Performance Studies of the p-spray/p-stop implanted Si Sensors for the SiD Experiment

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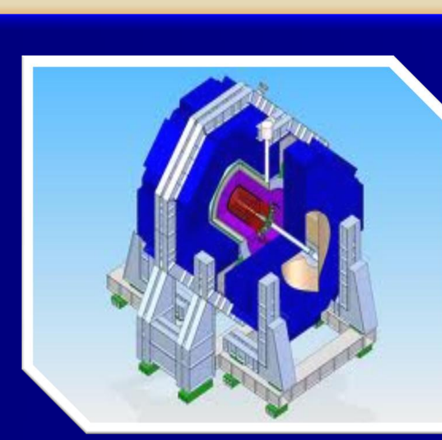
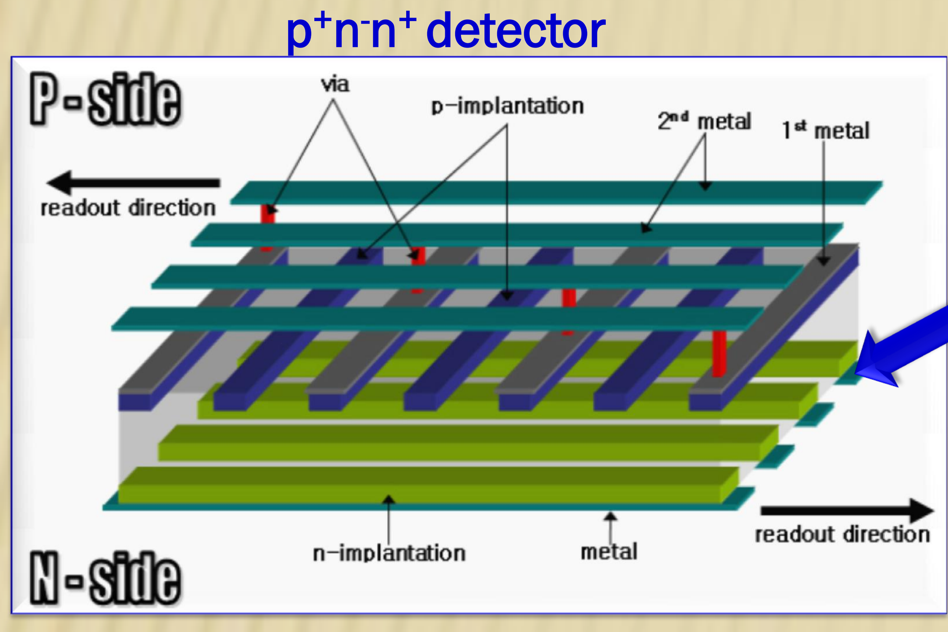


FRAMEWORK

- Silicon Detector (SiD) is one of the proposed detector for future $e^+ e^-$ linear collider experiments.
- Double-sided silicon strip sensor provides two-dimensional position information with high resolution.
- Innermost vertex detector : background of ~ 1 - 1.6 x 10^{10} 1-MeV equivalent neutrons cm^{-2} $year^{-1}$

$p^+n\text{-}n^+$ detector

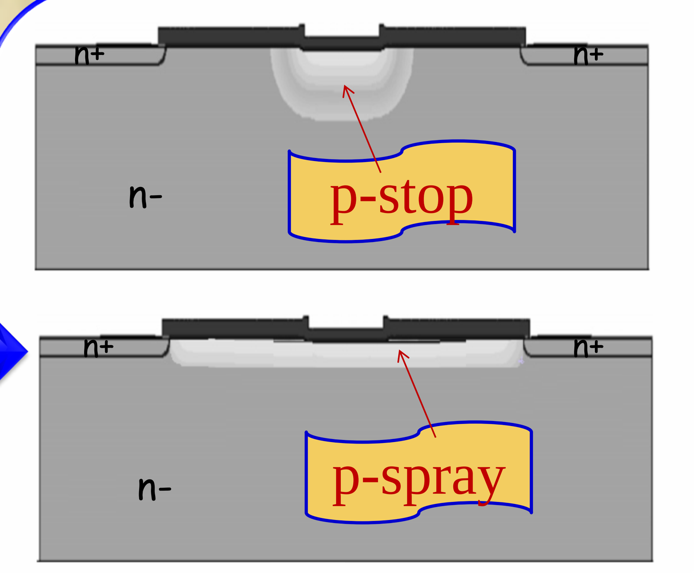


MOTIVATION

Shortening due to e⁻ accumulation on the n^+n^- side ➡ degradation in position resolution ➡ further problem because of ionizing radiation.

