T-CAD Analysis of surface damage in Gate controlled diode

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Outline

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- Device structure and model
- Simulation procedure
- Comparison with data from Experiment: CV (5, 10, 15 khz)
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- Summary
• Only damage in SiO₂ and Si-SiO₂ interface important
• Test structure: gated diode with 5 gate rings

Circuit for I-V and C-V/G-V measurement of gated diode
**Aim:** First step for detailed simulation of sensor including radiation damage effects

**Software:** 2-D Device simulation through ISE T-CAD DESSIS (Device Simulation for Smart Integrated Systems)

**Physics models used**

- SRH recombination
- Auger recombination
- Impact ionization
- Surface recombination
- Gate current (Lucky) model
- Trap models
  - solving Poisson and electron/hole current-continuity equations
  - dependence of life time of charge carrier ($\tau$) on interface trap density ($N_{it}$) taken into account.
Procedure

1. Design structure in MDRAW
2. Feed results into DESSIS
3. Combine simulation of device (DESSIS) and circuit (SPICE)

Input Parameters

- MOS capacitor of 50 x 50 micron
  - \( N_{oc} = 1.28 \times 10^{12} \text{cm}^{-2} \)
  - \( t_s = 0.405 \text{micron} \)
  - \( V_{bs} = -0.69 \text{V} \)
  - \( N_{ox} \) – Oxide trapped charge = \( 2.38 \times 10^{11} \text{cm}^{-2} \)
  - \( N_{n,ox}/N_{ox} = 2.1 \times 10^{11} \text{cm}^{-2} \)
  - \( \tau = 130 \text{microsecond} \)
  - \( c_{eff} (n/p) = 7 \times 10^{17} \text{cm}^{-2} \)
  - \( v_{ni}(n/p) = 2 \times 10^7 \text{cm/sec} \)
  - \( E_r = 0 \)
  - \( S_0 = 2.8 \text{cm/sec} \)
  - \( T_{ambient} = 300 \text{K} \)
  - \( f = 10 \text{kHz} \) & ac voltage = 0.1 volt

Si-SiO2 interface

n-type Si

Al gate

SiO2

Ncontact
Comparison with data from experiment

MOS capacitor of 50x 50 micron
$N_{ox} = 5.84 \times 10^{11} \text{cm}^{-2}$
$\varphi_{FB} = 0.60 \text{ Volt}$

$N_d$: Oxide trapped charges $2.33 \times 10^{11} \text{cm}^{-2}$

$N_{ox}(S) = N_{ox}(E)/1.12$

$N_{dop}(S) = N_{dop}(E) \times 4.6$

Due to donor trap

$C-V$ is almost experimental Fit.

- Two parameter Corrected i.e. $N_{ox}$, $N_{dop}$.

Experiment simulation

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Dependence of frequency (5 kHz) - Comparison with data from experiment
Status Report: Radiation Damage for X-rays in Si

On frequency - 15 khz

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G-V is very sensitive to Interface trap.

Trap type?
Donor, Acceptor, double ...with Nt

G-V curve changes with different trap.

Qualitatively, both curve (I & II) is well defined in all regions.
$G-V$ long peak increases with $N_\text{a}$ (Acceptor) at fixed frequency.

Trap type? Ans. Acceptor trap at some level.

$G-V$ curve shape change in accumulation zone due to $R_{\text{bulk}}$.

$Nox(S) = Nox(E)/1.07$
$Ndop(S) = Ndop(E) \times 2.60$
$Nit(S) = Nit(E) \times 37$
GV behaviour: On 5 KHz
* G peak is at same $V_g$ for different frequency.

* G peak is increases with frequency at fixed $N_{it}$.

* Effect of series resistance (accumulation zone) decreases at increasing frequency.
For same $R_{\text{bulk}}$, corrected $G-V$ simulation/experimental characteristics- both looks same.

$R_{\text{bulk}}$ is also important for $G-V$ experimental fit.

New MOS capacitor Design for 50 x 300 micron: $G-V$ and for $C-V$.

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Summary

- Simulated results for CV Characteristics is in good agreement with experimental result for unirradiated diode.

- GV characteristics is very sensitive to type of interface trap and interface trap density at different frequency.
  - Qualitatively, GV characteristics behavior is well explained for taken traps.