Measurements of LGAD

3rd. CiRfSE Workshop

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Talk Outline

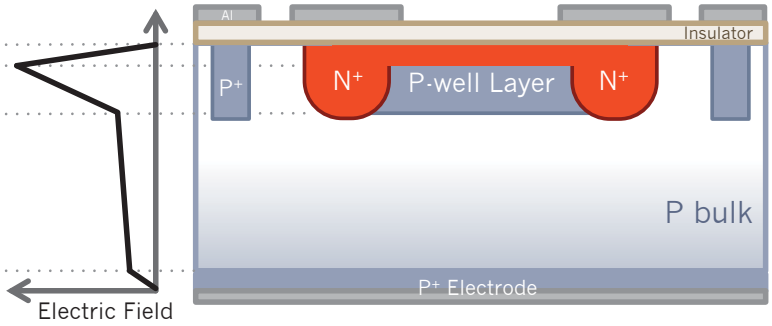
- Brief Introduction of LGAD
- IV Measurements (Pixel)
  - Setup description / Samples
  - Wavelength Dependence of IV (Strip CV)
  - Temperature Dependence of IV
- IV After Irradiation (Pixel)
  - γ-ray
  - Neutron

Low Gain Avalanche Detector

- N^+-on-P ⋙ N^+-P^+-P^--P^+
- Uniform high electric field

  @ N^+-P^+-junction (Thin multiplication layer) ⋙ Avalanche

  ⋙ Good time resolution (~50ps)

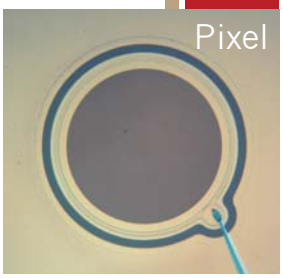


- Low Gain (~10)

  ⋙ Optimum S/N

  ⋙ Thinner detector possible

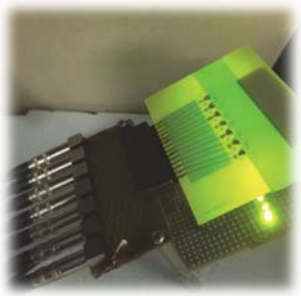
Samples from HPK



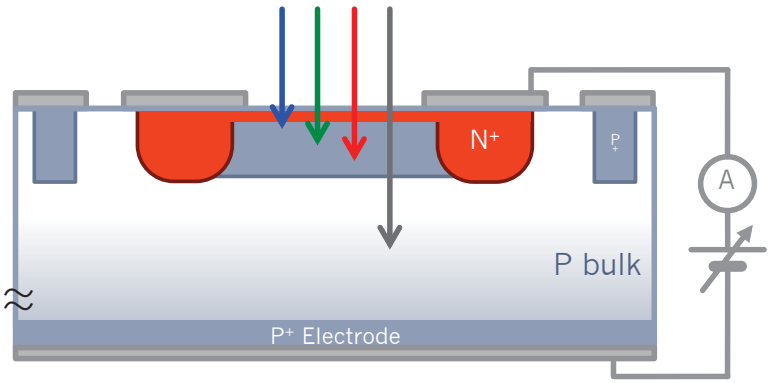
- Strip (chip size 6mm×12mm, strip 80 μm pitch)
- Pixel (chip size 2.5mm×2.5mm, window 1mmϕ)

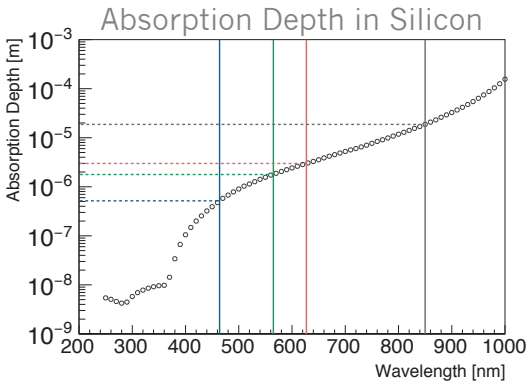
Wafer No.	Dose Gradations	Physical Thickness (μm)	Active Thickness (μm)	Sample Name
W02	A	150	50 (3~8kΩcm)	50A
W04(05)	B			50B
W07(08)	C			50C
W10(11)	D			50D
W13(14)	A		80 (1kΩcm)	80A
W16(17)	B			80B
W19(20)	C			80C
W22(23)	D			80D

IV Measurements ~ Setup



- Leakage
- LED Light Response
  - Blue (λ =464nm, D=0.5 μm)
  - Green (λ =565nm, D=2 μm)
  - Red (λ =627nm, D=3 μm)
  - Infra-red (λ =850nm, D=20 μm)

