Properties of HPK UFSD after neutron irradiation up to 6e15n/cm^2

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20190718

Pre-irradiation properties of HPK UFSD

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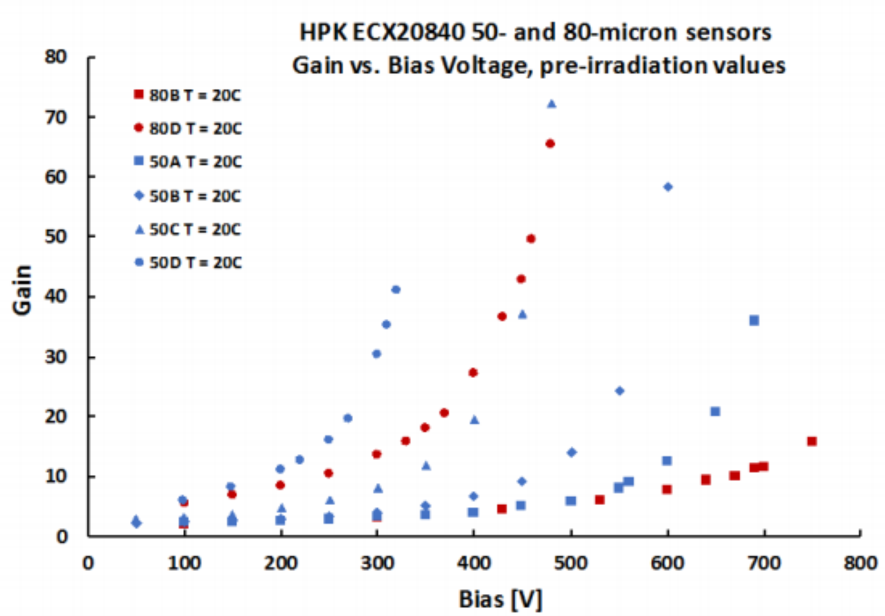


Figure 1 Gain vs. Bias voltage for the HPK 50 µm and 80 µm thick LGAD at +20 °C.

The four different sensors A-D reflect the four different doping profiles of the multiplication layer. Split D has the highest gain, and therefore the highest initial doping concentration, while split A has the lowest.

Sensors with higher initial doping concentration retained higher acceptor concentration after irradiation than those with lower initial concentration.

Neutron irradiation

The LGAD were irradiated without bias in the **TRIGA research reactor** of the Institut Jozef Stefan in Ljubljana.

The neutron spectrum and flux are well known and the fluence is quoted in 1 MeV equivalent neutrons per cm2. For each of the following fluence points **1e14, 3e14, 6e14, 1e15, 3e15 and 6e15** neq/cm2 one LGAD was irradiated.

After irradiation, the devices were **annealed for 80 min at 60C** following standard RD50 practices to account for the expected long-term annealing during operation.

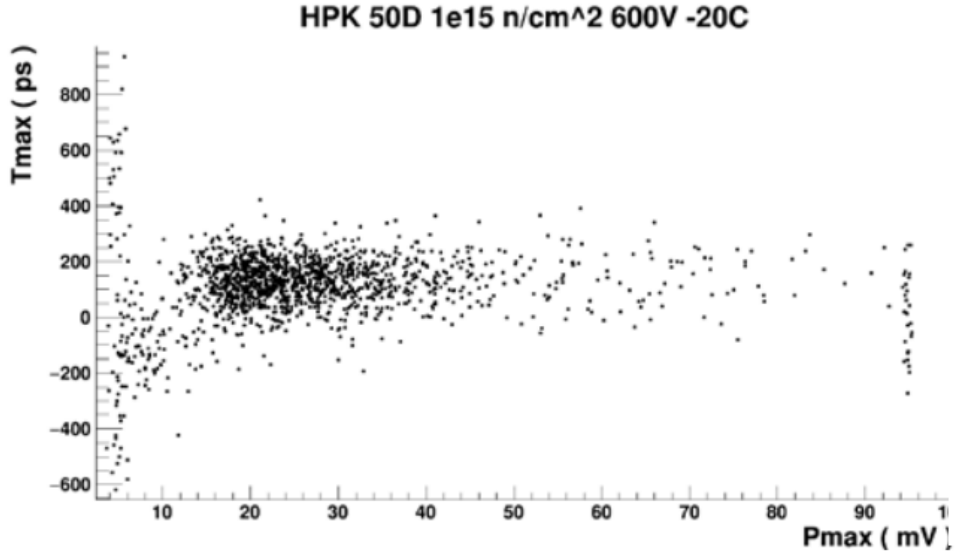
Capacitance-voltage scans were identical before and after annealing. Afterwards, the devices were kept in cold storage at -20 oC until their usage.

