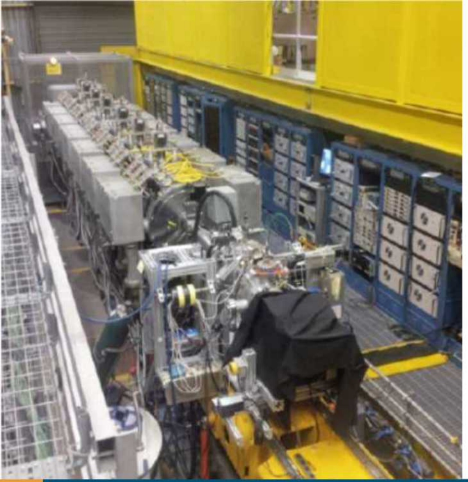

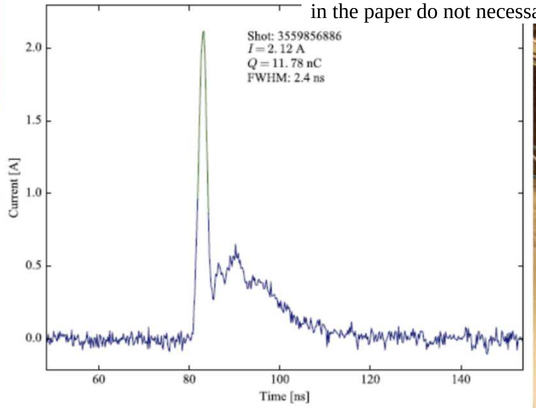

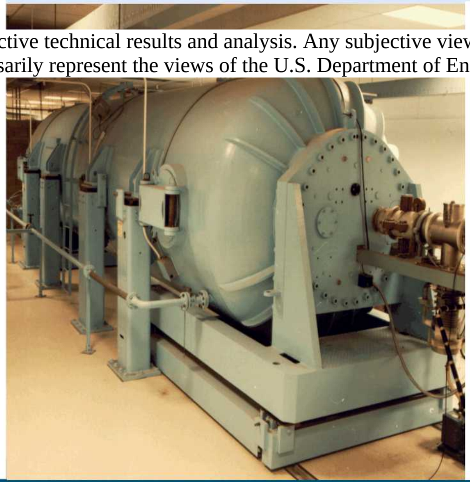

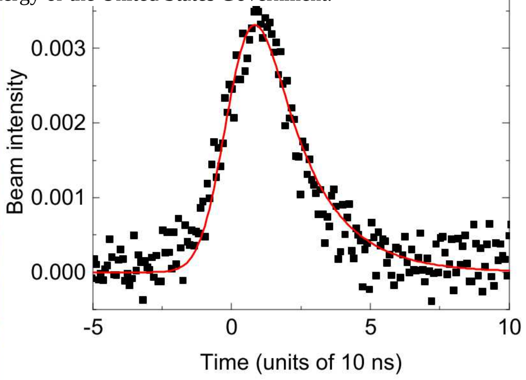

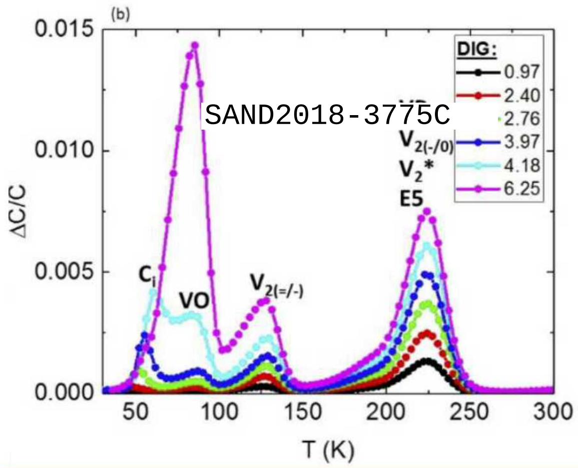

SAND2018-3775C

Comparison of High and Low Flux He Exposures on the Gain Degradation and Defect Spectra in Si pnp BJTs

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Sandia National Labs[1], Lawrence Berkeley National Labs[2]

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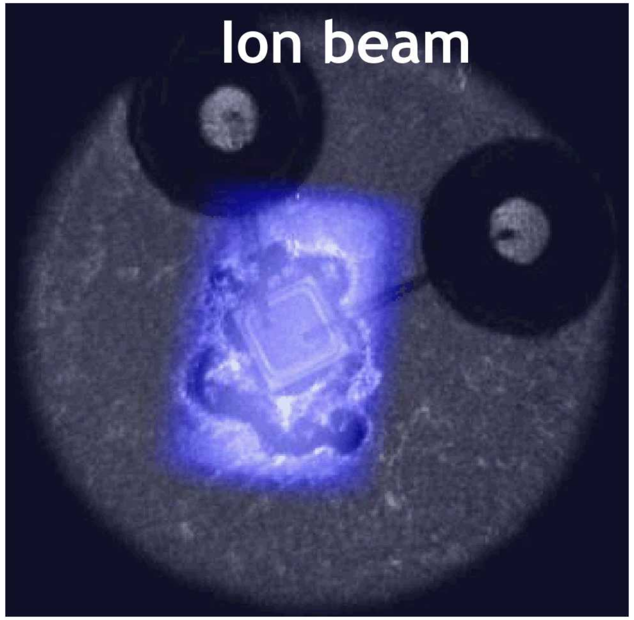
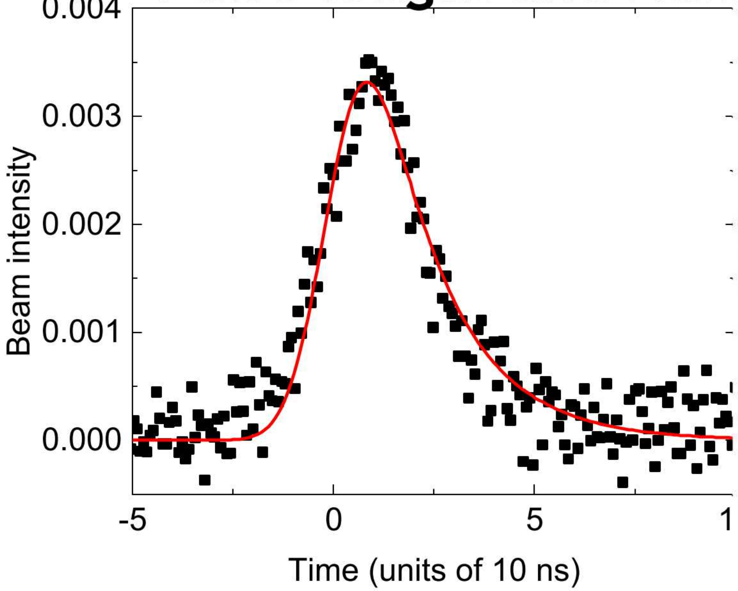
HEART conference, April 20th 2018, Tucson, AZ