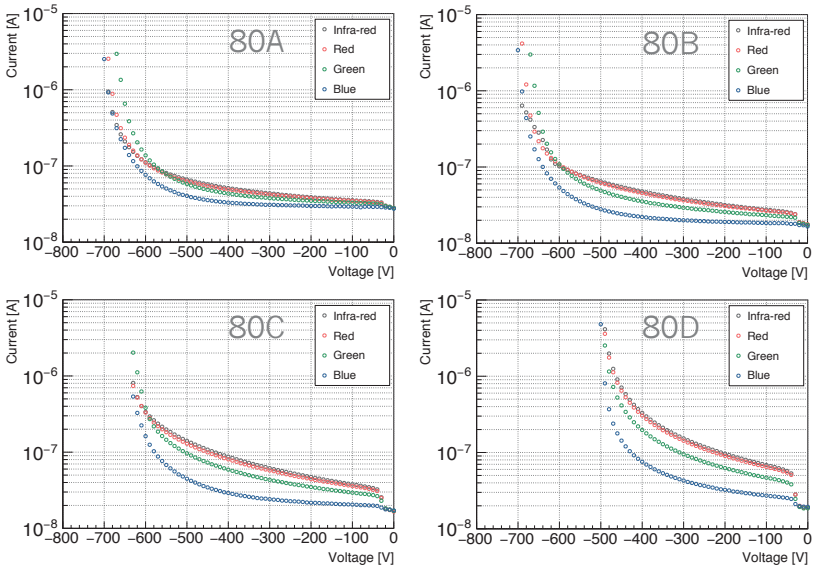




Wavelength Dep. of IV (0~700V)

Pixel (active thickness 80 μm)

@ 20℃



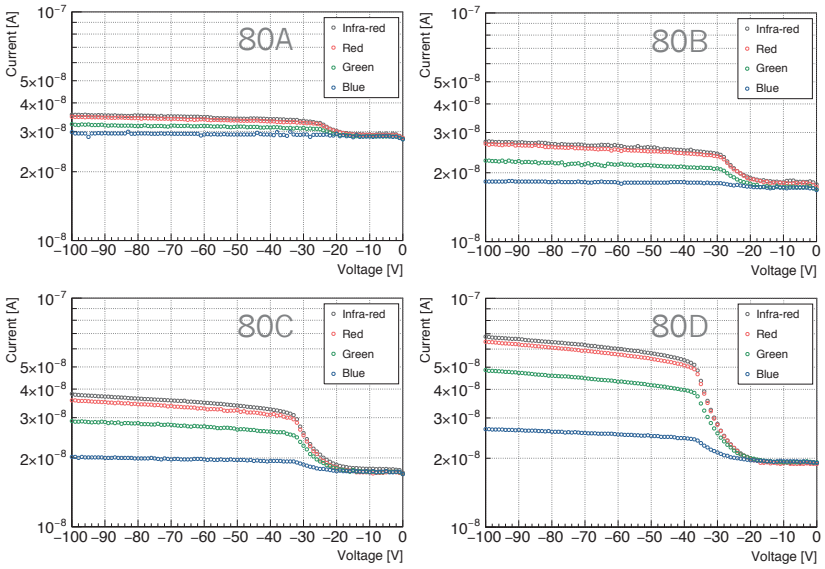
Dose : A < B < C < D

- Curves normalized @ 10V (Gain~1)
- Gain
  - Longer wavelength, higher gain
  - Jumps @ ~30V
- Breakdown Voltage
  - No Wavelength dep.

Wavelength Dep. of IV (0~100V)

Pixel (active thickness 80 μm)

@ 20℃

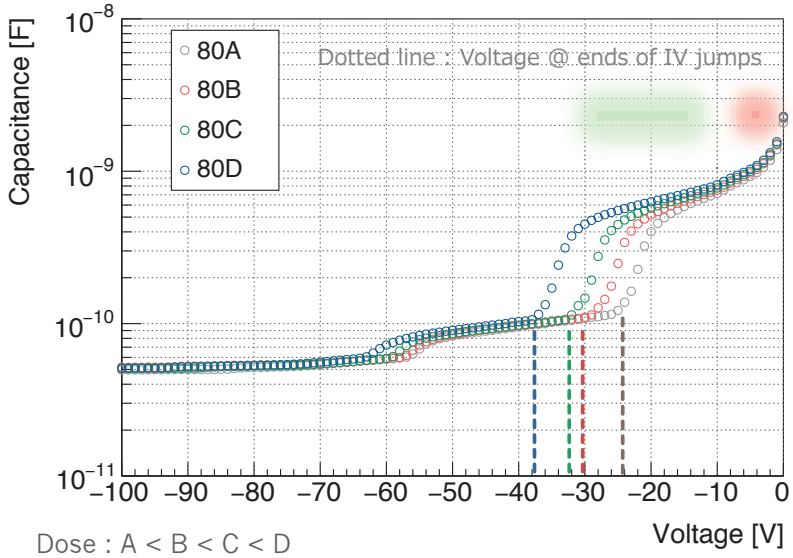


Dose : A < B < C < D

- Curves normalized @ 10V (Gain~1)
- More dose & Longer wavelength, Higher gain
- More dose, Higher voltage @ ends of jumps

