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## A-4-4 N-channel MNOS EAROM for TV Electronic Tuning System

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In order to obtain high speed read operation under positive power supply, n-channel MNOS memory devices have been intensively studied.<sup>1)-3</sup> However, n-channel MNOS devices generally sacrifice retentivity compared to p-channel devices when incorporated into LSI memory, because n-channel MNOS devices have negative center voltage of the threshold window which makes it difficult to fully utilize the whole threshold window.

This paper describes a threshold voltage control for n-channel MNOS devices by an optimized low energy ion implantation for better retentivity, and a newly developed MNOS EAROM for TV tuner spplying this technique.

In order to shift the center voltage in the positive direction, high impurity concentration of acceptor element such as  $\sim 10^{18}$  cm<sup>-3</sup> is needed at the silicon surface of MNOS structure because of large dielectric constant of silicon nitride and thin film thickness. When an acceleration voltage of ~60KV is used in boron ion implantation which has been commonly used for channel ion implantation, the implanted ion profile spreads into the substrate deeply, and most of implanted ions do not effectively contribute to the threshold shift, but also cause another failure operation in write-inhibiting mode. The writing and write-inhibiting characteristics of the implanted MNOS structure are shown in Fig.1. In the device with boron implantation at 60KV, the writeinhibiting operation, in which the drain and the source are also positively biased when the positive writing voltage is applied to the gate, can not be realized. Moreover, the threshold shift in the write-inhibiting mode is even larger than that in the writing mode. This would be explained by a model in which high boron dose will result in enough high field near the surface so that electrons shall be accelerated to induce impact ionization and to be easily injected into the nitride film. To overcome this problem, we tried to optimize the ion implantation energy and found that low energy boron ion implantation ( 20KeV,  $\sim 10^{13} \text{cm}^{-2}$  ) through the nitride film is effctive in controlling the threshold voltage and in eliminating the failure operation in write-inhibiting mode, as shown in Fig.1 and Fig.2. Fig.3 shows the typical long term retention characteristics of the implanted MNOS transistor at 80°C after 10<sup>4</sup> times of erasing/writing cycles. The retention time is estimated as  $10^{10}$  sec (~300 years) by extraporating this data to the threshold window of 1.0 V.

On the basis of this technology, the MNOS EAROM for TV tuner was designed and fabricated, whose device structure and microphotograph are shown in Fig.4 and Fig.5, respectively. This EAROM consists of 16-word X 16-bit array of two MNOS transistor cells and peripheral n-well CMOS circuits. The memory cell array is isolated from the peripheral circuits by the n-type diffused area, which reaches n-type silicon substrate. The MNOS transistors and the n-well CMOS circuits are formed in each epitaxial region. The main features of this MNOS EAROM are, the operation under positive power supply ( +10V, +33V), low power dissipation less than 1 mA, and long data retention time over 10 years at  $80^{\circ}C$ .

In conclusion, the threshold voltage control technique for n-channel MNOS transistor has been achieved by optimization of low energy boron ion implantation, which results in excellent retentivity. Based on this technique, n-channel MNOS EAROM for voltage synthesizer TV tuning system is successfully fabricated by incorporating n-channel MNOS transistors and CMOS peripheral circuits into a single chip.

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Fig.1 MNOS write-inhibiting characteristics.







Fig.4 Cross section of device structure.