Outline

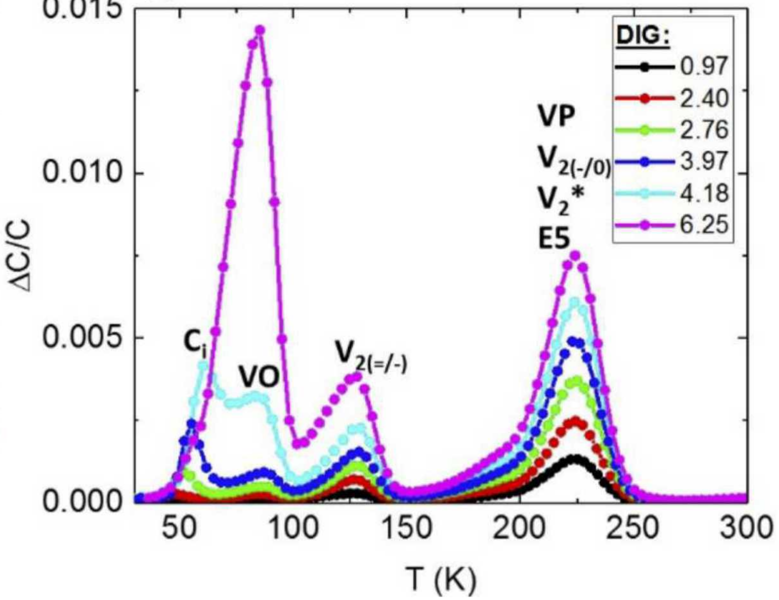
- Introduction
- Ion irradiations
- Pulse length and flux effects
- DLTS
- Summary



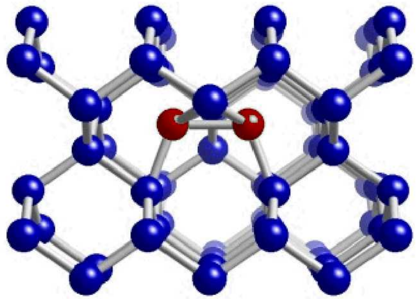
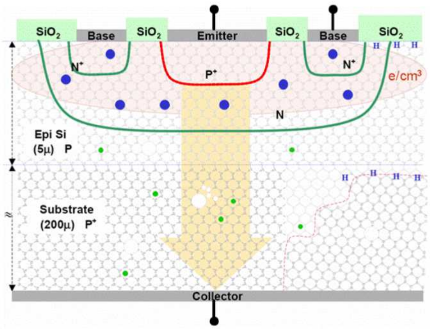
Pulse length and flux



DLTS



Introduction – Ion irradiations

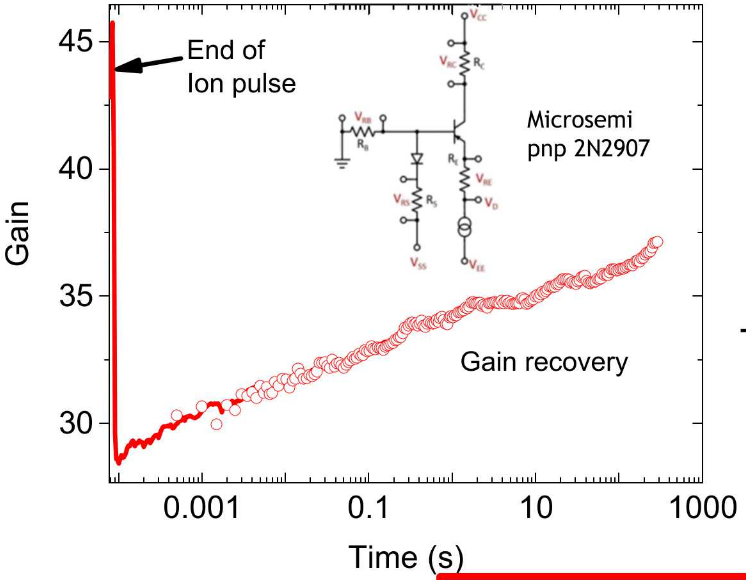
Fundamental Radiation Induced Defects

Of particular interest is early-time (<1s) gain degradation

Degradation of Device/Circuit Performance

Use ion irradiations to simulate fast neutron displacement damage

Early-time gain



- Ion to neutron damage equivalency

Messenger-Spratt (MS) equation

$$DIG = \left(\Delta\frac{1}{G}\right) = \frac{1}{G_{300\,s}} - \frac{1}{G_0} = k\Phi$$

$G_{300\,s}$ = Final gain

G_0 = Initial gain

k= Damage factor

Φ = Fluence

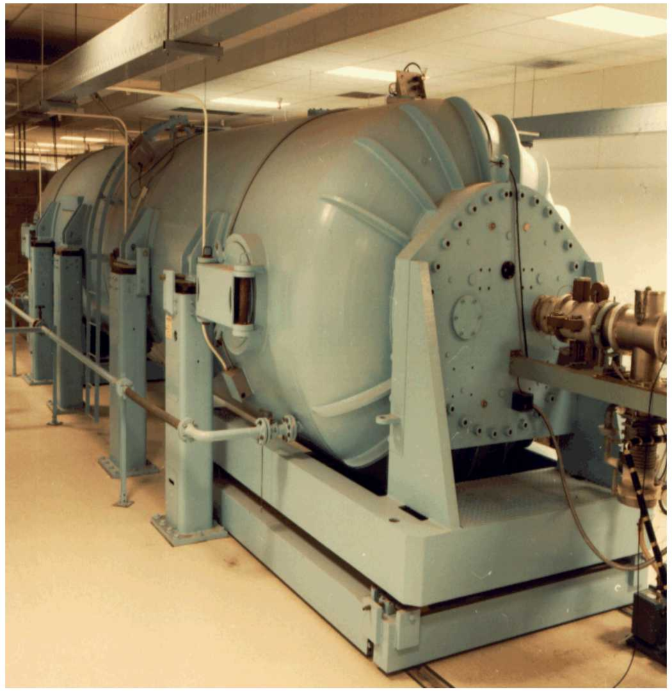
- Match late time gain degradation

$$k_{ion}\Phi_{ion} = k_n\Phi_n \rightarrow \Phi_{ion} = \frac{k_n\Phi_n}{k_{ion}}$$