ISOLATION TECHNIQUES

- **p-stop**: floating p-type implants introduced between the n^+ strips
- **p-spray**: uniform layer of p-type implant on the entire n^+ side
- **p-stop with p-spray**: combined use of both



RESULTS

Silvaco-TCAD, DEVICE SIMULATOR (ATLAS)

Semiconductor Eqns.

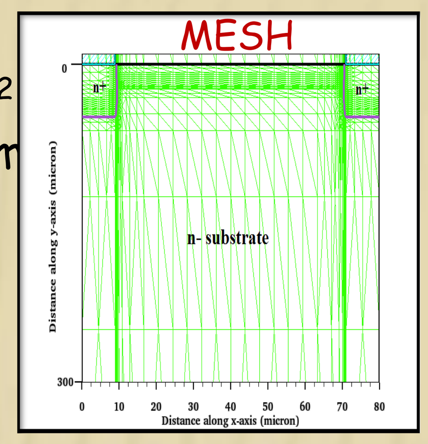
$\nabla.D = \rho$
$\nabla.(J_n /-q) = (G - R)$
$\nabla.(J_p /q) = (G - R)$

3coupled, nonlinear, second order PDE's for the 3 unknowns: V, n, p

Device Parameters

- Device Cross-section = 80x320 μm^2
- strip pitch=80μm, strip width=18μm
- n+ conc. = $1x10^{19}$ cm^{-3}, Gaussian
- Substrate conc. = $7x10^{11}$ cm^{-3}, Uniform
- peak p-spray conc. (Np)= $4x10^{16}$, $12x10^{16}$, $24x10^{16}$ (cm^{-3}), Gaussian
- Oxide charge density (Q_F) = $5x10^{11}$, 10^{12}, $2x10^{12}$ (cm^{-2})
- Models : conc. & field dependent mobility, SRH with conc. dependent lifetime, GRANT (Impact Ionization)

MESH

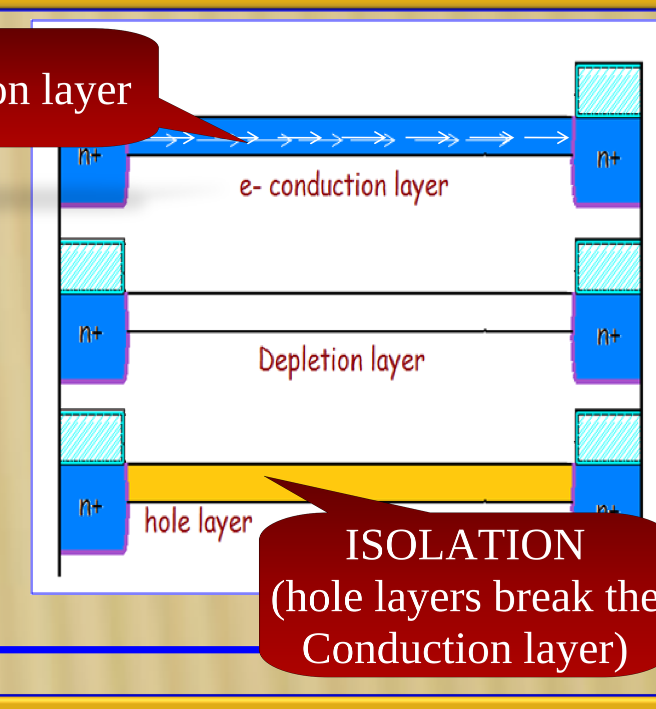


P-SPRAY EFFECT

AC char. → Interstrip Capacitance (Cint); Interstrip Conductance (Gint)

