DLTS RESULTS HAMBURG

Workshop on Defect Analysis in Radiation Damaged Silicon Detectors

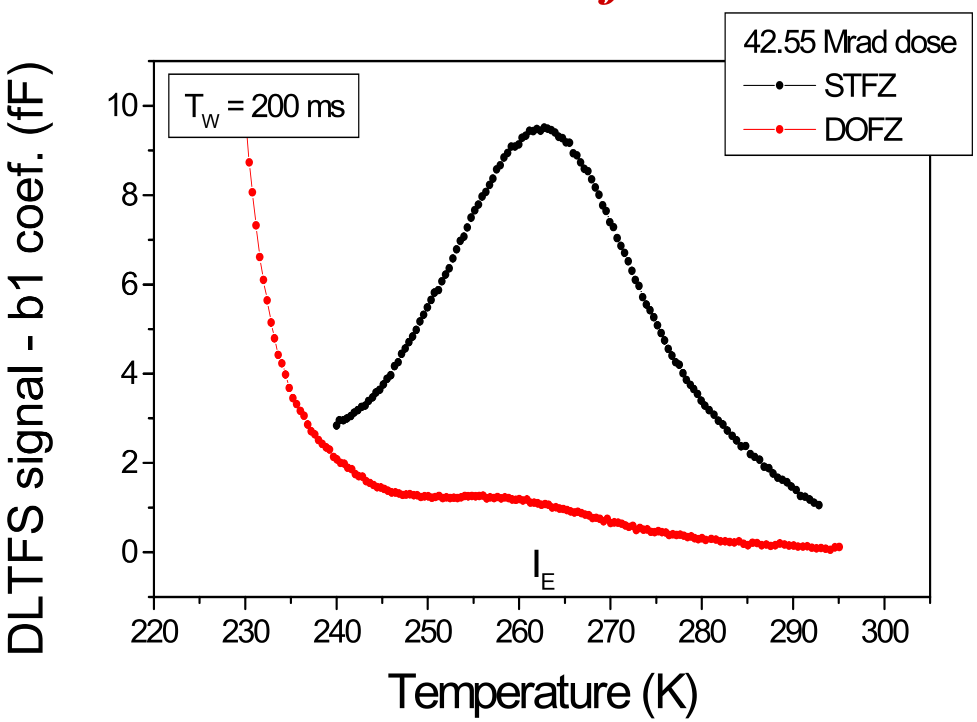
Hamburg, 23./24. August 2006

Frank Hönniger

The I center – can explain 85% from the damage after ^{60}Co-gammas

Detected by DLTS investigations in highly irradiated diodes (> 10 Mrad)

- emission of electrons



$$N_T^{DLTS}(T) = N_{TE} - n_E(T)$$

$$n_E(T) = N_{TE} * \frac{c_n(T)*n + e_p}{e_n(T) + e_p(T) + c_n(T)*n + c_p(T)*p}$$

$$with\ \ c_{n,p}(T) = \sigma_{n,p}(T) * v_{th,n,p}(T);$$

$$e_{n,p}(T) = c_{n,p}(T) * N_{C,V}(T) * \exp(\pm \frac{E_T(T) - E_{C,V}}{k_b T})$$

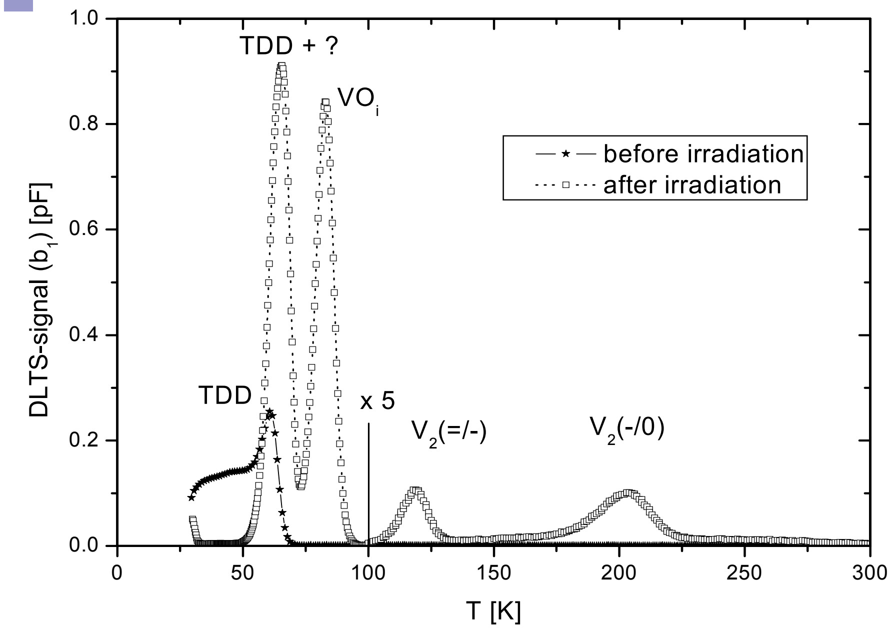
- **Ea = Ec – 0.545 eV**
- **σ_n = (1.7±0.2)x10^{-15} cm^2**
- **σ_p = (9±1)x10^{-14} cm^2 - from $N_T^{DLTS}(T)$**

