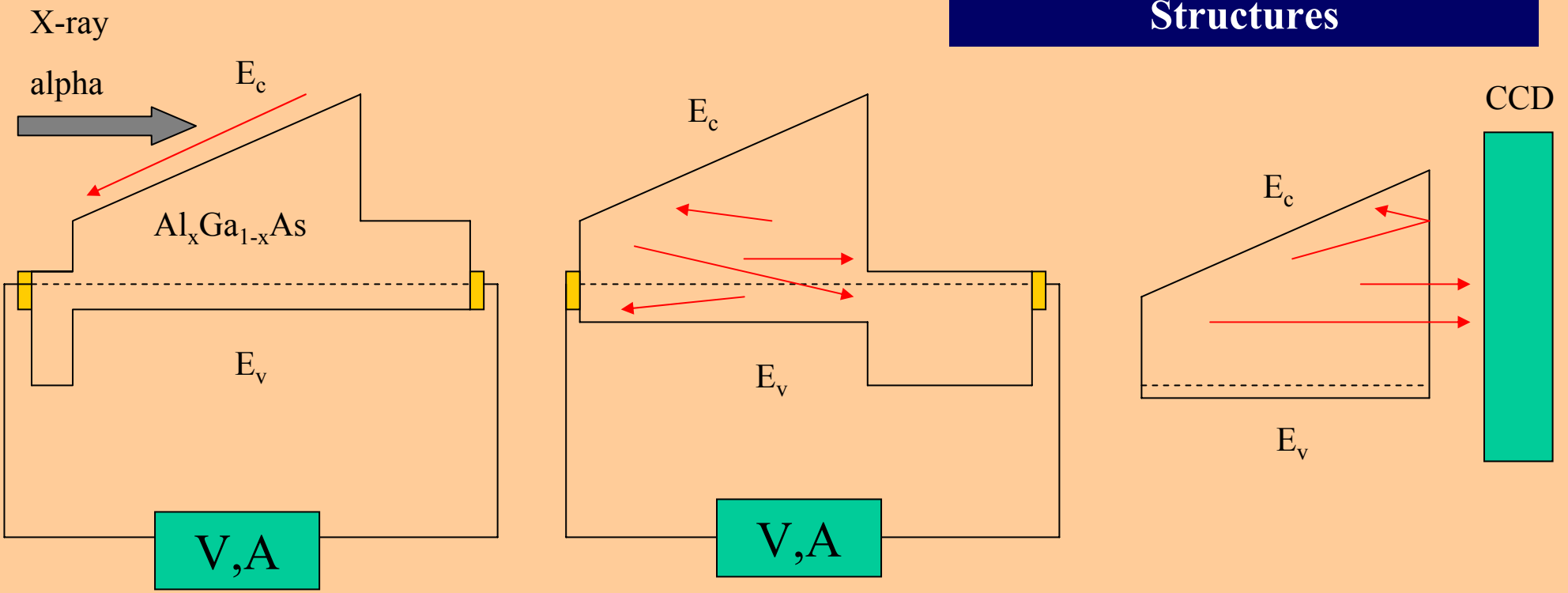
Radiation hardness of graded-gap AlGaAs X-ray detectors