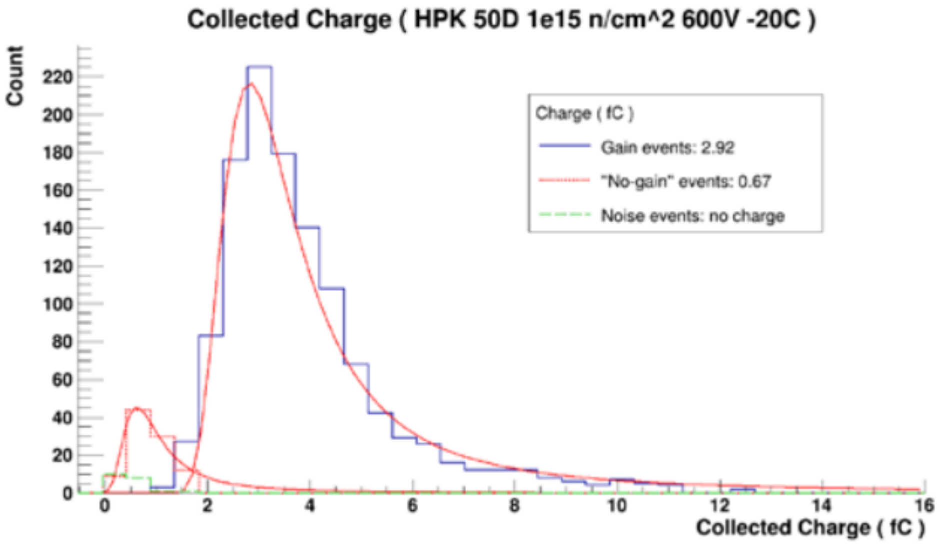
Beta source method is used to study the sensor performance.

Data analysis

CFD20

The digital oscilloscope records the full voltage waveform of both trigger and DUT in each event, so the complete event information is available for offline analysis.





Scatter plot of the time of the pulse maximum, Tmax, vs. the maximum pulse height, Pmax, (left) for the LGAD exposed to a neutron fluence of 1e15 n/cm2

The distribution of the integrated charge for the signals close in time to the trigger shows the form of a Landau distribution

Results

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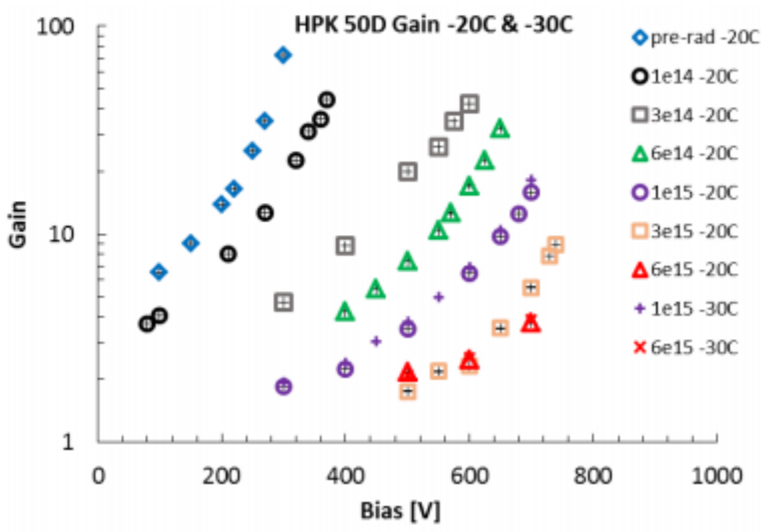
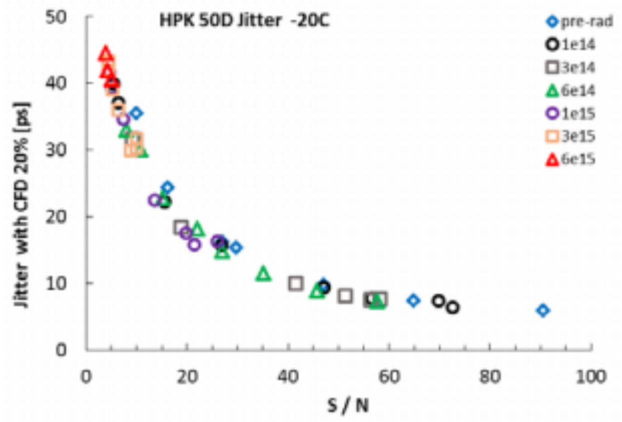