Ion to neutron damage equivalency using $\frac{k_n}{k_{ion}}$

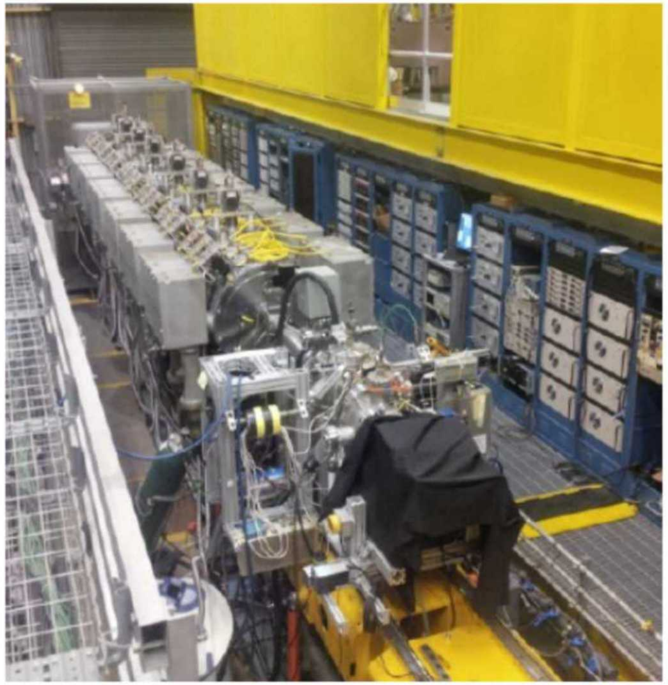
Ion irradiations

Tandem accelerator – IBL/SNL



- Pulse length <20 ns (short) – 100 us (long)
- Ion Flux ~2×10^{14} ions/cm^2/s

NDCX-II – LBNL

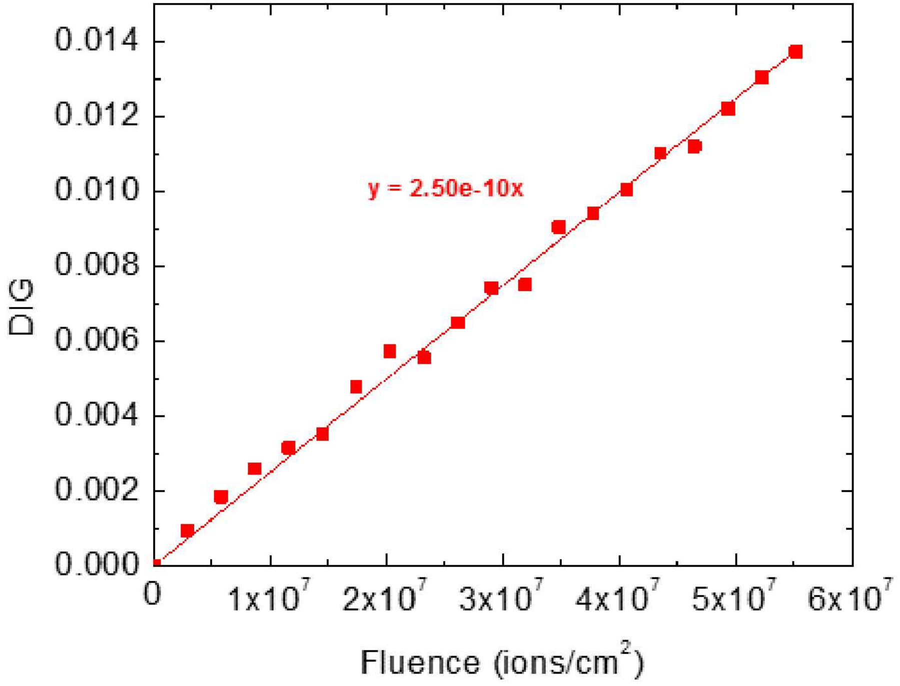


- Pulse length <10 ns
- Ion Flux ~1.5×10^{19} ions/cm^2/s

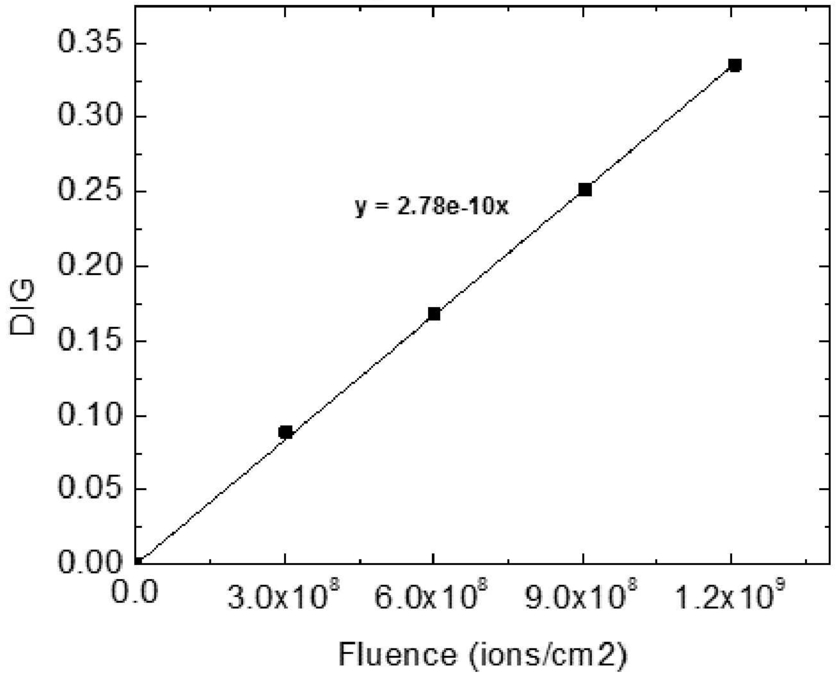
Effect of Ion Pulse Length

4.25 MeV Si (EOR) Irradiation on the Tandem using both short and long pulses

Short Pulse Tandem



Long Pulse Tandem



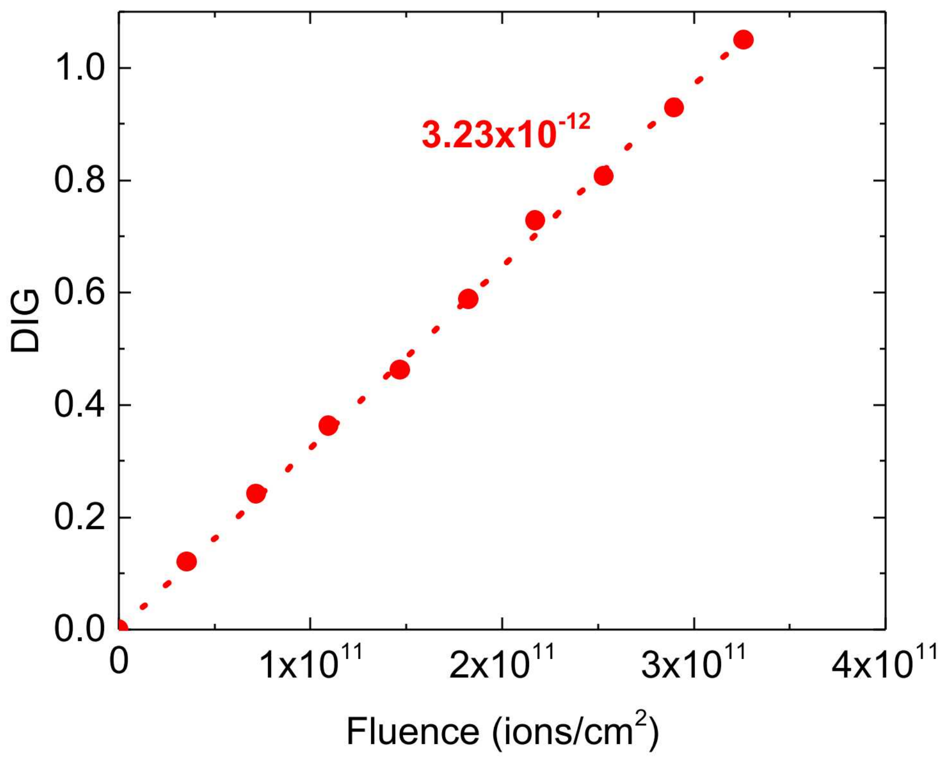
Pulse length <20 ns (short)
Ion Flux ~$2x10^{14}$ ions/cm^2/s