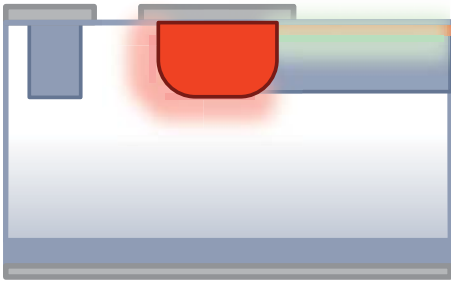
P^+ Dose Dependence of CV

Strip 80 μm @ 1500Hz



Dose : A < B < C < D

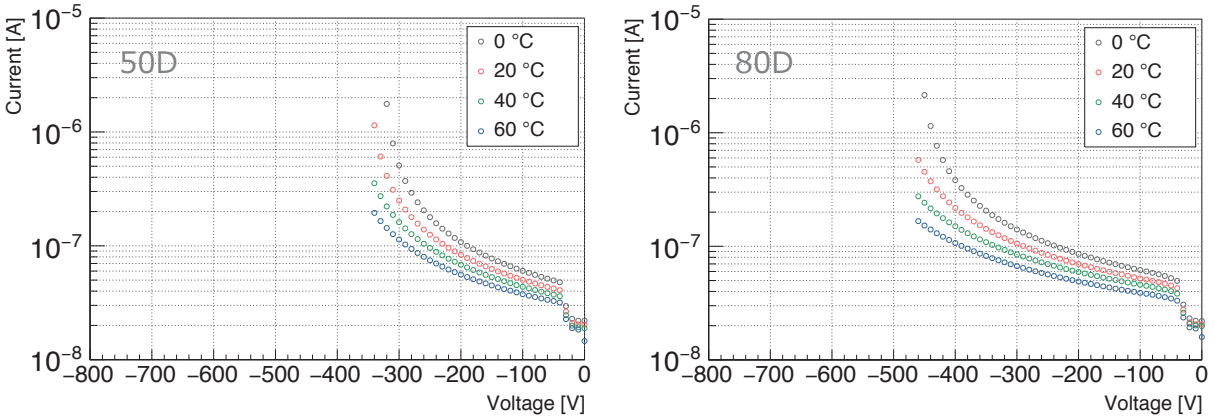
- Depletion voltage
  - in agreement with IV
  - 1st. Depletion
    - Electrode side way
  - 2nd. Depletion
    - Multiplication layer
  - 3rd. Depletion
    - Bulk's depletion