Gain as a function of bias of the HPK 50D LGAD irradiated to the indicated neutron fluences at -20C and -30C

$$\sigma_t^2 = \sigma_{Jitter}^2 + \sigma_{LandauNoise}^2 + \sigma_{Distortion}^2 + \sigma_{Timewalk}^2,$$



Jitter Noise/(dV/dt) as a function of the signal-to-noise ratio S/N

Results

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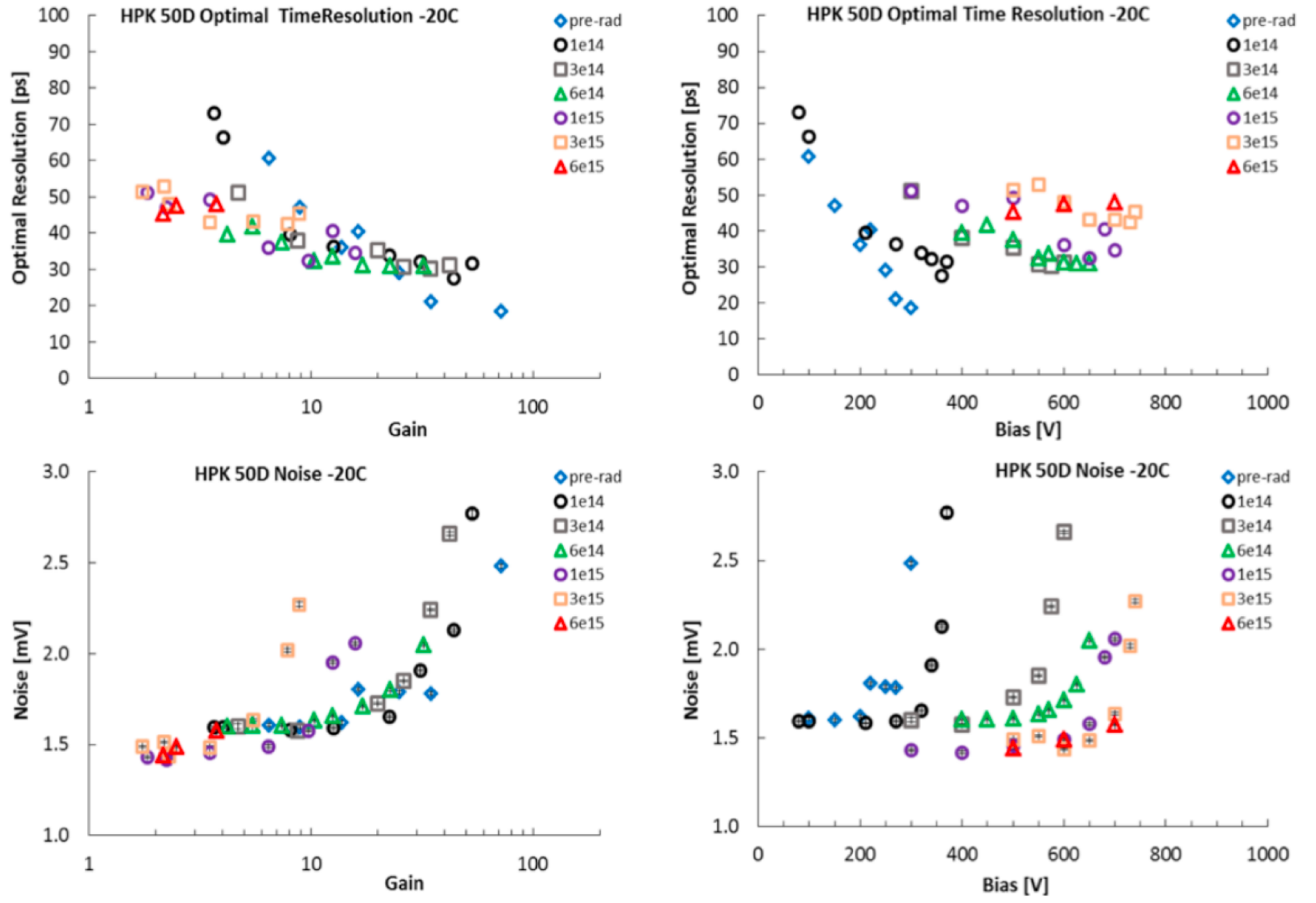