Pulse length 40 us (long)
Ion Flux ~$2x10^{14}$ ions/cm^2/s

Messenger-Spratt damage factors are the **SAME**, no effect of pulse length

Effect of Ion Flux

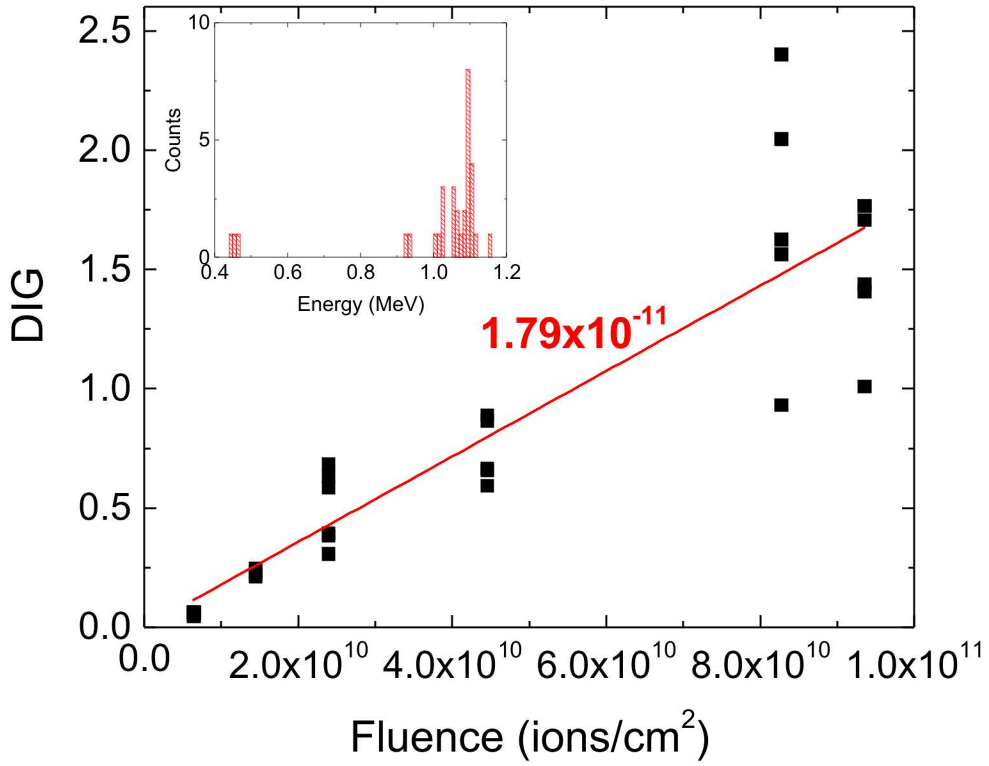
Tandem



Pulse length 100 us

Ion Flux ~$2x10^{14}$ ions/cm^2/s

NDCX-II

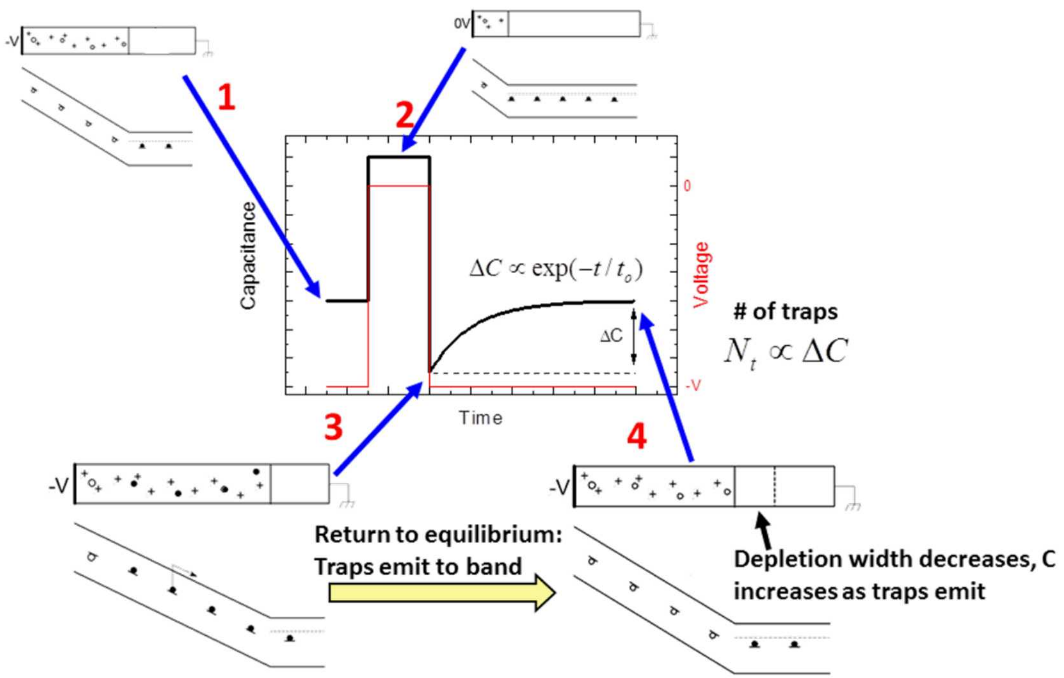


Pulse length <10 ns

Ion Flux ~$1.5x10^{19}$ ions/cm^2/s

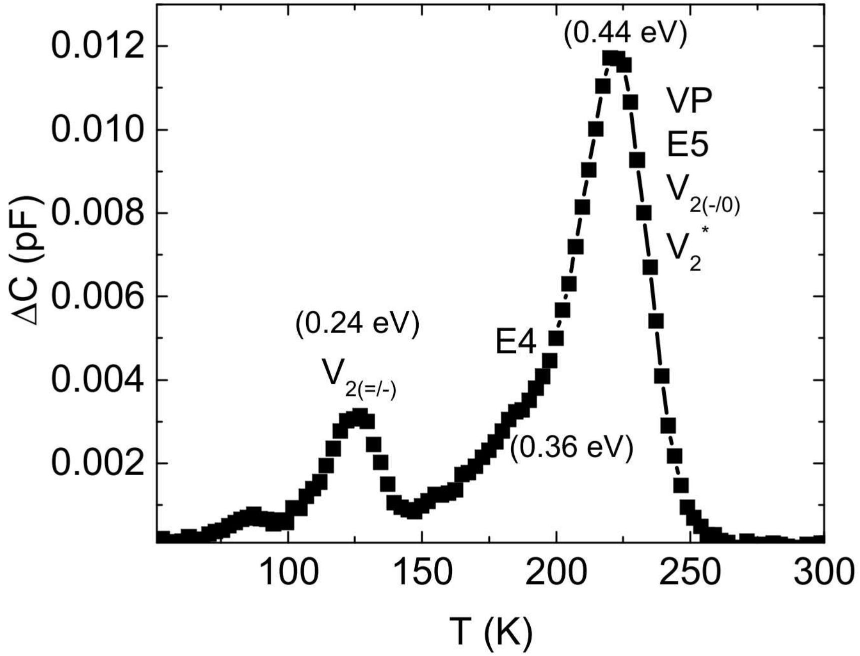
