A new dynamic RAM cell with dynamically switched buried channel (DSC cell), and with readout signal gain is proposed. The cell has extremely small collection efficiency of charges generated by alpha-particle, and allows large amount of leakage charges due to its peculiar structure, therefore can achieve high packing density, compared with any other proposed cells such as SCM(1), TI RAM cell(2) and DMOS cell(3).

Fig. 1 shows DSC cell structure and its equivalent circuit. DSC cell is composed of an MOSFET, an MOS capacitor and a JFET with a buried channel under the MOS capacitor. The buried channel is cut off when charges are stored in the capacitor through the MOSFET ("1" state), then readout current does not flow between WB and RW lines. While it is not cut off when no charges are stored ("0" state), then the current flows.

Experimental test devices were fabricated using double polysilicon and FIPoS(4) techniques. Fig. 2 shows write and readout waveforms. Since readout current of DSC cell is due to electrons injected from N⁺ layer to the P region, large readout current can be obtained, compared with unipolar JFET, as shown in Fig. 3.

Permitted numbers of leakage charge \( N_e \) in DSC cell is large compared with other gain cells, because large surface-potential can be applied under the capacitor without charge injection from substrate (i.e., the insulator or reverse-biased N layer). It was experimentally confirmed that

\[
N_e = S_c \left( C_{ox} \left( V_{si} - V_{sf} \right) / q + \Delta V \cdot N_A \right),
\]

\[
V_{sf} = qN_A d^2 \left( 2K_{SiO2} - 2 \phi_f \right),
\]

\[
\Delta V = \frac{2K_{SiO2} \phi_f}{qN_A} \left( \frac{V_{si}}{2} + V_{sf} - \frac{2 \phi_f + V_{sf}}{2} \right),
\]

where \( S_c \) is capacitor area, \( C_{ox} \) is gate oxide capacitance, \( V_{si} \) is surface potential of writing level, \( V_{sf} \) is surface potential at which dynamic deep depletion layer width becomes equal to the P region thickness \( d \), and \( \Delta V \) is change of the depletion layer width due to \( \Delta V \left( = V_{si} - V_{sf} \right) \). N_A dependences of \( N_e / S_c \) and \( \Delta V \) are shown in Fig. 4. From Fig. 4, it is found that DSC cell has large \( N_e \), which is based upon large \( \Delta V \).

The collected numbers of alpha-particle-generated electrons \( N_X \) in DSC cell is very much small, because the P region is sufficiently thin and diffusion component of electrons generated beneath the depletion layer is negligible due to insulator substrate or built-in mechanism. Fig. 5 shows calculated minimum capacitor area required to hold stored "1" state for 4 msec, for typical leakage current flow of 1 \( \mu A/cm^2 \) at 90°C and one strike of typical 5 MeV alpha-particle with incident angle of 45°. From Fig. 5, it is found that capacitor area of DSC cell can be extremely reduced, which is based upon both small \( N_X \) and sufficient \( N_e \).
Comparison among DSC cell, other gain cells and single transistor cell is summarized in Table 1. DSC cell is the most competent device for high packing density and alpha-particle-immunity in the future.

References

![DSC Cell Structure and Equivalent Circuit](image)

Fig. 1 (a) DSC cell structure,
(b) Equivalent circuit of DSC cell.

![Write and Read Waveforms](image)

Fig. 2 Write and readout waveforms. (a) "1". (b) "0". (V = 5 V. 100Ω resistor is connected between RW line and ground.)

![N_a Dependence of Readout Current](image)

Fig. 3 N_a dependence of readout current.

![Minimum Capacitor Area vs. Impurity Concentration](image)

Fig. 5 N_a dependence of calculated minimum capacitor area.

**Table 1. Comparison of d-KAM cells.**

<table>
<thead>
<tr>
<th></th>
<th>DSC</th>
<th>TI</th>
<th>SCB</th>
<th>DMOS</th>
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<tr>
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<td>Cell Size (um)</td>
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<td>9</td>
<td>9</td>
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<td>Permitted Leakage Charges</td>
<td>3.3x10⁻¹⁵</td>
<td>1.7x10⁻¹⁴</td>
<td>~4x10⁻¹⁵</td>
<td>~8x10⁻¹⁵</td>
<td>1.8x10⁻¹⁴</td>
</tr>
<tr>
<td>Collected Number of Alpha-Particle- generated electrons</td>
<td>3.2x10⁻¹⁵</td>
<td>3.8x10⁻¹⁵</td>
<td>~1x10⁻¹⁴</td>
<td>~1x10⁻¹⁴</td>
<td>6x10⁻¹⁴</td>
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<tr>
<td>Alpha-Particle Numbers Inducing Soft Error</td>
<td>1</td>
<td>~0.4</td>
<td>~0.8</td>
<td>0.3</td>
<td>1.9</td>
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</table>

Fig. 4 N_a dependences of leakage charge per unit area and permitted surface potential change.