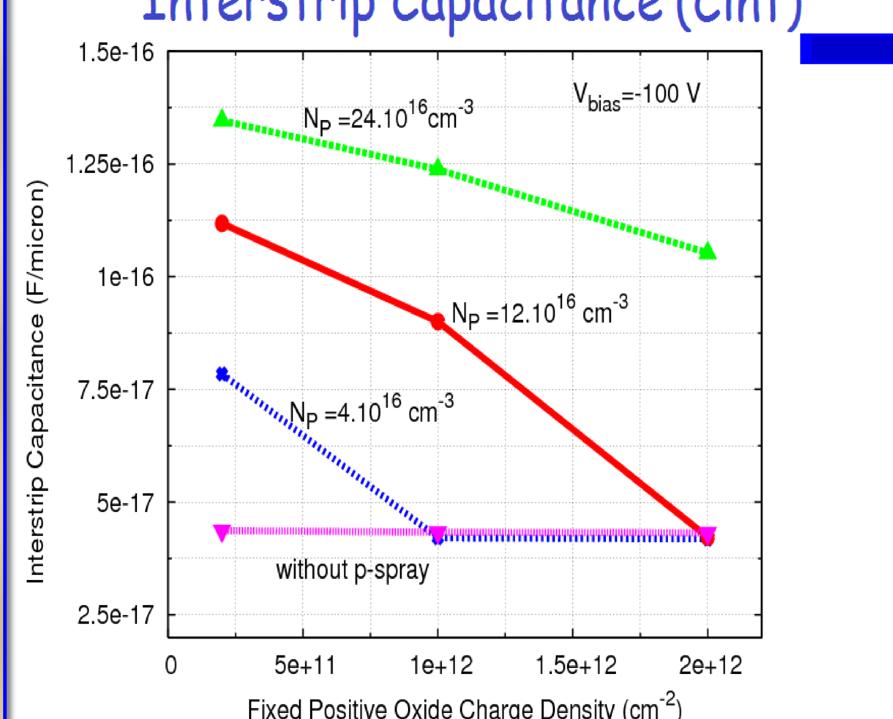
- Addition of p-spray/p-stop results in hole layer. For effective isolation, holes must be in excess of e⁻.
- p-spray: affects Cint, Gint & V_{BD}.

Radiation damage → Bulk Damage; Surface Damage ➡ Modeled by ↑ in Q_F



ISOLATION CHARACTERISTICS

Interstrip Capacitance (Cint)



w/o p-spray

- Low Q_F : Gint is high, Cint is low
- Influence of Radiation
  - ➡ Q_F increase
  - ➡ Gint increase
  - ➡ isolation deteriorates