Formation of the I-defect is suppressed in oxygen rich materials

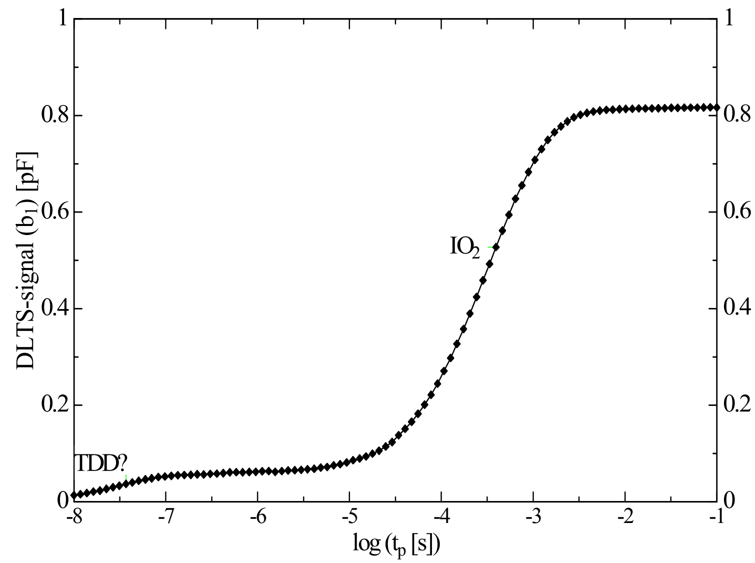
The IO_2 and TDD

Czochralski (Cz) material:

