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B6-2 N-channel Si-gate MOS Devices on Sapphire Substrates

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Increasing interest is being shown in MOS LSI's using SOS (Silicon on Sapphire) and C-MOS integrated circuits on SOS have been actively developed [1]. E/D type (Enhancement/Depletion type) MOS devices on SOS, however, have not been reported. In this work, we have successfully fabricated the n-channel E/D type MOS devices using Si-gate and ion implantation technologies.

SOS films used were high resistivity (100)-oriented P-type Si films of 1 μm thick. Figure 1 shows gate voltage vs. drain current of an SOS n-channel MOS transistor (channel length L=8 μm, channel width W=100 μm) without ion implantation. The drain leakage current of 3.6×10^{-10}A was obtained at 20 °C. The temperature dependence of the drain leakage currents over the range of 25 °C to 150 °C showed activation energies ranged from 0.54 to 0.59 eV. . The same values were obtained in the p-channel MOS transistors on SOS. These values are consistent with Boleky's result [1] obtained from the p^+-n and n^+-p diodes. These results suggest that the leakage current may be due to the generation current. In Fig. 2, the effective mobilities in the triode region of the n-channel transistors are shown in comparison with those of bulk Si n-channel transistors. As seen in Fig. 2, the mobilities of SOS n-channel transistors are 60～70 % of those of bulk Si n-channel transistors. On the other hand, no difference was found in the mobility between the bulk Si and the SOS p-channel MOS transistors.

We have succeeded in introducing ion implantation technology to the SOS MOS process. The use of this technology leads to more precise control of threshold voltage (V_T) and more simple process than the two stage epitaxial method [2] in the fabrication of E/D type or C-MOS circuits. Figures 3(a) and (b) show the drain current characteristics of an E-type and a D-type n-channel MOS transistor fabricated using ion implantation respectively. For the E-type transistors, boron ions were implanted at 60 kV, and for the D-type transistors, phosphorus ions were implanted at 170 kV.

Using the above-mentioned technologies, we have fabricated n-channel E/D type ring oscillators of 21-stages. The ratios of W/L of the load and driver transistors of each stage are 16 μm/ 6 μm and 32 μm/ 6 μm, respectively. The wave form of the ring oscillator at a supply voltage of 5 V is shown in Fig. 4. The propagation delay time is 1.7 nsec/stage with V_{TE} of 0.9 V and V_{TD} of -3.4 V. In spite of low effective mobilities of the transistors as shown in Fig. 2, we have succeeded in fabricating such a high speed MOS IC.

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References :

(1) E. J. Boleky et al., IEEE J. Solid-State Circuits, SC-7 (1972) 135

(2) E. J. Boleky, RCA Rev., 31 (1970) 372

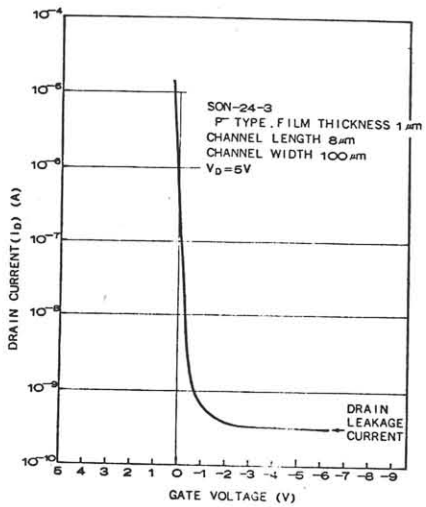
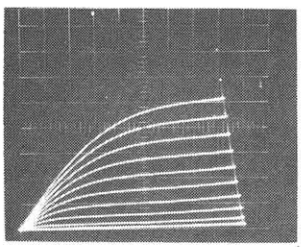
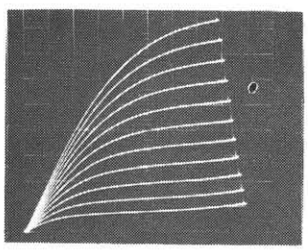


Fig. 1 V_G - I_D characteristic of n-channel transistor



(a) E-type transistor, V_{TE}=1.1V



(b) D-type transistor, V_{TD}=-2.4V

Fig. 3 Drain current characteristics of n-channel transistors

V_D=1 V/DIV.
I_D=1 mA/DIV.
V_G=1 V STEP
(0 10 V)

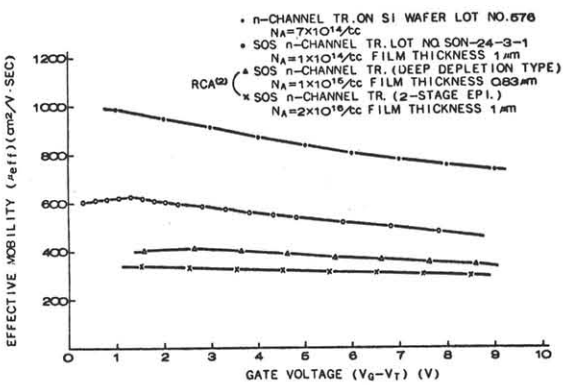


Fig. 2 Effective mobility of n-channel transistors

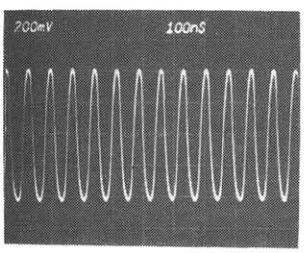


Fig. 4 Oscillation wave form of ring oscillator