A. Silenas, L. Dapkus, K. Pozela, J. Pozela, V. Juciene, V. Jasutis

Semiconductor Physics Institute, Gostauto 11, Vilnius 01108, Lithuania

Structures



$$\beta = \frac{\tau_{rec}}{t_{dr}}$$

$$\eta = \frac{1}{1 + \tau_r / \tau_{nr}}$$

$$\tau_{rec} = \tau_r + \tau_{nr}$$

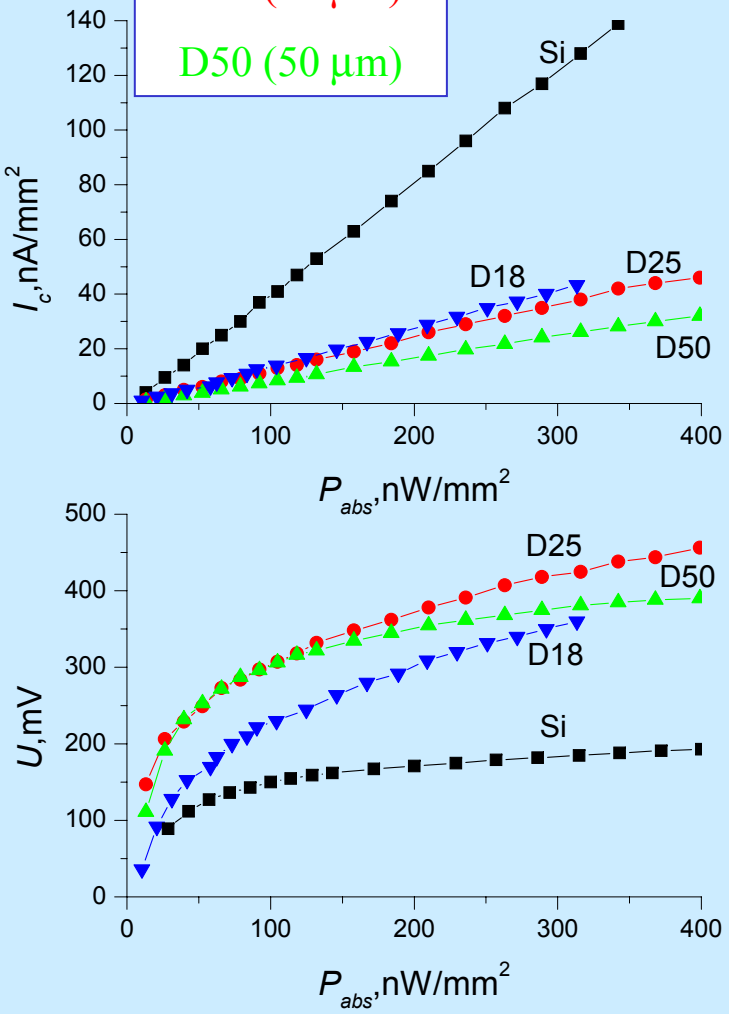
$$\eta_{ef} = \frac{1}{2}\eta\left(1 + \frac{1}{2}\eta + \frac{1}{4}\eta^2 + \ldots\right)$$

Current and voltage response

D18 (18μm)

D25 (25 μm)

D50 (50 μm)



$$I_{ph} = \frac{P_{abs}}{E_{th}}\eta_{ef}$$

$$I_{\max} = 0.25 P_{abs}$$

D18, D25

$\beta_I \approx 0{,}13$ A/W $\eta_{ef} \approx 0{,}52$

D50

$\beta_I \approx 0{,}07$A/W $\eta_{ef} \approx 0{,}27$

β_I - current sensitivity

η_{ef} - quantum efficiency

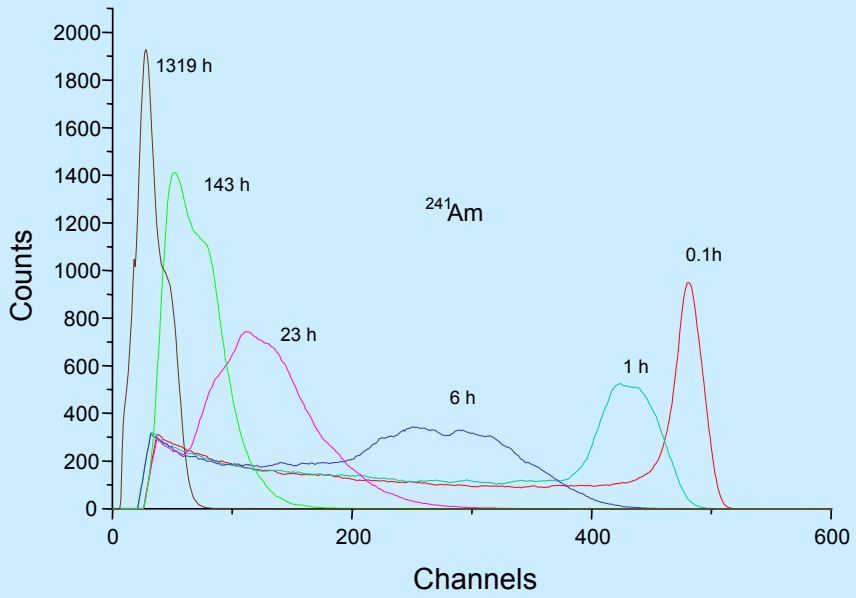
$$U = \frac{kT}{q}\ln\frac{I_s + I_{ph}}{I_s}$$