Messenger-Spratt damage factors are different*

Introduction – DLTS



# of Traps $\propto \Delta C$

Transition energy $\propto T$

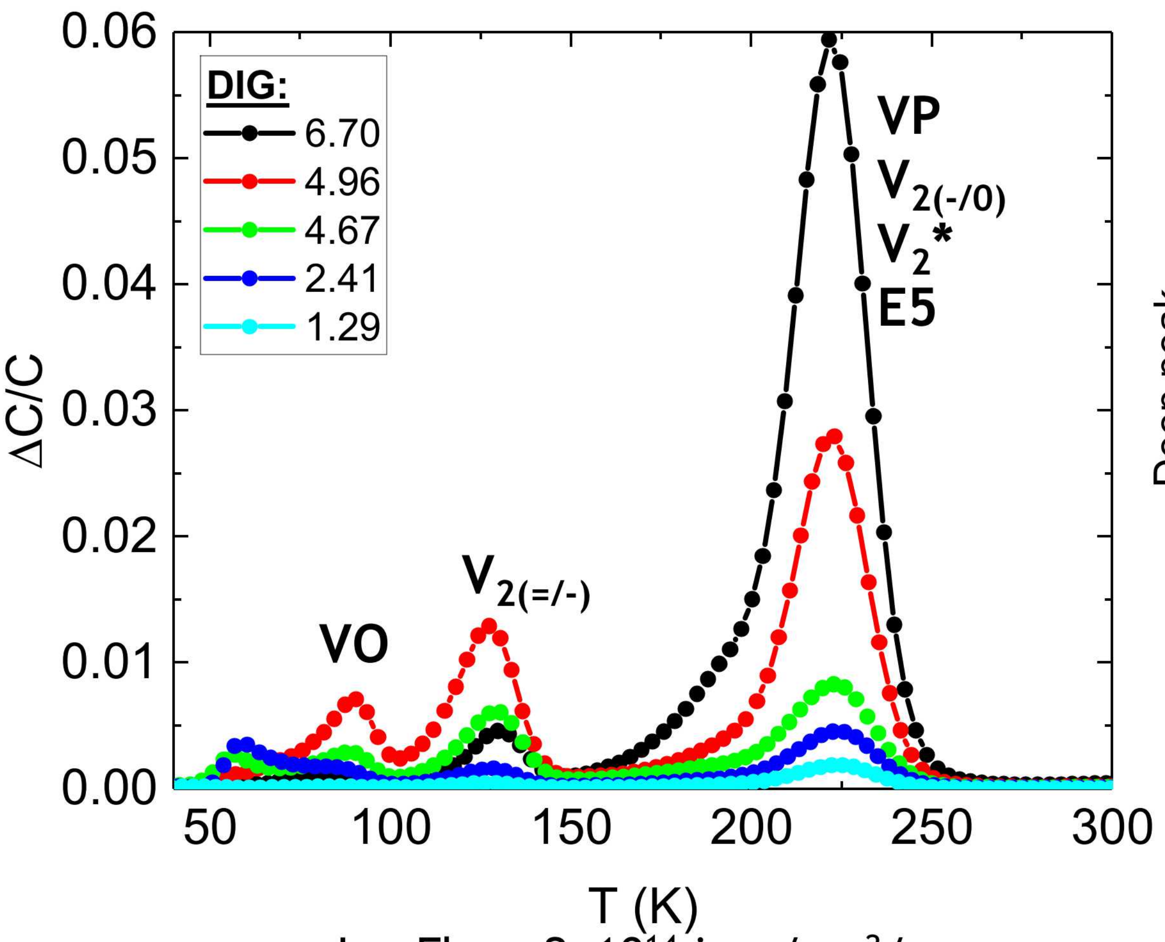


Deep Peak
(Mid-gap Traps)

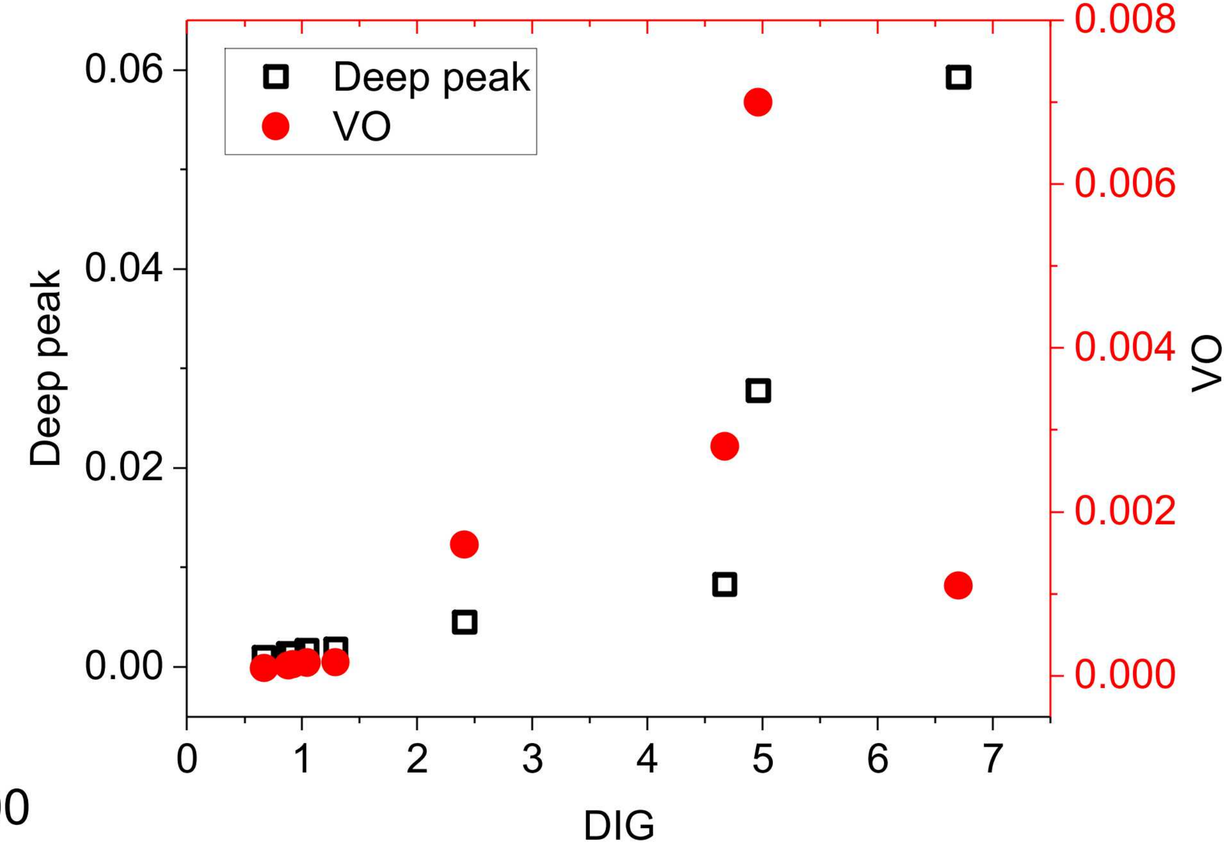
- VP = Vacancy-Phosphorous defect
- E5 = E4 → Same divacancy-like defect with different charge state
- $V_{2(-/0)}$ = $V_{2(=/-)}$ → Same divacancy defect with different charge state
- V_2^* = Strain divacancy defect

