# Effects of Nitridation-treatment for Electrical Properties of MONOS Nonvolatile Memories

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## INTRODUCTION

Metal/Oxide/Nitride/Oxide/Semiconductor (MONOS) memories have been proposed because of their low program voltage and scalability [1]. The possibility of using a 0.1-um generation MONOS memory cell has been demonstrated [2]. In our fabrication process of a MONOS nonvolatile memory, we apply nitridation treatment before the silicon nitride film is formed. The treatment affects the electrical properties of the MONOS transistor, i.e., the data erase and the data retention times decrease, but the ratio of these times increase [3]. However, the mechanism is not clear yet.

In this paper, the dominant mechanism that decreases the data erase time of MONOS nonvolatile memories using the nitridation treatment is investigated.

## SAMPLE AND EXPERIMENT

Two kinds of transistors were prepared: MOS, for measuring the current through gate dioxide film, and MONOS. The nitridation treatment with various conditions was applied after the gate silicon dioxide film or the tunnel oxide film formed. To investigate nitrogen concentration in tunnel oxide films, Auger electron spectroscopy (AES) was used.

## RESULTS AND DISCUSSION

Figure 1 shows AES spectra of nitrogen concentration in the tunnel oxide film. Figure 2 shows the program and data erase time of MONOS transistors as a function of nitrogen concentration in tunnel oxide films. Data erase time decreases exponentially as the nitrogen concentration increases; nevertheless, program times do not change. I-V separation experiments of the electron and hole currents through the gate silicon dioxide film of MOS transistors were carried out [4]. The electron currents were measured by using Nch MOS transistors and hole currents were measured by using Pch MOS transistors. The hole current was found to increase as the nitride concentration increases, but the electron current does not change. We also measured the electron and hole currents through tunnel oxide film as a function of temperature. The electron current does not increase as the temperature increases, but the hole current increases. An activation energy of the hole current of 0.12-0.14eV was obtained. These results suggest that nitrogen atoms penetrate into the tunnel oxide film and generate hole traps [5]. Data-erase phenomena of MONOS nonvolatile memories occur by a hole injection from the silicon substrate to silicon nitride film through tunnel oxide film by a direct tunneling mechanism [6]. Hole traps make the hole current through the tunnel oxide film increase, and therefore the data erase time decreases.

## CONCLUSIONS

We found that,

(1) The data erase time of MONOS nonvolatile memories decreases exponentially as nitrogen concentration in tunnel oxide film increases.
(2) Hole current increases as nitrogen concentration in it increases, but electron current does not change.
(3) The hole current increases as temperature increases, but the electron current does not change.
(4) The activation energy of the hole current in the tunnel oxide of 0.12-0.14 eV is obtained.

These results suggest that, during nitridation-treatment, nitrogen atoms penetrate into tunnel oxide film, and hole traps are generated in it. Thus, hole traps make the hole current increase through the tunnel oxide film and, therefore, make the data erase time of MONOS nonvolatile memories decrease.

## References

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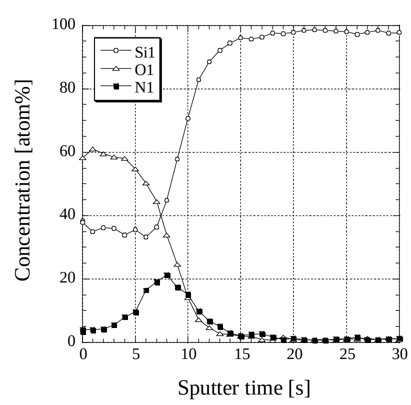


Fig. 1 AES spectra of SiO2/Si Nitridation treatment

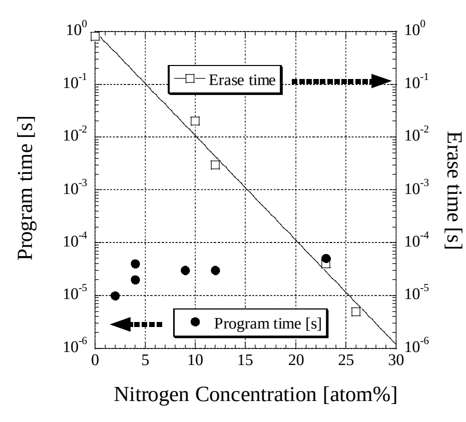


Fig. 2 Program and date erase time of MONOS transistors