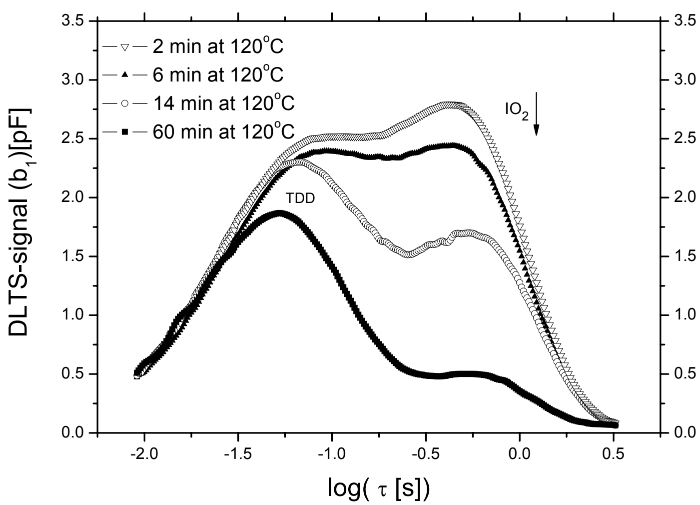
Sumitomo-Sitix <100>, n/P, 1.2 kΩcm



DLTS spectra before and after 1 Mrad γ–irradiation U_R=-20V, U_P=-0.5V

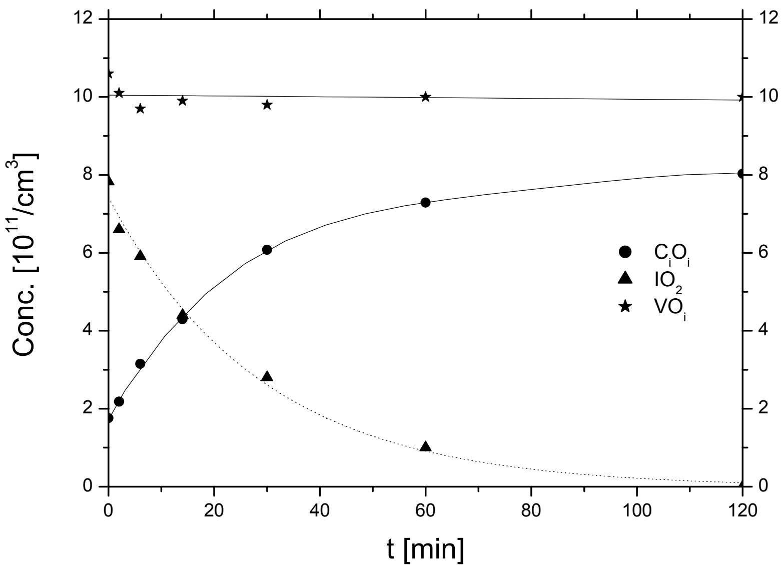


Direct measurement of capture cross-section for electrons at 60K



High-resolution DLTS spectra performed at 62K during - isothermal annealing at 120°C

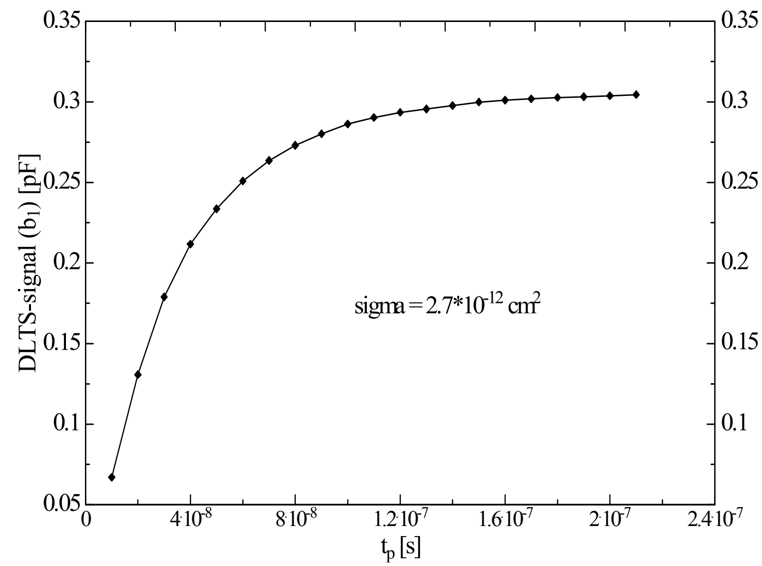
The IO_2 and TDD



Isothermal annealing at 120°C

Time constants for decrease of $[IO_2]$ and increase of $[C_iO_i]$ are identical within 10%.

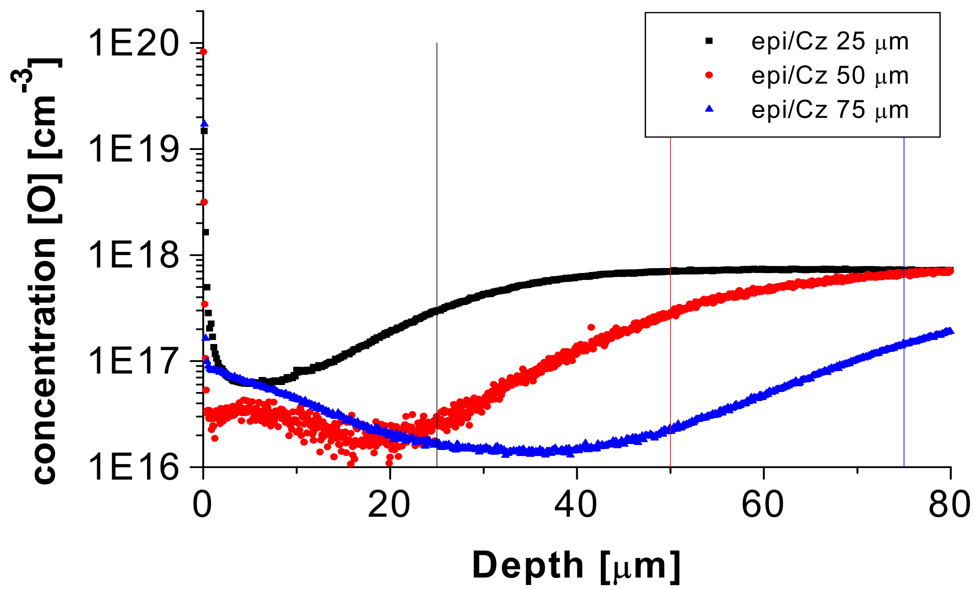
(29min : 26min)



