Robustness improvement of an SRAM cell against laser-induced fault injection

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Radiation emitted from the sun is a major threat for electronics devices.

Effect of radiation could be tested by:
- Cyclotron
- Pulsed Laser equipment

Possible simulation:
- TCAD
- Electrical simulation
Characterization and modeling of CMOS devices under laser illumination

Confirm the simplify model on CMOS gate:

e.g.: inverter, SRAM cell…

Try new solutions in order to improve CMOS gates robustness

A. Sarafianos and al, Building the electrical model of the pulsed photoelectric laser stimulation of an NMOS transistor in 90nm technology, IRPS 2013.

A. Sarafianos and al, Building the electrical model of the pulsed photoelectric laser stimulation of a PMOS transistor in 90nm technology, IPFA 2013.
4 zones sensibles en théorie

- 2 à l’état "0"
  - Drain de MP1
  - Drain de MN2

- Et 2 autres à l’état "1"
  - Drain de MP2
  - Drain de MN1

**Presentation of the SRAM cell**

**CSRAM 5T**
Caractéristiques de l’équipement laser

<table>
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<tr>
<th>Caractéristique</th>
<th>Valeur</th>
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<tr>
<td>Longueur d’onde</td>
<td>1064 nm</td>
</tr>
<tr>
<td>Taille de spot</td>
<td>1 µm</td>
</tr>
<tr>
<td>Durée de l’impulsion</td>
<td>50 ns</td>
</tr>
<tr>
<td>Puissance laser</td>
<td>1.7 W</td>
</tr>
</tbody>
</table>

Seulement 3 zones sensibles vues en mesures

→ 2 à l’état “0”
   • Drain de MP1
   • Drain de MN2

→ Et une autre à l’état “1”
   • Drain de MP2
Hypothesis

Important area of the drain of MN2

Close to

Small area of the drain of MP2

Masking effect
Electrical modeling for confirming the hypothesis

Sub circuit for each kind of PN junction

\[ I_{ph} = (a \times V + b) \times S \times \alpha_{gauss} \times V_{laser \_ trig} \]

\[ a = p \times P_{laser}^2 + q \times P_{laser} + r \]
\[ b = s \times P_{laser} \]

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>N+/Psub</th>
<th>P+/Nwell</th>
<th>Nwell/Psub</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>4E-4</td>
<td>9E-2</td>
<td>6E-11</td>
</tr>
<tr>
<td>Q</td>
<td>-5E-7</td>
<td>2E-4</td>
<td>9E-9</td>
</tr>
<tr>
<td>R</td>
<td>9E-6</td>
<td>-5E-6</td>
<td>1E-7</td>
</tr>
<tr>
<td>S</td>
<td>4E-6</td>
<td>1.2E-3</td>
<td>6E-8</td>
</tr>
</tbody>
</table>

\[ \alpha_{gauss}(d) = \beta \times \exp\left( -\frac{d^2}{c_1} \right) + \gamma \times \exp\left( -\frac{d^2}{c_2} \right) \times w \]

Trig signal

Takes into account of the spatial dependency

Dependency of the pulse width
Measurement vs electrical simulation for the PN junction under pulsed laser illumination

Good correlation obtained between measurement and electrical simulation permits to build an electrical model of the SRAM cell under pulsed laser illumination.
Electrical modeling of the SRAM and results

Electrical modeling

Electrical simulation results

Measurement
Effect of NISO implant on NMOS transistor

NMOS NISO

(a)

P_w
N_w
P_sub

NMOS STD

(b)

Measurement

NMOS NISO

NMOS STD

PhotoCurrent (mA)

Time (s)

-8
-6
-4
-2
0
2
4
6
8

0E-06
5.0E-06
1.5E-05
2.5E-05

-1.5
-1
0
0.5
1
1.5

0E-06
5.0E-06
1.5E-05
2.5E-05

PhotoCurrent (mA)

Time (s)
Robustness improvement on a 6T SRAM cell
Simulation permits to improve the robustness of the masking effect.

The topology of the cell has an important effect!

The validity of our modeling approach is assessed by the good correlation obtained between simulations and measurements.

Perspectives: Simulate new solution more robust against laser injection.
Thank you for your attention…

Q & A