Time resolution evaluated at the optimized CFD fractions and the noise RMS vs. gain and bias for the different fluences at -20C

Results

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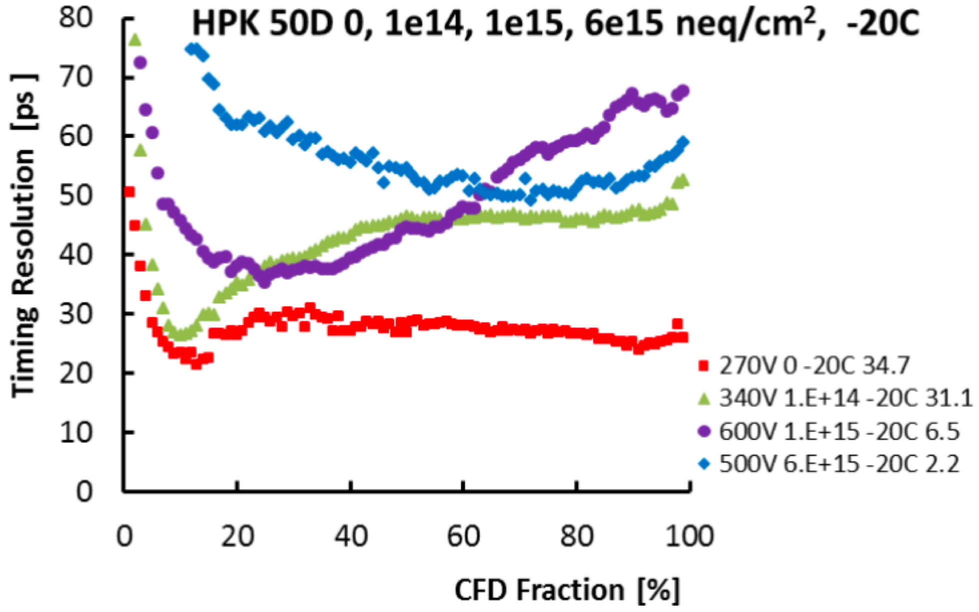

Time resolution for selected fluences as a function of CFD threshold

Results

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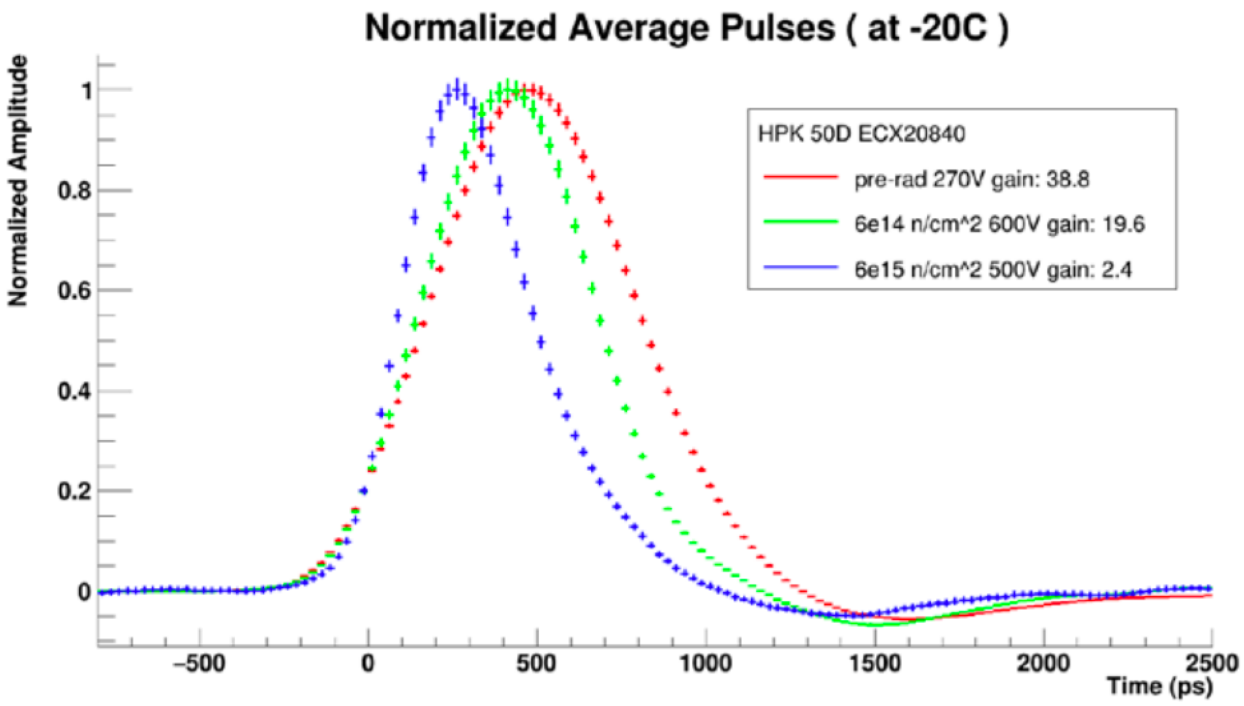