Direct measurement of the TDD electron capture cross-section performed at 60K.

IO_2 in EPI

Epi/Cz: <111>, n/P, 50 Ωcm, **25**, **50**, **75** µm on 300 µm Cz-substrate, CiS process

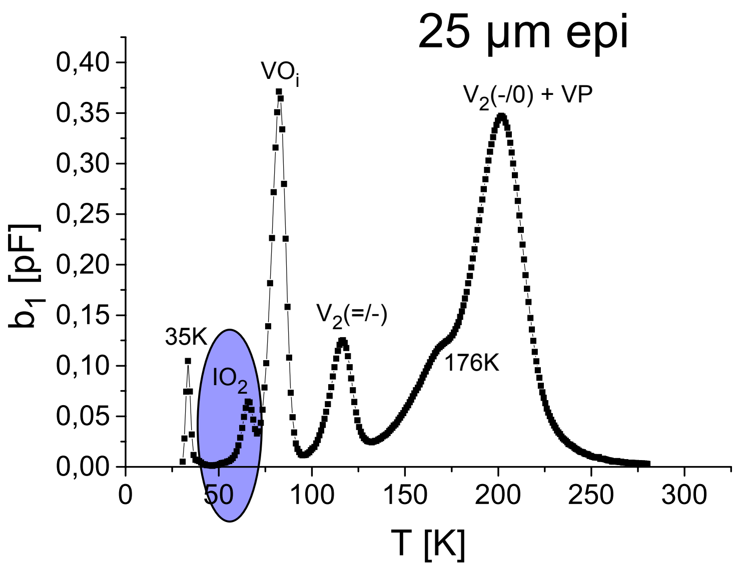


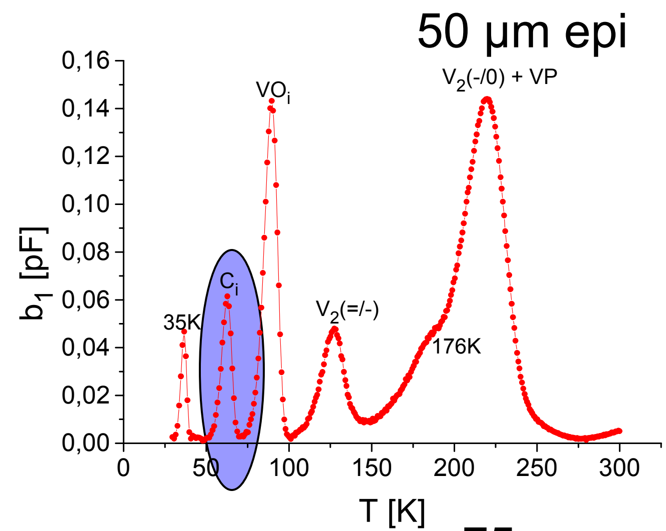
Carbon concentration for all materials at detection limit [C] ≈ $5.7 \cdot 10^{15}$ cm^{-3}