$\beta_v > 10^6$ V/W

$P_{abs} = 50$ nW/mm^2

Cu anode E = 8keV

Alpha particle spectrum



^{241}Am E = 5.48MeV

1h→10^8 particles/cm^2

$$\frac{a_\alpha}{a_0} = \frac{\tau_{rec}}{t_{dr}}\left[1 - \exp\left(-t_{dr}/\tau_{rec}\right)\right]$$

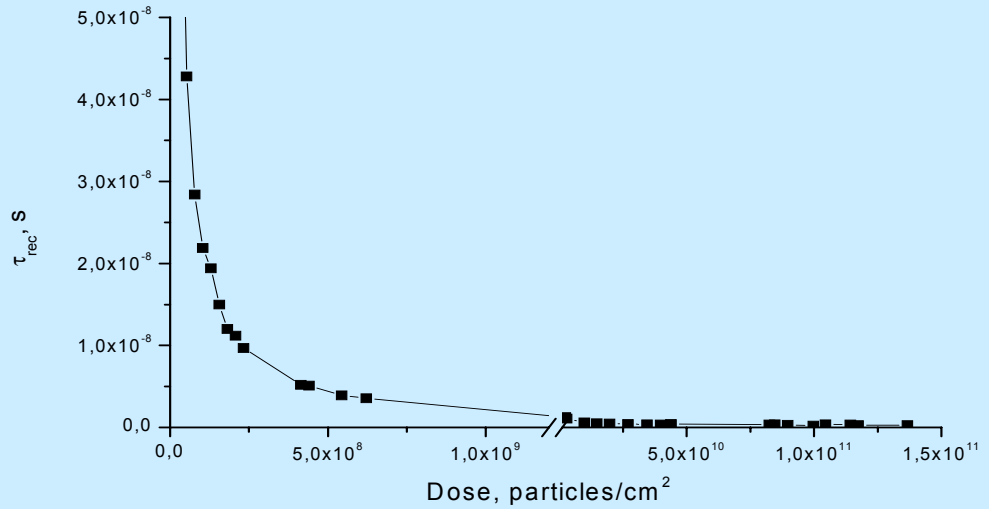
l = 25μm,

E = 120 V/cm, $t_{dr} \approx 5$ns if $\tau_{rec} = 10^{-8}$s

CCE→100%

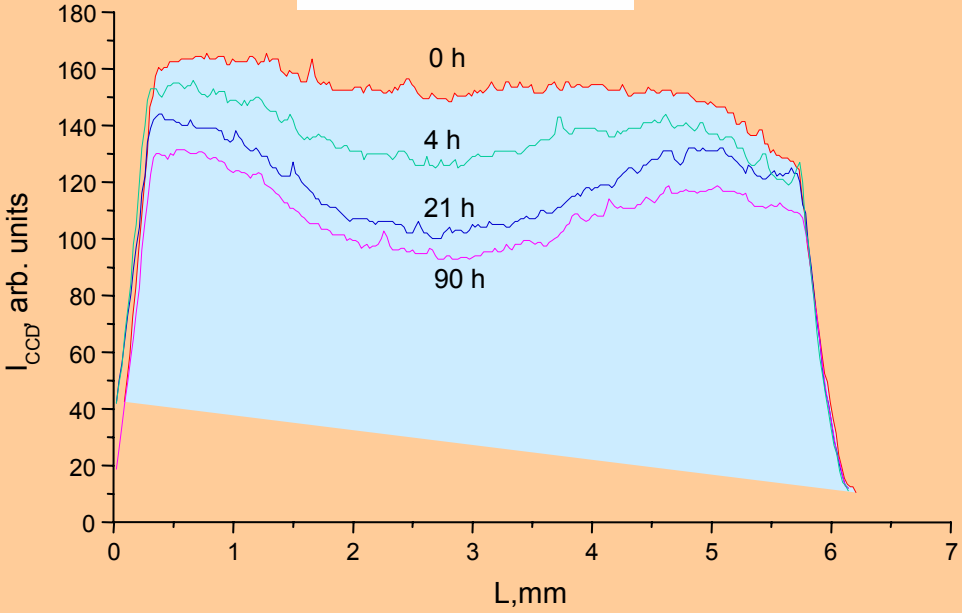
Decrease of current response about an order

