Visualization using the Scanning Nonlinear Dielectric Microscopy of electrons and holes localized in the thin gate film of Metal-Oxide-Nitride-Oxide-Semiconductor type flash memory

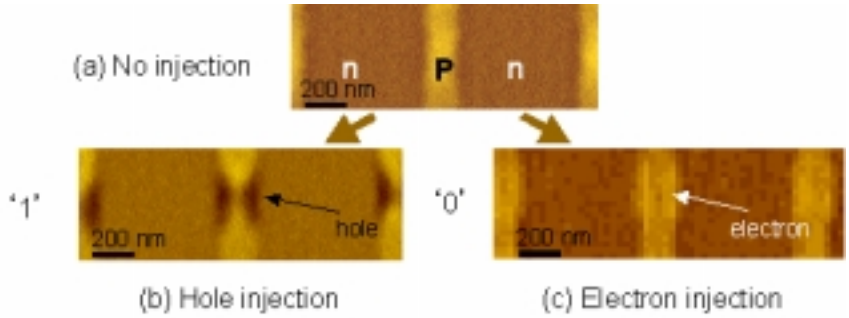
Koichiro Honda [1)], Sunao Hashimoto [2)], and Yasuo Cho [2)]
1) Memory Device Lab. Fujitsu Laboratories Ltd.
10-1 Morinosato-Wakamiya, Atsugi 243-0197, Japan
2) Research Institute of Electrical Communication, Tohoku University
2-1-1 Katahira, Aobaku, Sendai 980-8577, Japan

By applying Scanning Nonlinear Dielectric Microscopy (SNDM) , we succeeded for the first time in the world in clarifying the position where electrons/holes existed in the gate thin SiO_2-Si_3N_4-SiO_2(ONO) film of the Metal-ONO–Semiconductor(MONOS) type 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 neighborhood of the sample is detected.

The charge accumulated in the ONO film can be detected by SNDM as a change in capacity by scanning the surface of the ONO film. In the SNDM image (Figs.1(a), (b) and (c)), a bright contrast existed in the neighborhood of the source in the channel area, when electrons were injected. On the other hand, a black contrast existed in the source neighborhood in the channel area, when holes were injected.

These images can be interpreted as the visualization of the polarization of the electron-hole pair. When the positive charge exists in the insulation film, the minus charge is introduced from the drain area in neighborhood in the channel and a positive charge-minus charge pair is formed. When the electric field is impressed from the substrate side, the capacity of this polarization becomes small. (dC/dV < 0). Therefore, the contrast becomes black. On the other hand, when the minus charge exists in the ONO film, the positive charge is generated from the Si substrate of p type. In this case, when the electric field is impressed from the substrate side, capacity grows (dC/dV > 0), and the contrast becomes white. Therefore, the SNDM signal will be reversed by the positive and negative of the charge in the ONO film.



Figs.1 (a), (b) and (c). The SNDM image of the sample not injected (a), the sample after electrons were injected (b), and after holes were injected (c).

It was also clarified that the electron is localized in the Si_3N_4 part in the ONO film. On the other hand, the results showed that the hole not only existed in Si_3N_4 but also extended to the Bottom-SiO_2.

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