Updates on Punch-through Protection

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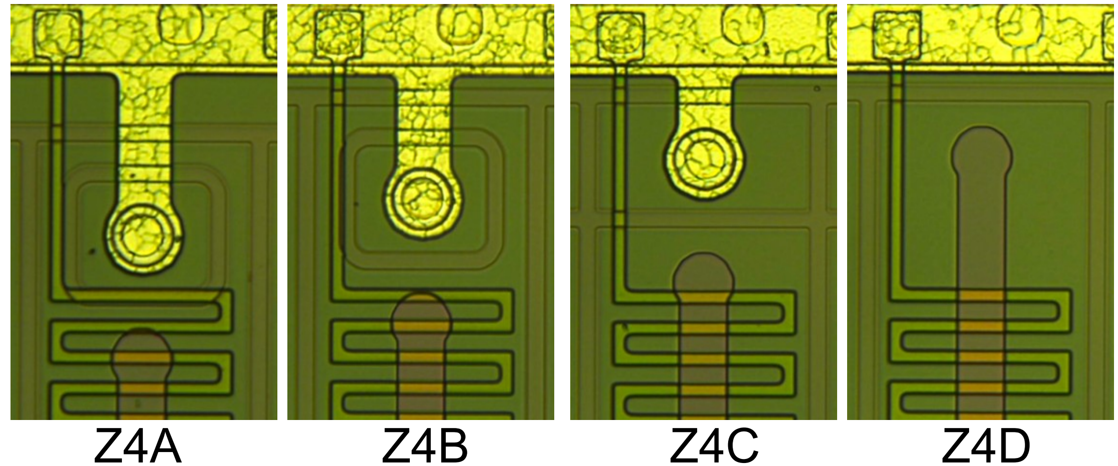
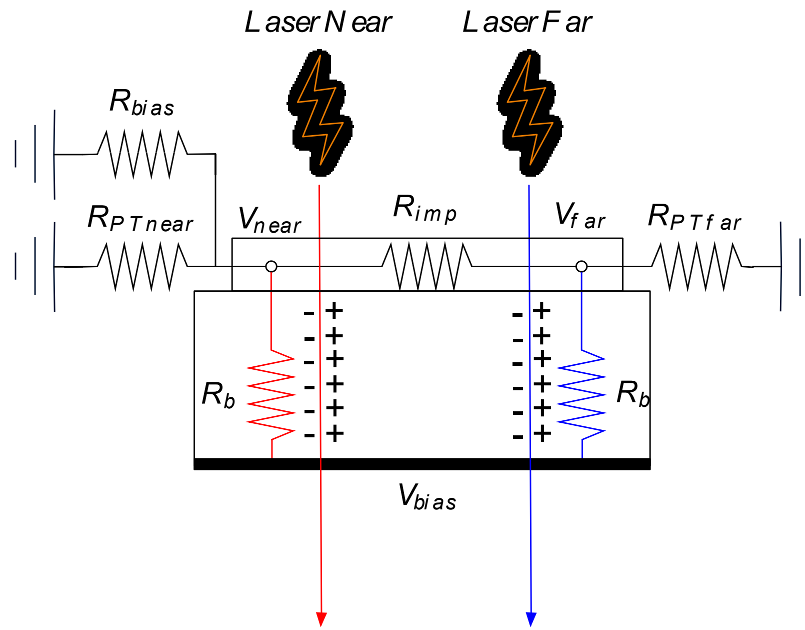
- Punch-through Protection against Large Voltages on Implants
- Testing of Field-breakdown with an IR Laser
- F. o. M. : Bulk Resistance / Saturation Resistance
- Extraction of PT parameters: DC 4-R Model
- Radiation and Temperature Effects
- P-Dose (spray and stop)
- Role of Implant Resistance: Mitigation ?
- R-C Filter Circuit, has no effect
- Gate effect of biasing resistor