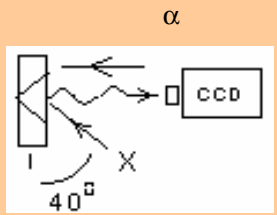
Confirmed by 8 keV X-ray measurement

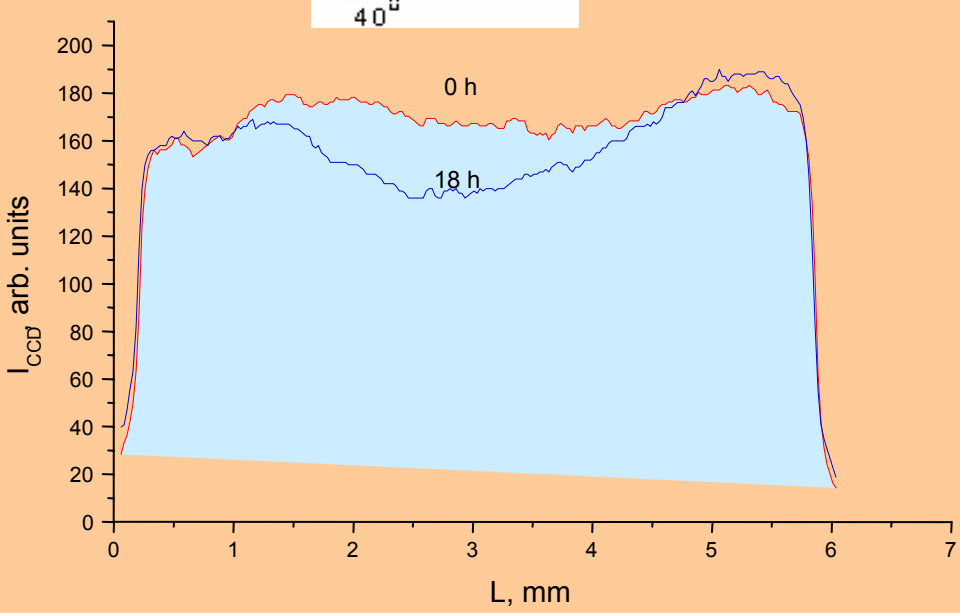


Optical response

$S = 5 \times 6\ mm^2$



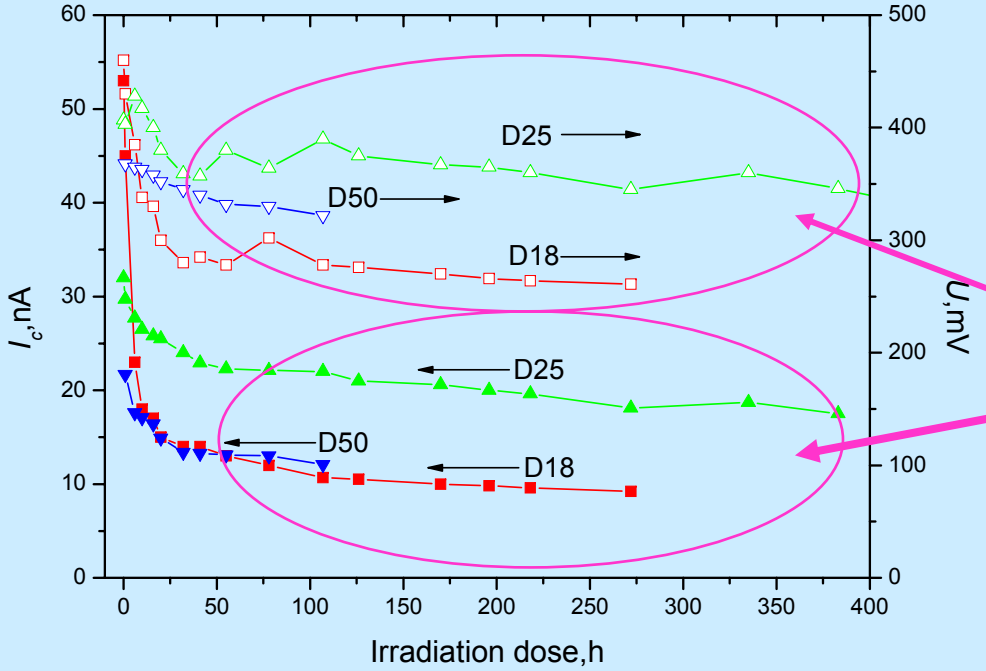




Decrease of optical response about 1.5 times

Defects generated by alpha particles are not only non-radiative but also radiative recombination centers

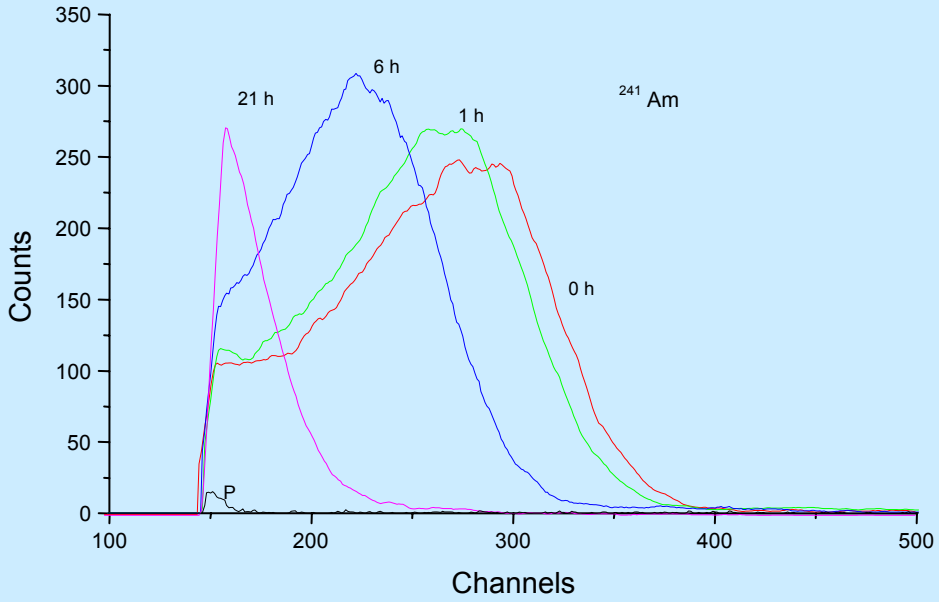
Internal optical response



Response remains nearly constant when irradiation dose larger than $5*10^9$ particles/cm^2

The decrease of response at small irradiation dose is less significant for thick samples (D25 and D50) when penetration depth of alpha particle is less than distance to p-n junction.

Penetration depth of alpha particle in GaAs is about 20 μm



Conclusions

Decrease of current response under alpha particle irradiation (about an order at irradiation dose 10^{10} particles/cm^2) is caused by growth of recombination rate.

The much better alpha particle irradiation hardness (decrease of detector sensitivity about 1.5 times at irradiation dose $5*10^9$ particles/cm^2) is obtained for detectors with optical response.

The internal quantum efficiency of the X-ray conversation to light remains almost constant because the increase of the non-radiative recombination rate is compensated by increase of radiative recombination rate.

The best alpha particle irradiation hardness is obtained for detectors made on base of structure *p*-$Al_xGa_{1-x}As$ – *n*-GaAs with p-n junction in the wide gap side, when thickness of graded-gap $Al_xGa_{1-x}As$ layer is larger than alpha particle penetration length.

Increase of radiative recombination rate have to determine high operating speed .

This work was supported by

Lithuanian State Science and Studies foundation