

In conclusion, it is clarified by means of the newly developed TEM analysis that one of causes for retention failures is the oxygen precipitation. This FIB marking technique, which can specify a malfunctioning bit, is very effective in XTEM structural analysis in the situation where the memory chip is dotted with only a few failure bits among millions of normally working bits. This method is indispensable for establishing a failure analysis procedure for megabit memories and VLSIs.

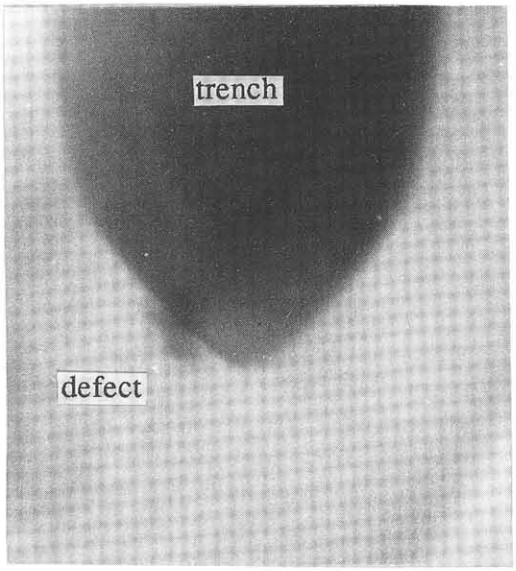
(references)

[1] K.Shiotani, Japanese patent applied for in Dec., 1989.
[2] M.Kitakata, 1988 ECS meeting Extended Abstract, pp.694-695.



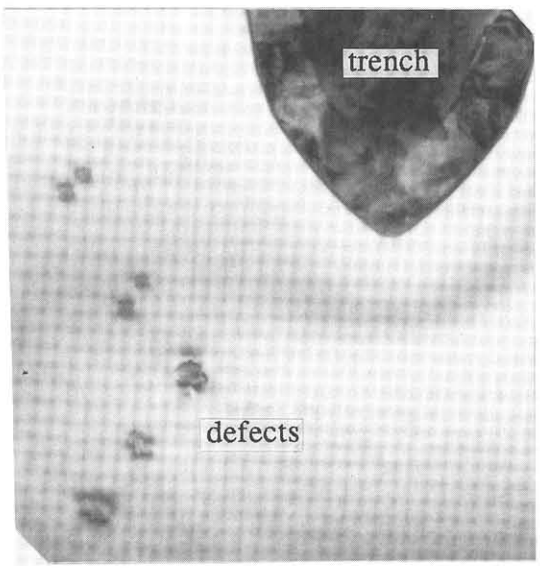
20μm

Fig.1. Optical photograph of FIB patterns to identify failure bit.



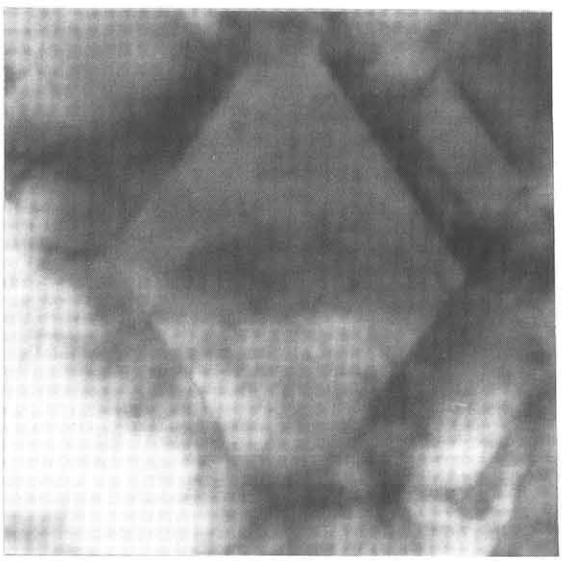
500nm

Fig.2. XTEM photograph of failure bit-A. Defects exist at the bottom of the trench capacitor.



500nm

Fig.3. XTEM photograph of failure bit-B. Defects exist adjacent to the bottom of the trench capacitor.



50nm

Fig.4. XTEM photograph of one of the defects shows octahedral structure, peculiar to oxygen precipitate.