Type and number of electrically active traps from DLTS

DLTS on low flux irradiations (Tandem)

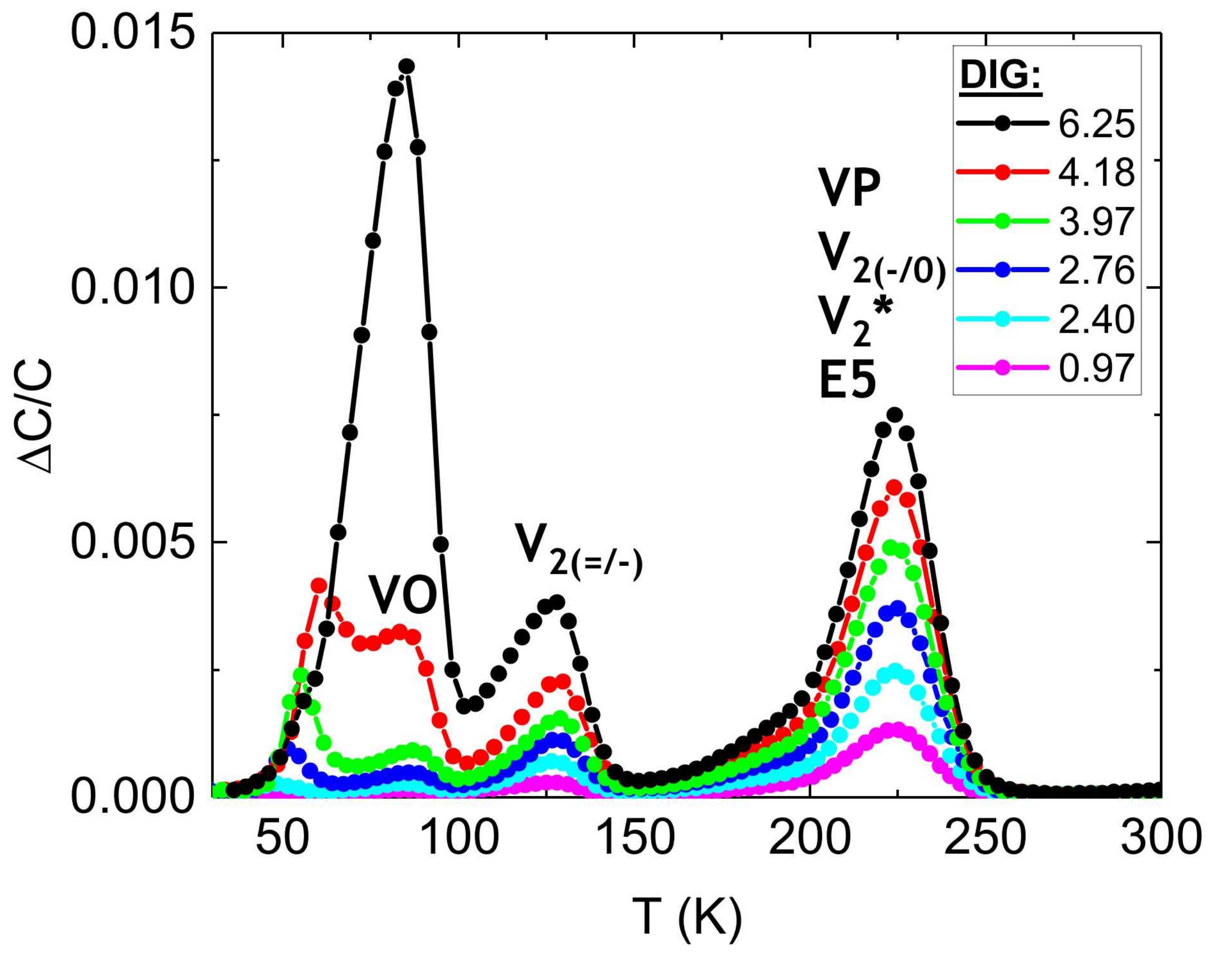


Ion Flux ~2×10^{14} ions/cm^2/s

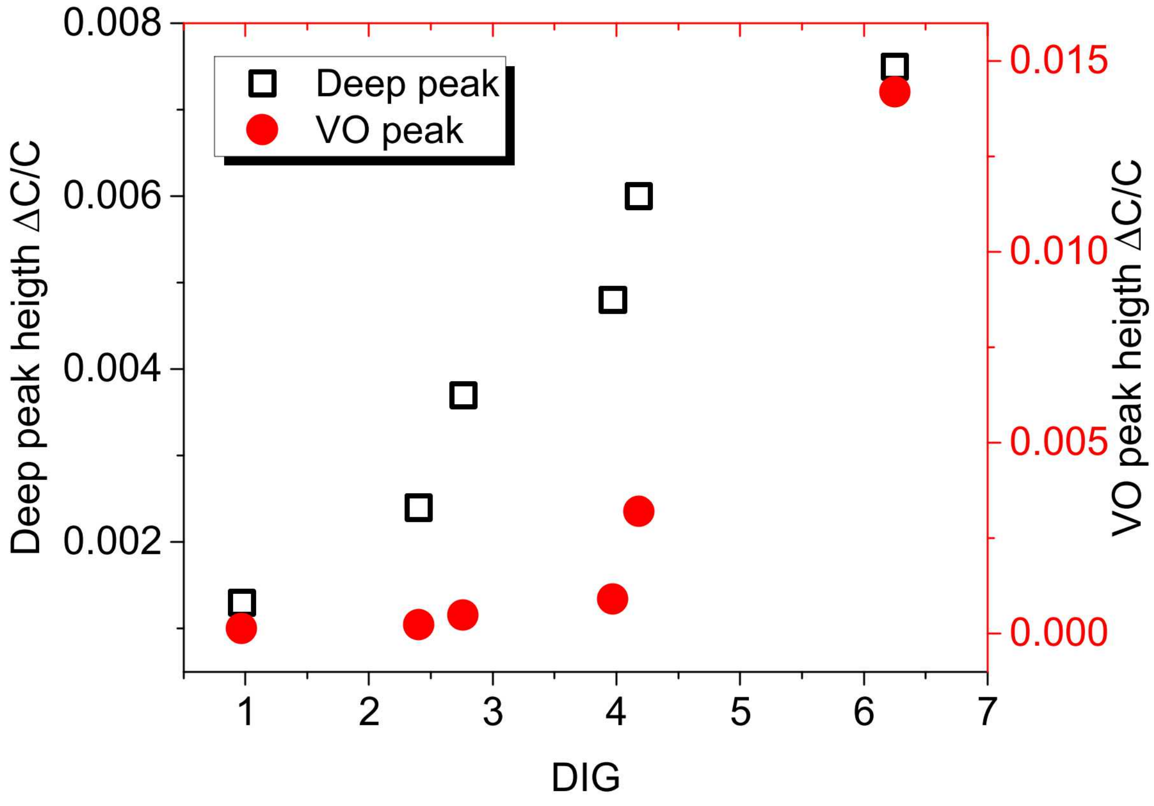


- Non-linear increase of VO and deep DLTS peaks

DLTS on high flux irradiations (NDCX-II)