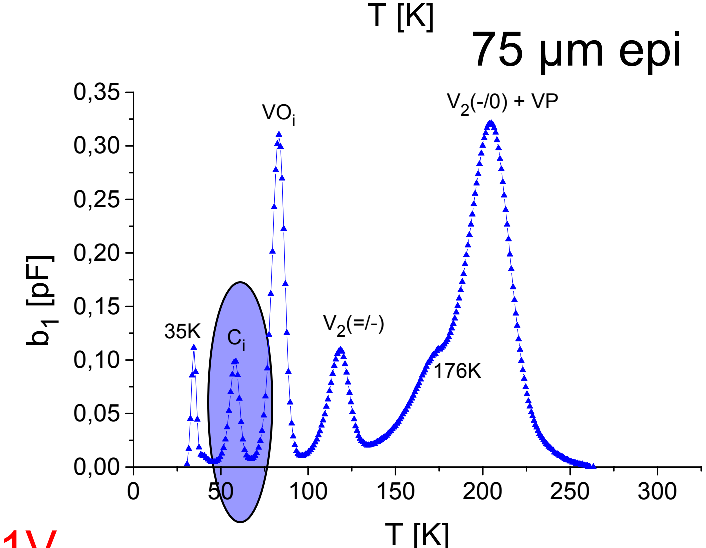
SIMS-measurements: A.Barcz, ITME

Irradiation: 23 GeV protons

IO_2 in EPI







Φ(25, 75 µm epi) = $1.2 \cdot 10^{12}$ p/cm²

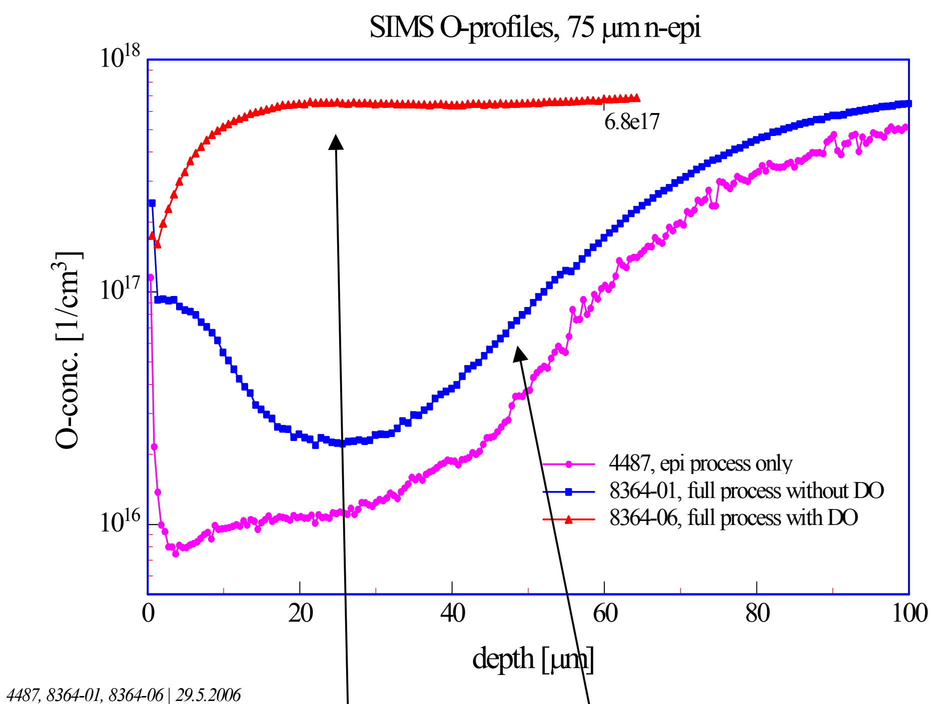
Φ(50 µm epi) = $1 \cdot 10^{12}$ p/cm²

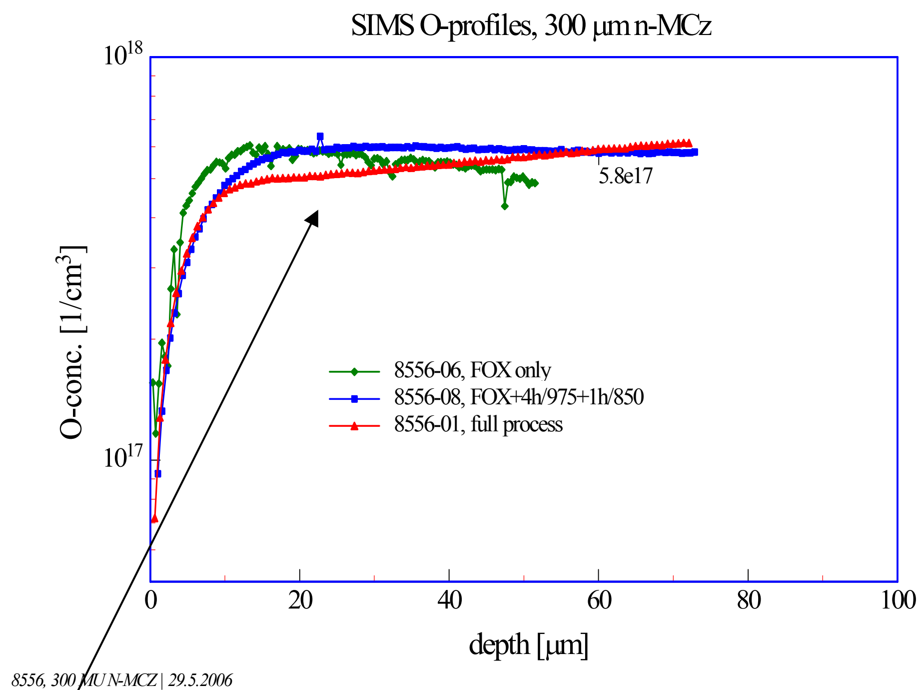