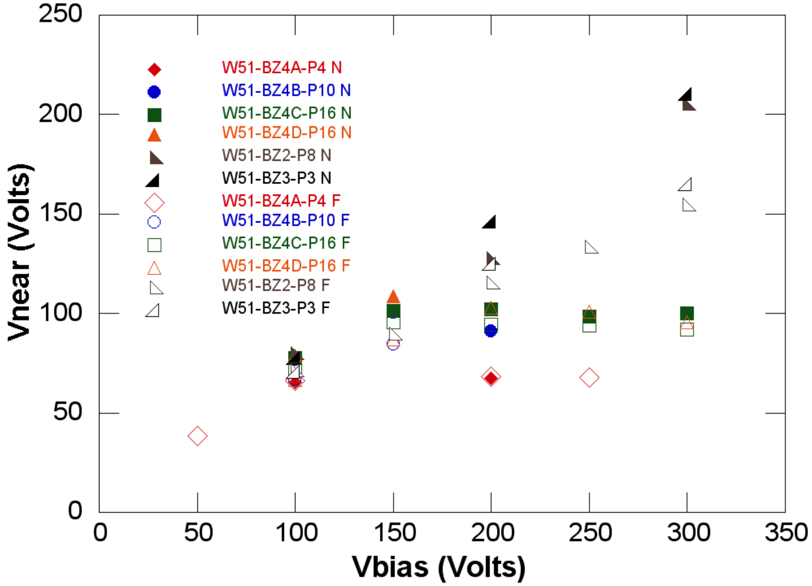
Punch-through Protection in ATLAS07

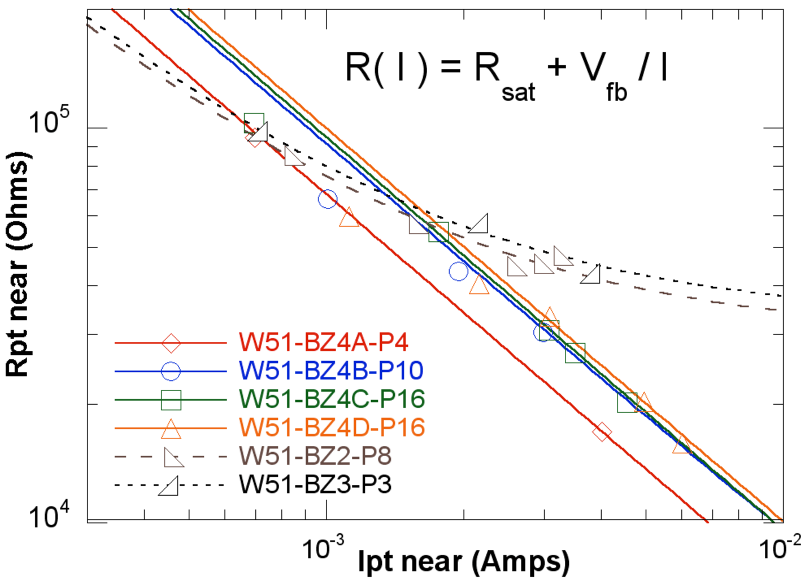
- Strip Implants susceptible to large voltages, on the order of the bias voltage during beam losses
- A layer of SiO_2 couples the implants to the AC readout strips, held to ground through the readout electronics
- This layer of SiO_2 is typically rated to about 100V, putting them it risk during beam losses
- Punch-through effect is used to "short" the implant to the grounded bias rail, in an attempt to limit these large implant voltages
- Beam loss is mimicked using IR cutting laser, and measuring resulting implant voltages
- Detector modeled as consisting of 4 resistors





Effectiveness of PTP Structures





- PTP structures "work", i.e. limit the implant voltages at a saturation voltage V_{fb}
- Using the 4-resistor model we can calculate all relevant currents and resistances from measured implant voltages
- At high currents, the punch-through resistance can be written as

$$R_{PT} = R_{sat} + \frac{V_{fb}}{I}$$

- The effectiveness of PTP at high currents can be see by writing the implant voltage

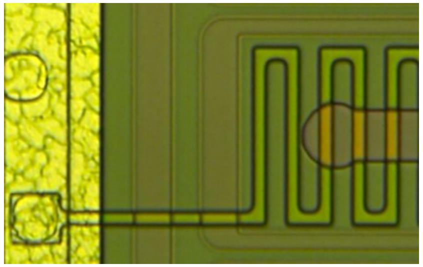
$$V = \frac{V_{bias} + \alpha V_{fb}}{1 + \alpha}$$

- Parameter $\alpha = R_{bulk}/R_{sat}$ determines if we see voltage saturation: small α => $V \sim V_{bias}$ (large R_{sat})
  large α => $V \sim V_{fb}$ (low R_{sat})

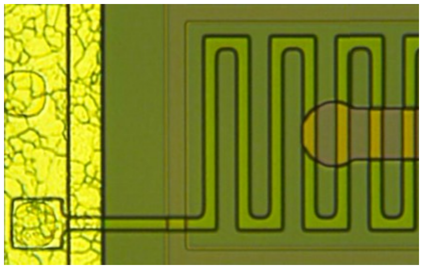
- Sensors with PTP structures show saturation of the implant voltage since α large (low R_{sat}), to further decrease V_{fb} need to decrease engineer channel.