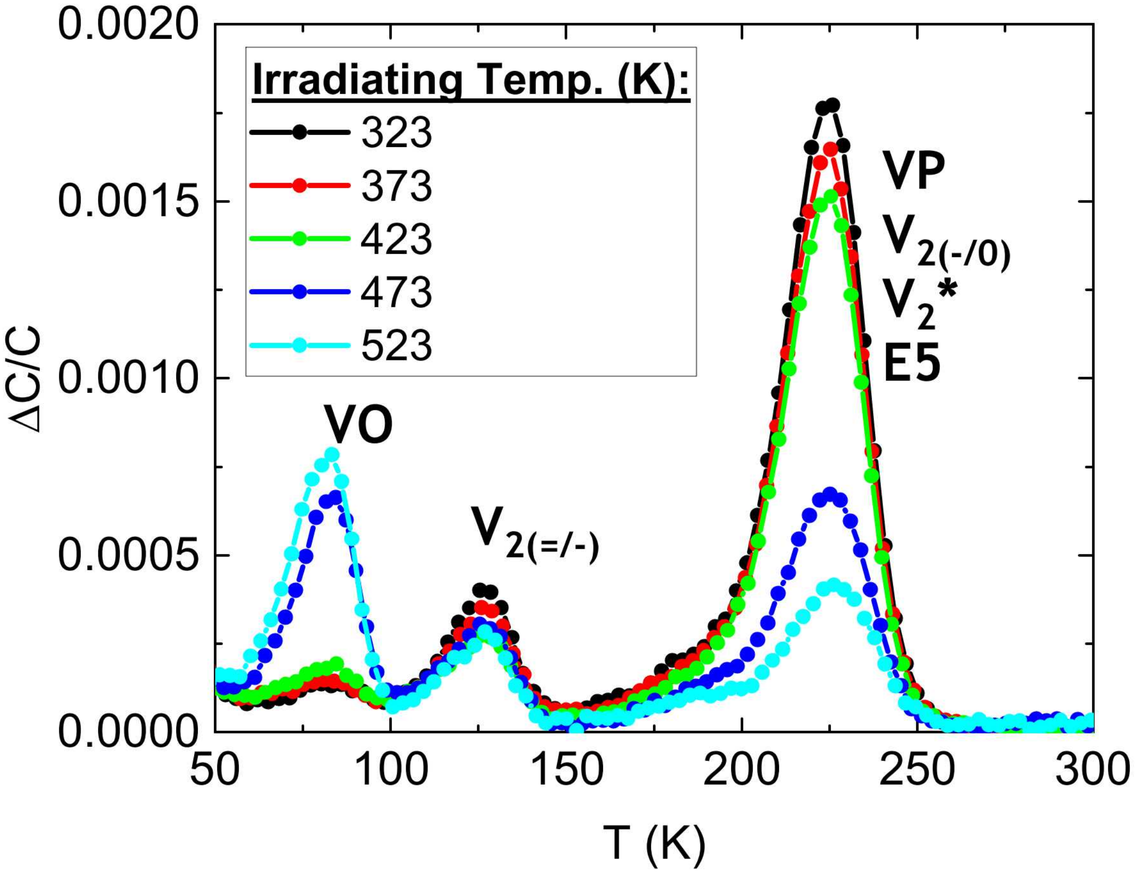


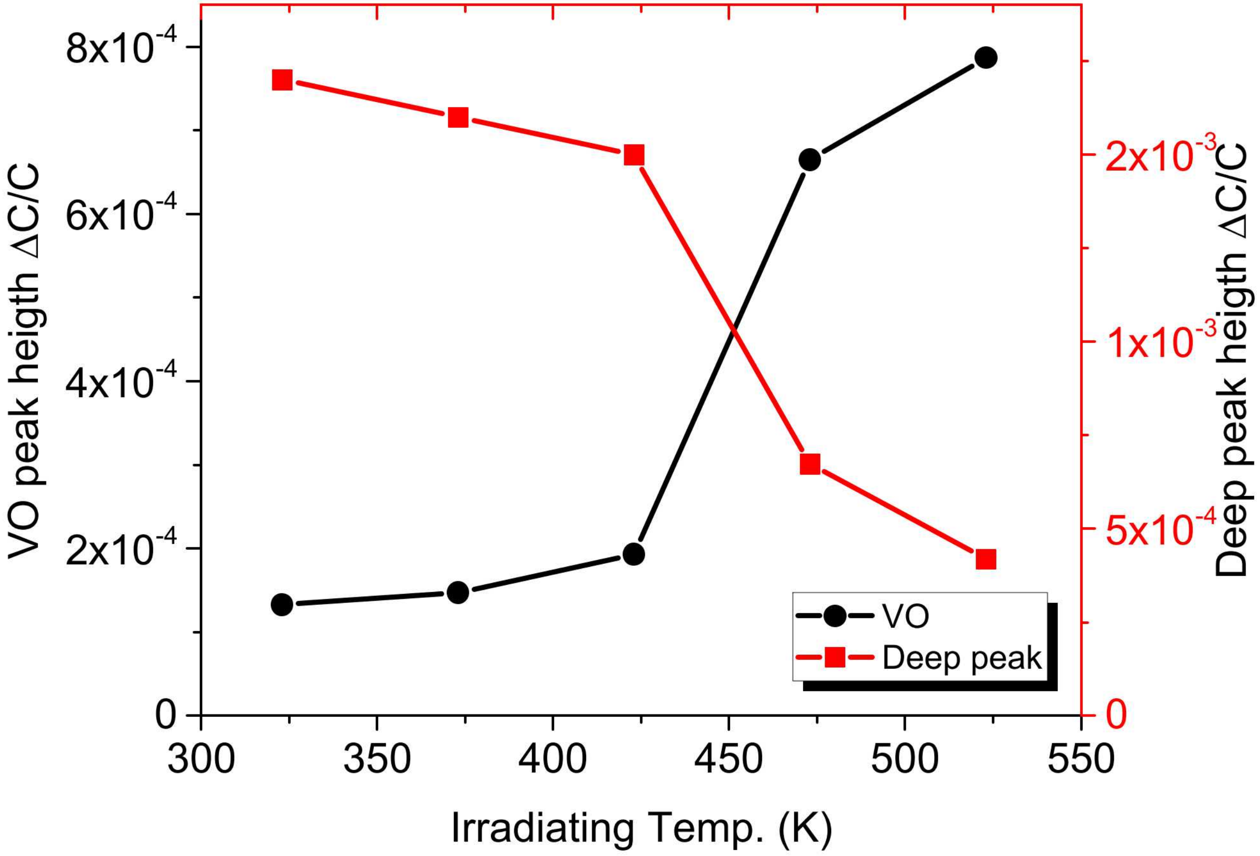
Ion Flux ~1.5x10[19] ions/cm[2]/s



- Linear increase of deep peak
- Non-linear increase of VO peak
  - DIG
  - Localized annealing

Effect of In-situ Annealing on DLTS





Effect of annealing temperature

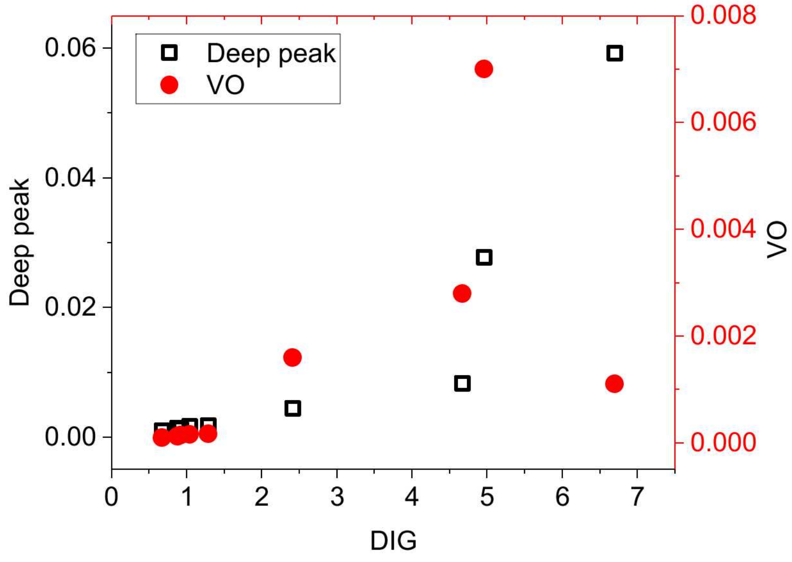
- Less number of defects

Annealing temperature:

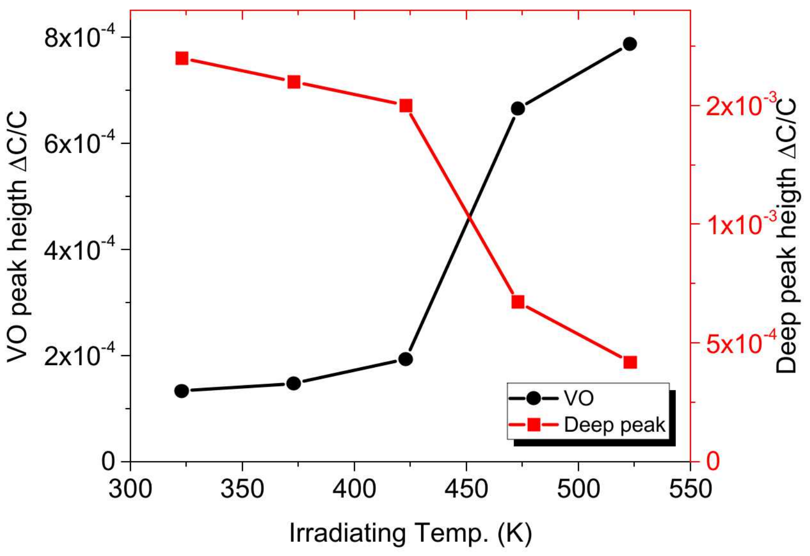
- Decreases the deep peak
- Increases VO peak