Temperature Dependence of IV

Pixel 50 μm & 80 μm

@ 20℃

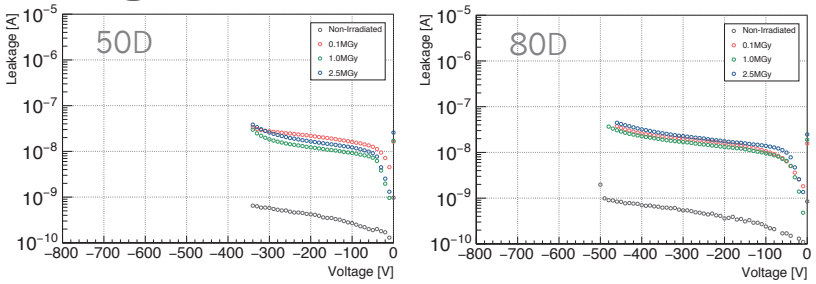


- Green LED Light Response
  - Lower temp., larger current ⋙ Avalanche

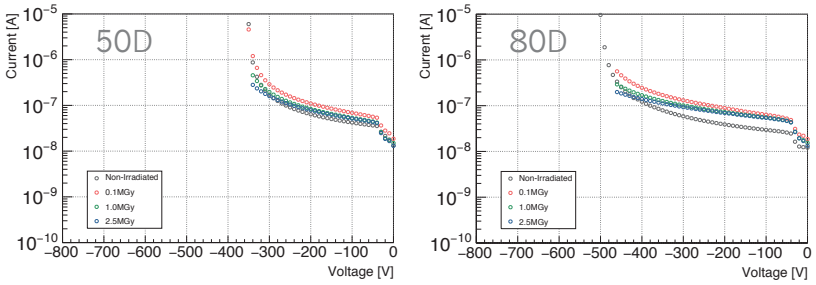
IV After γ-ray Irradiation

@ 20℃

Leakage



Green Light Response



TARRI(QST), Japan

24 Nov. - 20 Dec. 2016

- 0.1MGy
- 1.0MGy
- 2.5MGy

- Leakage increase
  - no dose independence

because of surface damage

- Green LED response not changed

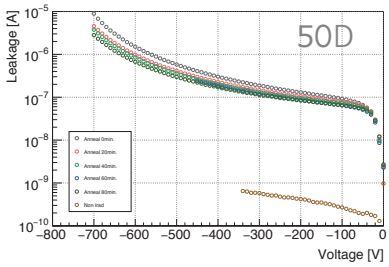
⋙ Gain retain

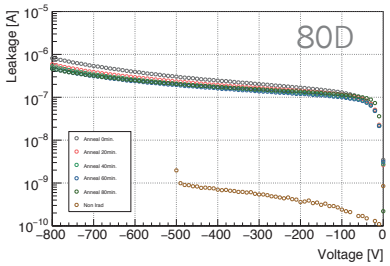
IV Annealing After Neutron Irradiation

$1.0\times10^{15}n_{eq}/cm^2$

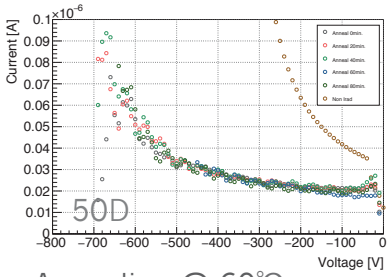
@ −20℃

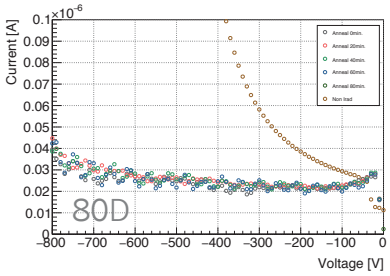
Leakage





Green Light Response





Annealing @ 60℃

Ljubljana, Slovenia

15 Dec. 2016

- $0.3\times10^{15}n_{eq}/cm^2$
- $1.0\times10^{15}n_{eq}/cm^2$ ⟪
- $3.0\times10^{15}n_{eq}/cm^2$

- Leakage increase
- Gain retain
  - appear @ higher voltage
  - e.g. 50D (280V→700V)

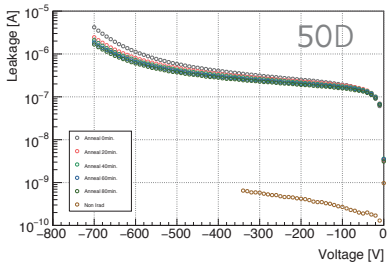
Gain ~5

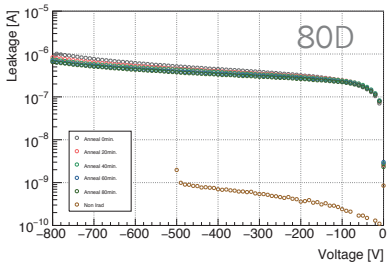
IV Annealing After Neutron Irradiation

$3.0\times10^{15}n_{eq}/cm^2$

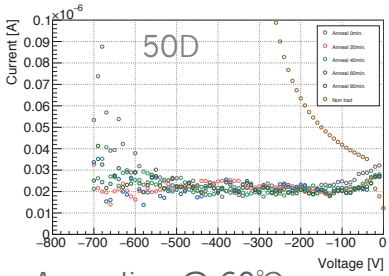
@ −20℃

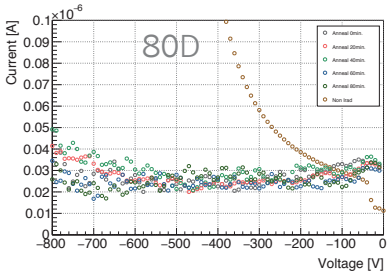
Leakage





Green Light Response





Annealing @ 60℃

Ljubljana, Slovenia

15 Dec. 2016

- $0.3\times10^{15}n_{eq}/cm^2$
- $1.0\times10^{15}n_{eq}/cm^2$
- $3.0\times10^{15}n_{eq}/cm^2$ ⟪

- Leakage increase
- Gain disappear? (< 800V)

Conclusions / Future Work

- Understood the structure of LGAD from HPK
- Gain retain after γ-ray irradiation (2.5MGy)
- After neutron irradiation, ($1.0\times10^{15}n_{eq}/cm^2$) gain retain

  ($3.0\times10^{15}n_{eq}/cm^2$) gain disappear (< 800V)

- Measure Laser & β-ray Response
- Proton Irradiation (Feb. 2017 @ CYRIC)