25 µm epi: defect at **67K**

50, 75 µm epi: defect at **58K**

T_W = 200 ms, tp= 100 ms U_R=-20V, U_P=-0.1V

IO_2 in EPI an MCZ



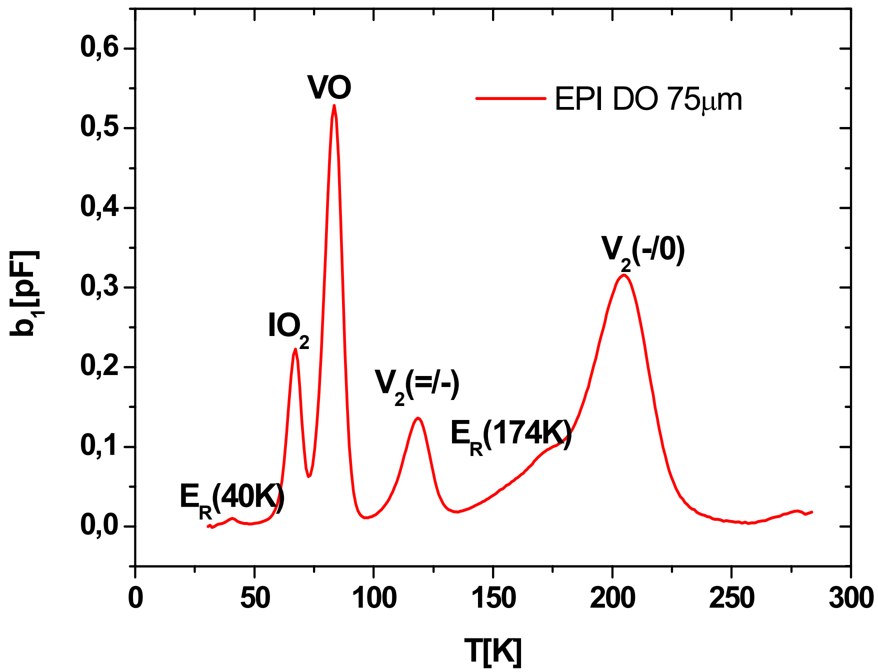


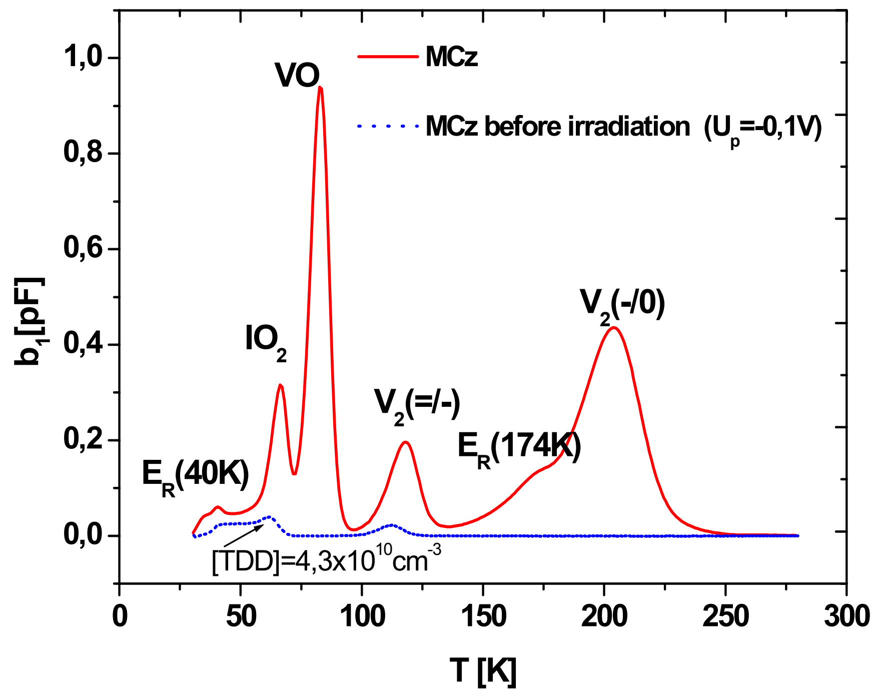
Epi/Cz: n-type, 145 Ωcm, 75 µm on 300 µm Cz-substrate, Cis process