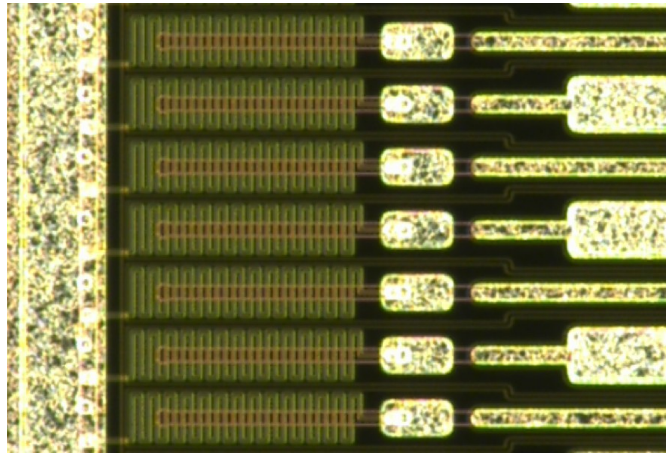
PTP and the Gate Effect

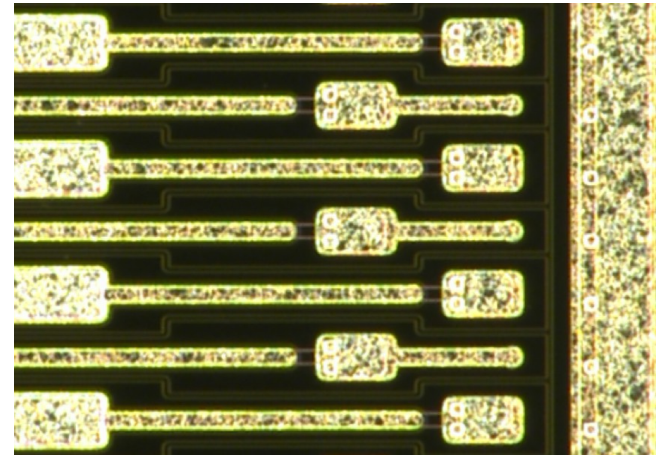
Z2

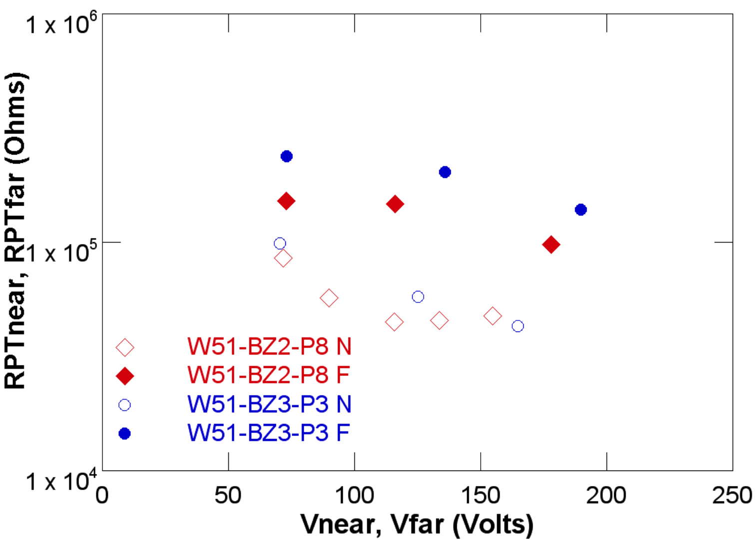


Z3





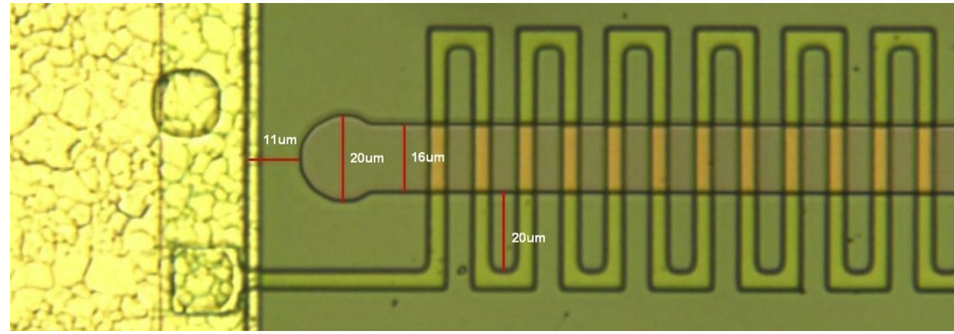


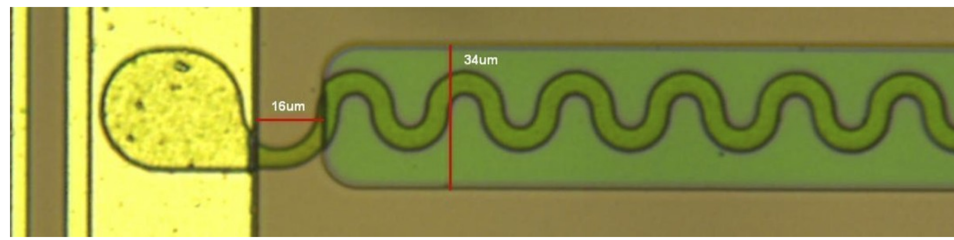


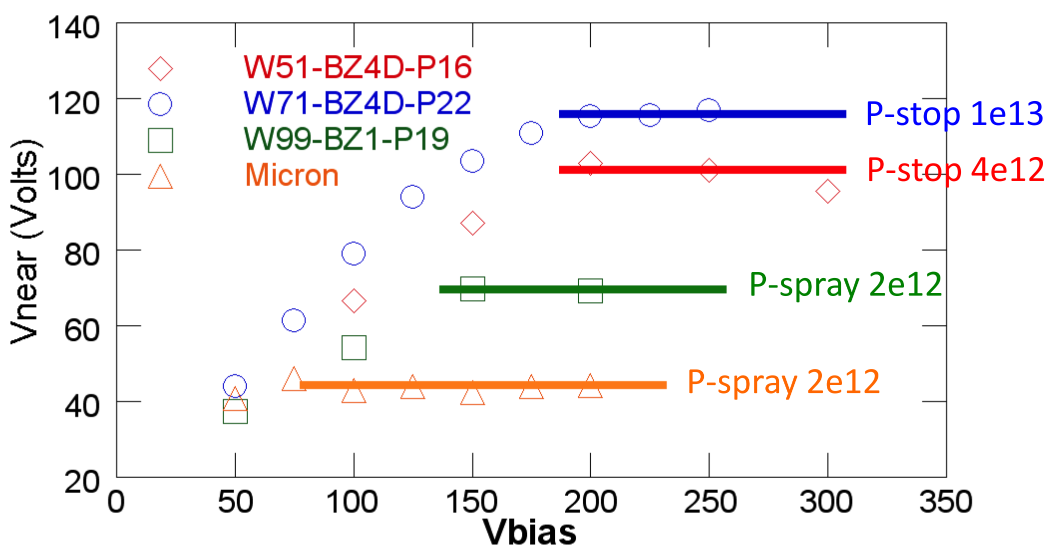
- Large difference between RPTnear and RPT far even for non-PTP structures
- The placement of the polysilicon biasing resistor significantly reduces the resistance between the implant and the bias rail.
- This is explained by the fact that the bias resistor provides a gate in 3 terminal device (implant, bias resistor, bias rail), which increases the current flow between the implant and bias rail.
- Increasing the coverage of the bias resistor over the channel length increases the effect of the gate, and hence increases the effectiveness of PTP structures.

PTP and the Gate Effect (cont'd)

- MICRON sensors have a lower V_{fb} than HPK zone 1 sensors, even though they have similar p-spray concentration and channel length
- The lower V_{fb} can be attributed to a larger gate effect due to the placement of the polysilicon bias resistor running more directly over the channel length
- By placing the biasing resistor directly over the channel length, a lower V_{fb} can be achieved