Averaged pulse shapes at three bias voltages pre-irradiation, and after fluences of 6e14 and 6e15 n/cm2.

Results

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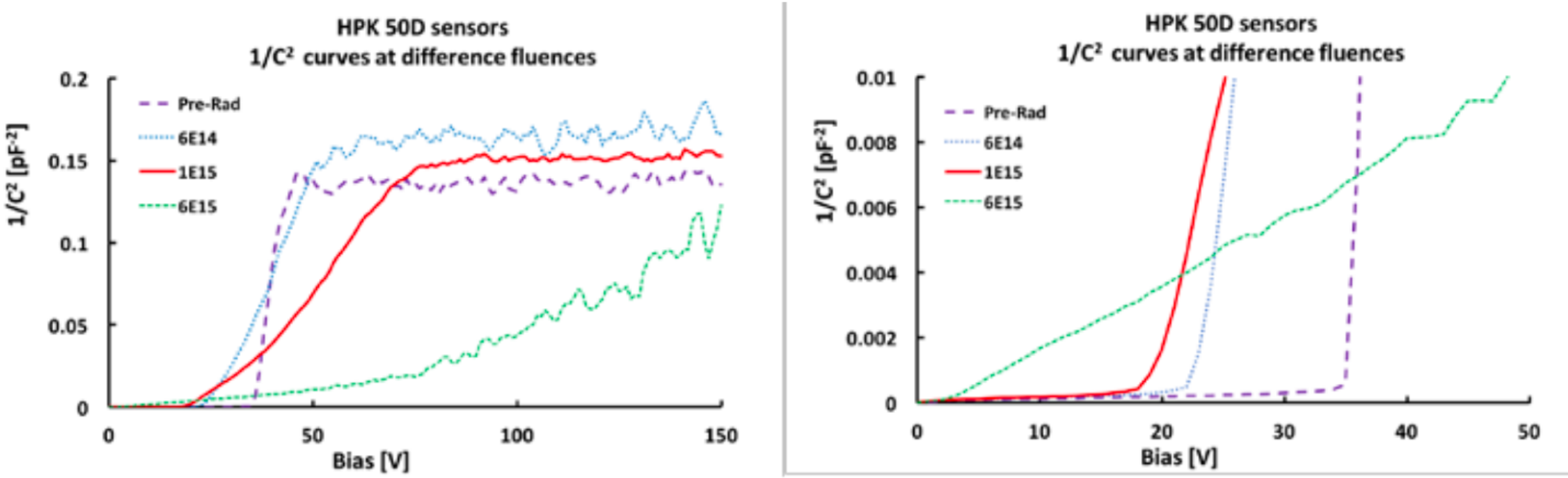

Bias scans of 1/C2for four fluences (zoomed on the right plot). The bias voltages lag ("foot") and the slope of the curves change with fluence, indicating both acceptor removal in the multiplication layer and acceptor creation in the bulk.