(with and without DO)

MCZ: n-type, 880 Ωcm, 300 µm , Cis process

DLTS Spectra





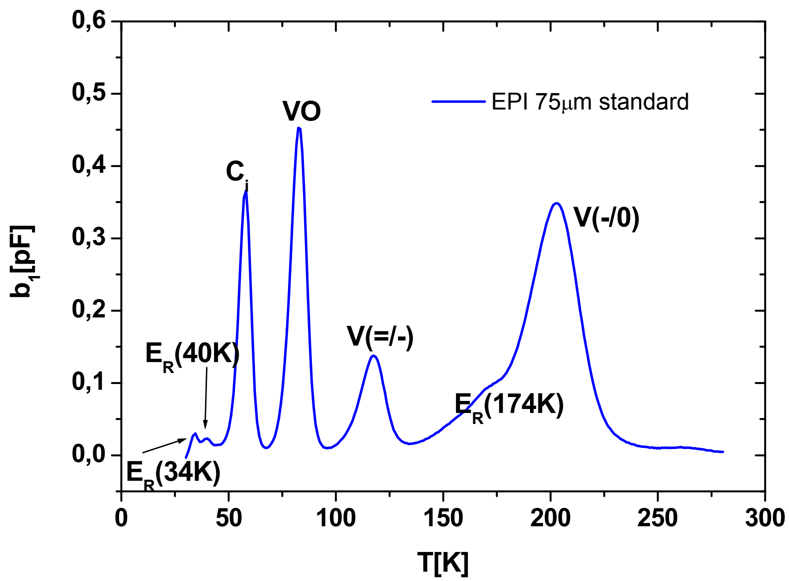
EPI DO:

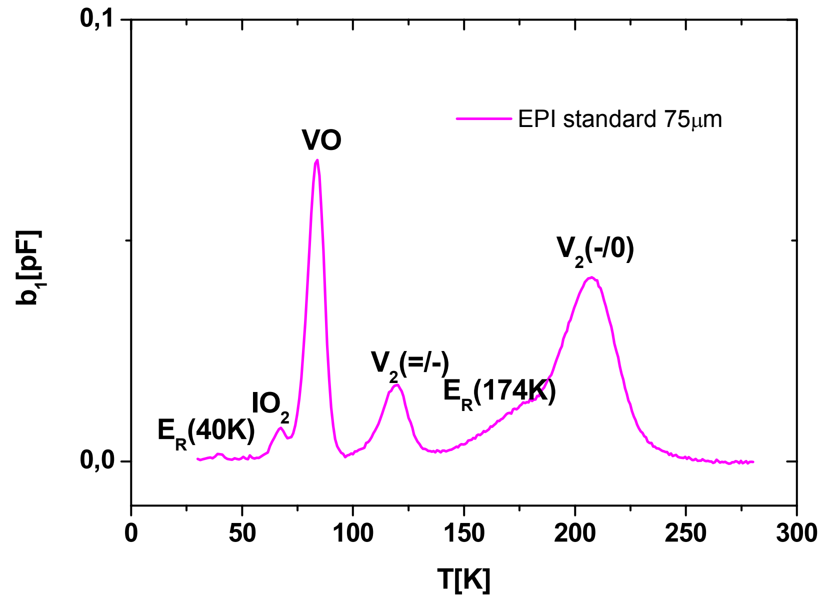
- Φ_{eq}= 8.2 x 10^{11} cm^{-2} p^{+} 26 MeV
- U_R= -20V, U_P=-0.1V
- T_W= 200ms, T_P= 100ms