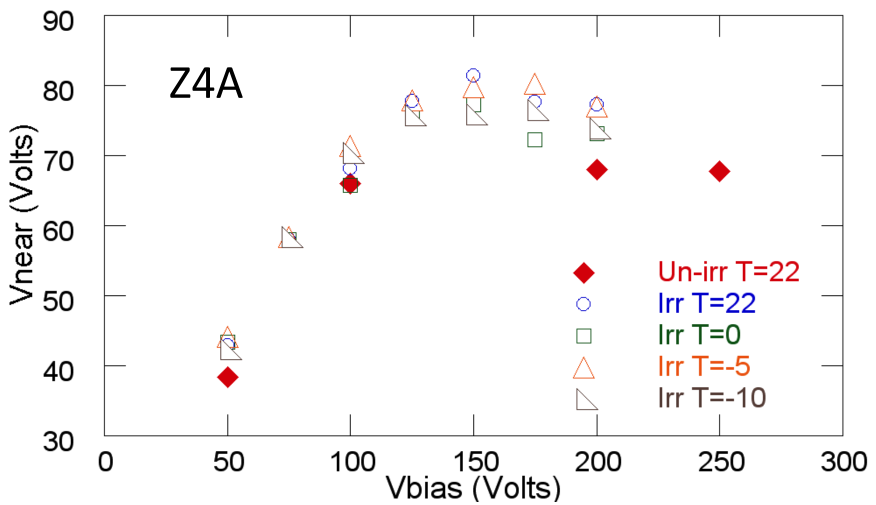


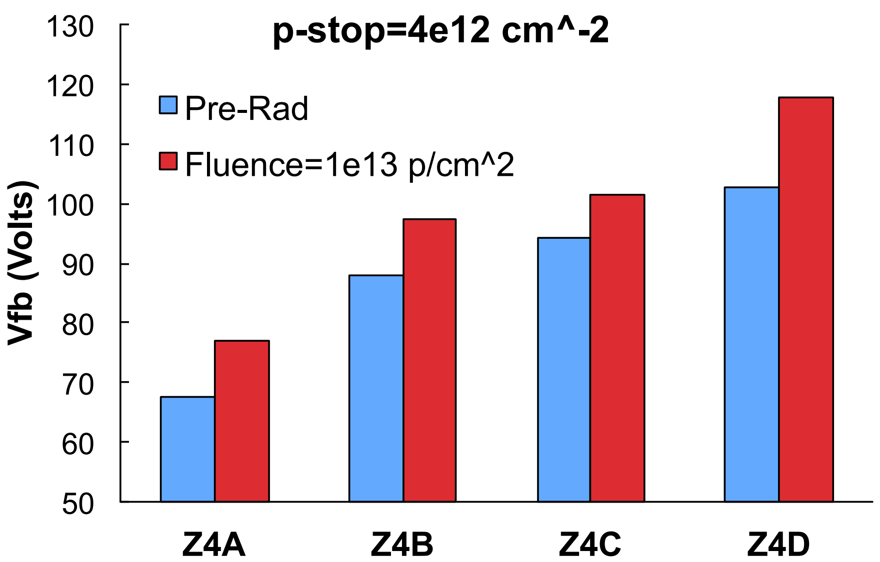


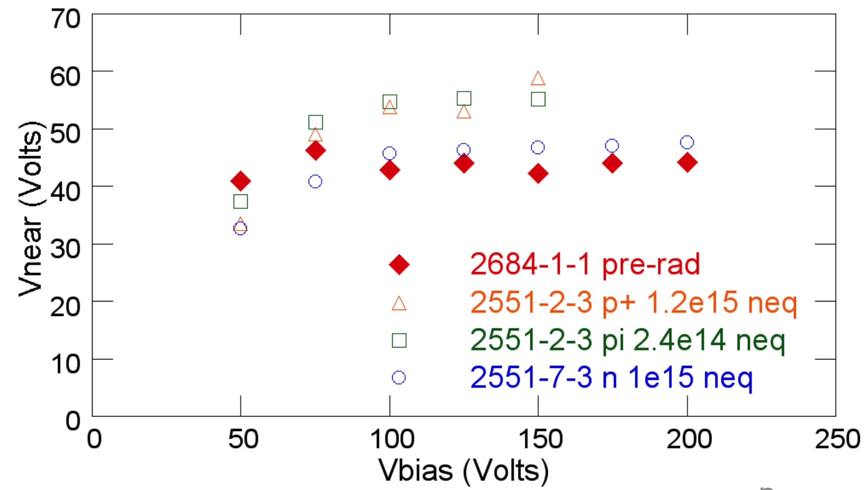


Radiation Damage and PTP

- Saturation voltage increases for all punch-through structures after irradiation with protons
- Increase in voltage already shows saturation at a relatively low proton fluence of 1e13 neq/cm^2
- Protons and pions both increase saturation voltage, while neutrons have no effect! This indicates that the origin of punch-through is from surface charge, not bulk doping density
- Punch-through protection still works even at high fluences







Status on Punch-through Protection

- Testing of Field-breakdown with an IR Laser works, DC testing of limited value
- Saturation Voltages achieved ~ 50 V
  (compare to coupling capacitor safe voltage ~100 V)
- Extraction of PT parameters: DC 4-R Model quasi-DC
- F. o. M. : Bulk Resistance / Saturation Resistance (explains large voltages on implants even when field is not completely broken down at reduced laser intensities)
- Radiation and Temperature Effects indicate surface effect
- P-Dose (spray and stop) similar
- Role of Implant Resistance: Mitigation with low-resistance strip implants?
- R-C Filter Circuit, has no effect
- Clear gate effect of biasing resistor, should be explored further