3-Dimensional IC's Fabricated by Using Ar⁺ Laser Recrystallization

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This paper describes the first successful fabrication of 3-dimensional (3-D) IC's, in which an SOI-MOSFET is fabricated directly above another MOSFET with insulator in between. This structure and process technology offer the basis for extention to more than two levels of devices.

Figure 1 shows an SEM micrograph of a fabricated 3-D 7-stage CMOS ring oscillator. A schematic cross section of this device is shown in Fig.2. An n-channel Si-gate SOI-MOSFET is made in a laser recrystallized silicon-island directly above a p-channel Si-gate bulk MOSFET. Devices are interconnected by a single level aluminum wiring. The enlarged SEM micrograph of the central part of Fig.2 is shown in Fig.3.

The bottom p-channel Si-gate MOSFET's are made on an n-type (100) 10 \Re cm single crystal silicon substrate. Then a 0.4 μ m polysilicon layer is deposited on an intermediate insulating layer composed of Si₃N₄ and PSG films over the bottom MOSFET's. The PSG is reflowed to make a flat surface. The Si₃N₄ prevents phosphorus diffusion from PSG to the silicon layer during laser irradiation and subsequent process steps. The polysilicon layer is recrystallized by a scanning cw-Ar⁺ laser with a 5 W power, a 40 μ m spot size and a 12 cm/s scanning speed at 450 °C in air. Then the recrystallized silicon layer is patterned by etching and the top SOI-MOSFET's are fabricated. Sputtered aluminum is used for the interconnecting wiring to avoid step coverage problems.

Figure 4 shows an output waveform of the seven-stage 3-D CMOS ring oscillator. A propagation delay of 430 psec is obtained at a power supply voltage of 5 V. Channel lengths and widths are 2 Am and 18 Am, respectively, for both the n- and p-channel MOSFET's. Threshold voltages are 1.2 V for the n-channel SOI-MOSFET's and -0.8 V for the p-channel bulk MOSFET's. Field effect mobilities are 360 cm²/V·s for the SOI-MOSFET's and 230 cm²/V·s for the bulk MOSFET's.



- Fig.]. SEM micrograph of the top and cross sectional view of the fabricated 3-D CMOS IC after removal of cover PSG. This is a 7-stage CMOS ring oscillator.
- Vour Si₃N₄ Si₃N₄ PSG n^{*} Si
- Fig.2. Schematic cross section of the 3-D CMOS IC, showing an n-channel MOSFET in the recrystallized silicon and a p-channel MOSFET on the single crystal silicon substrate.



Fig.3. Enlarged SEM micrograph of the central part of Fig.2.



Fig.4. Output waveform of the 7-stage CMOS ring oscillator at a power supply voltage of 5 V. Channel lengths are 2,4 m for both n- and p-channel MOSFET's. Propagation delay is 430 psec.