Combined mechanisms – DIG and localized annealing

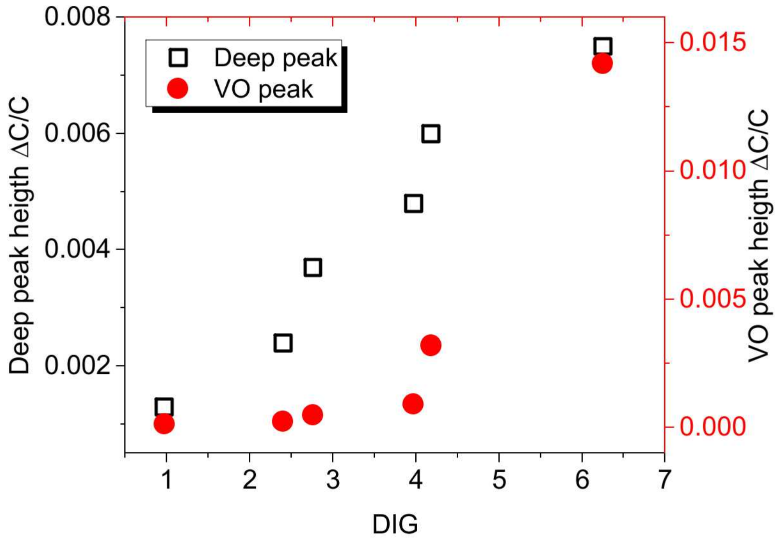
DIG – low flux



Localized annealing – low flux



High flux



Summary

Low flux irradiations

-Non-linear growth of deep peak and VO peak with increasing DIG

- Sample annealing during irradiation decreases deep peak growth and increases VO peak

High flux irradiations:

- DIG and localized annealing determine the VO and Deep peak DLTS growth
- k-factor is 5x larger than k-factor in low flux irradiations