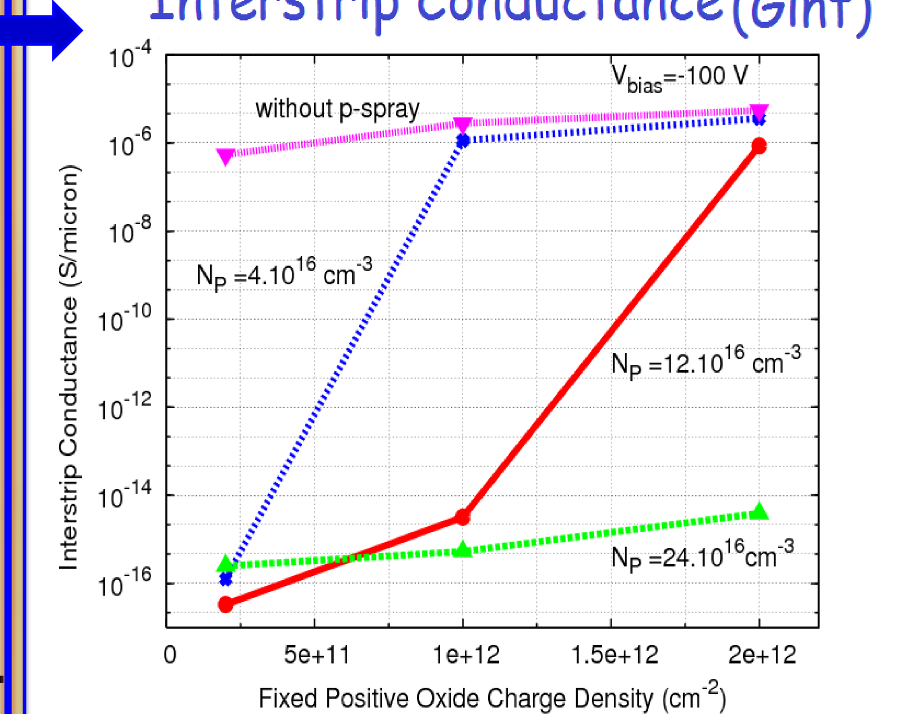
with p-spray

low dose ($4x10^{16}$ cm^{-3}) — medium dose ($12x10^{16}$ cm^{-3}) — high dose ($24x10^{16}$ cm^{-3})

- For a given Q_F : Cint increases with increase in N_P.
- For Q_F = $2x10^{11}$ cm^{-2} ➡ Gint decreases for all the p-spray doses (improves isolation) compared to w/o p-spray.
- For Q_F = $10x10^{11}cm^{-2}$ ➡ "low dose" can not provide good isolation (higher Gint)
- For Q_F = $24x10^{11}$ cm^{-2} ➡ only "high dose" can provide isolation (low Gint)

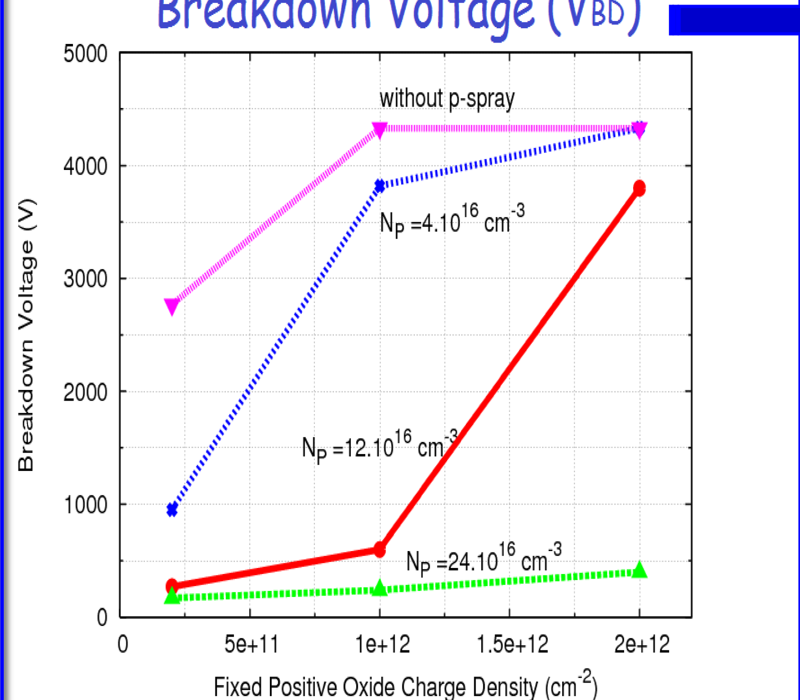
High N_P PROVIDES BETTER ISOLATION (LOW Gint)

Interstrip Conductance (Gint)