Results

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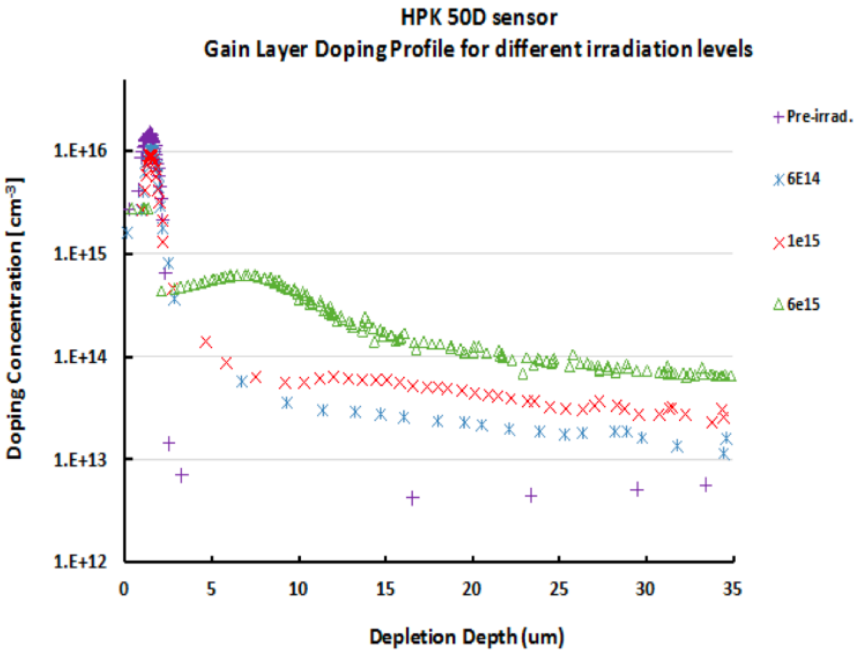

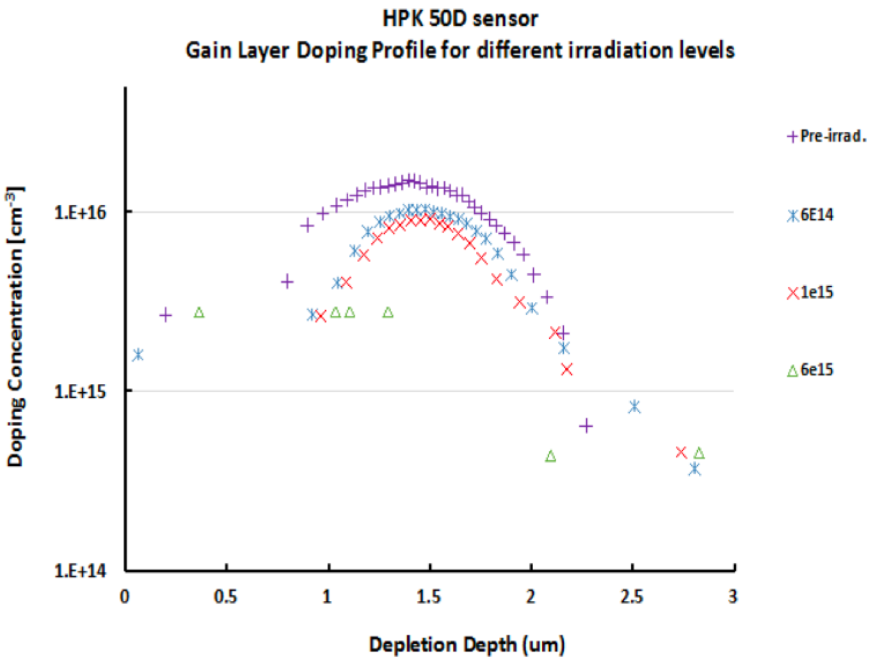

Extracted doping profile for four fluences. As explained in the text, the curves are obtained starting from the measured1/C2vs. bias plots.

Xin

- The paper concludes with:

- For a CFD fraction optimized for each fluence and bias, the time resolution increases from 20 ps pre- irradiation to 40 ps after 1e15 n/cm2 to 50 ps for 6e15 n/cm2.

- Could you explain the relation between the CFD and fluence? Shouldn’ t the time resolution comparison for different fluence done with same CFD value?

---- As long as we can distinguish 2 events, I think the CFD value doesn’t need to be fixed at a certain value(just my personal understanding).

Yuzhen

- In 3 NEUTRON IRRADIATION, second passage:

- After irradiation, the devices were annealed for 80 min at 60C following standard RD50 practices to account for the expected long-term annealing during operation. Capacitance-voltage scans were identical before and after annealing. Afterwards, the devices were kept in cold storage at -20C until their usage.

- My question: Does that mean to test the sensor performance after irradiation, the sensor need to be annealed firstly?

Ryuta

- Q. in the section 6.6 (page 15), the change of pulse rise time due to irradiation is explained such as (i)-(iii).

- Is this change also confirmed (but, I do not know that the same comparison can be done or not) from the recent test-beam analysis ?