

Visualization of charges stored in the floating gate of Flash memory using the Scanning Nonlinear Dielectric Microscopy

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By applying Scanning Nonlinear Dielectric Microscopy (SNDM), we have succeeded for the first time in the world in clarifying the position where electrons/holes are located in the gate thin $\text{SiO}_2\text{-Si}_3\text{N}_4\text{-SiO}_2$ film of the MONOS type flash memory. [1] Following this previous work, we succeeded in clarifying the electrons existed in the poly-Si layer of the floating gate of flash memory.

SNDM is an atomic force microscopy measurement technique where a ring electrode is used in conjugating with the cantilever. Alternating electric field is biased between this electrode and the sample, and the capacitance variation of the surface region of the sample is detected.

The charge accumulated in the floating gate can be detected by SNDM as a change in capacitance the poly-Si (floating gate) by scanning the surface of the ONO film covering the floating gate. In the SNDM image (Fig), a black contrast existed in the floating gate area, where electrons were injected. On the other hand, there appeared no clear contrast of the floating gate where electrons were not injected. There appeared no contrast of source lines and drain areas.

These images can be interpreted as the visualization of the depletion layer of the floating gate poly-Si. When charge does not exist in the poly-Si, the floating gate is electrically neutral. In this case, the poly-Si is almost semi-insulating (500 ohm-cm). When the electric field is impressed from the substrate side, capacitance does not change ($dC/dV = 0$), and the contrast does not change either. On the other hand, when the electrons are injected in the poly-Si, there exist movable excess carriers. When the electric field is impressed from the substrate side, carriers move to the substrate side, and the capacitance of the poly-Si becomes small. ($dC/dV < 0$). Then, the contrast becomes dark.

Therefore, the SNDM signal contrast appeared when charge is stored in the floating gate.

As shown, SNDM is a powerful method for visualizing charge spatial location in a dielectric material.

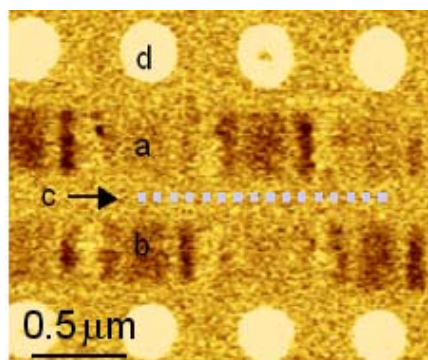


Fig. The SNDM image of the floating gate type Flash memory cell. Non-injected cell (a), electron injected cell (b), source line (c), and drain contact (d).

[1] K. Honda, S.Hashimoto, Y. Cho, Nanotechnology **16**, S90 (2005)