ELECTRICAL CHARACTERISTICS

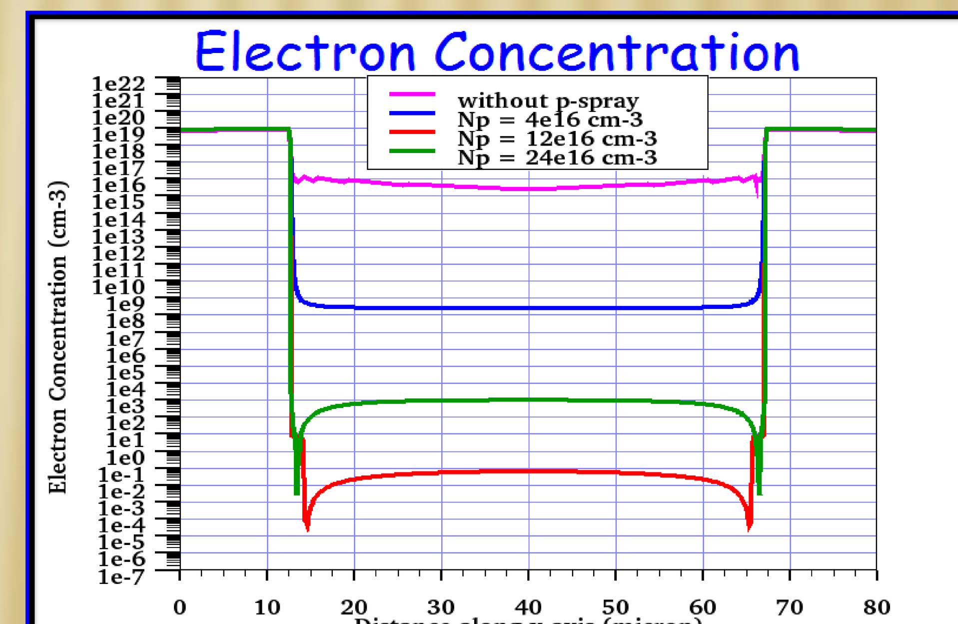
Breakdown Voltage (V_{BD})



- For a given Q_F , w/o p-spray : high V_{BD}. Further ↑ Q_F ➡ improves the V_{BD} (in the range of 2500-5000 V)
- As Np increases ➡ V_{BD} decreases
- For high dose ➡ lowest V_{BD}, 150-500 V (function of Q_F)

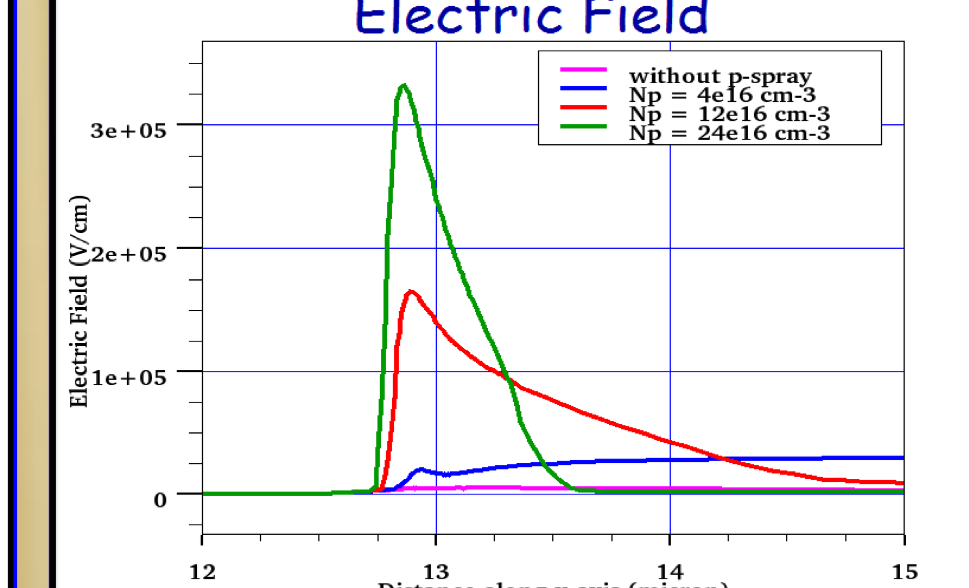
LOW N_P PROVIDES BETTER V_{BD}

Electron Concentration



At V_{bias}= -100V, Q_F= $10x10^{11}$ cm^{-2}

Electric Field



At V_{bias}= -100V, Q_F= $10x10^{11}$ cm^{-2}

- e-/hole conc. provides all the needed information of AC characteristics (Cint & Gint)
- electric field provides information of breakdown characteristics.

SUMMARY

1. The $p^+n\text{-}n^+$ silicon detector has been investigated with respect to isolation & breakdown char.
2. The isolation is important for position resolution in DSSD.
3. In order to achieve good isolation (low Gint) & reasonable breakdown voltage (high V_{BD}), we need to optimize N_P dose

FUTURE OUTLOOK

--Ongoing studies with p-stop and comparison between p-stop & p-spray isolation technique.

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