MCZ:

- Φ_{eq}= 4.6 x 10^{11} cm^{-2} p^{+} 26 MeV
- U_R= -20V, U_P=-5V
- T_W= 200ms, T_P= 100ms

DLTS Spectra





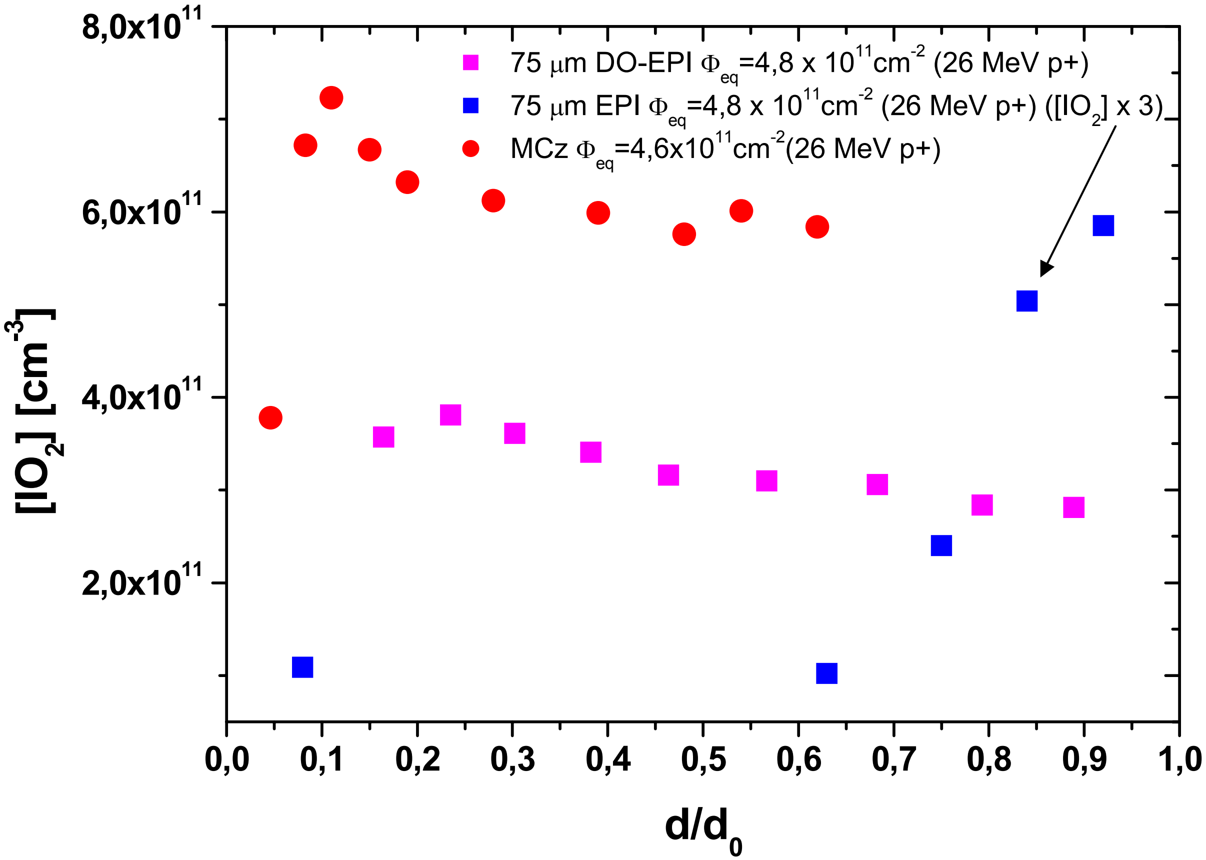
EPI standard:

- Φ_{eq}= 8.0 x 10^{11} cm^{-2} p^+ 26 MeV
- U_R= -20V, U_P=-0.1V
- T_W= 200ms, T_P= 100ms

EPI standard (backside):

- Φ_{eq}= 8.0 x 10^{11} cm^{-2} p^+ 26 MeV
- U_R= -80V, U_P=-60V
- T_W= 200ms, T_P= 100ms

Depth profil IO_2

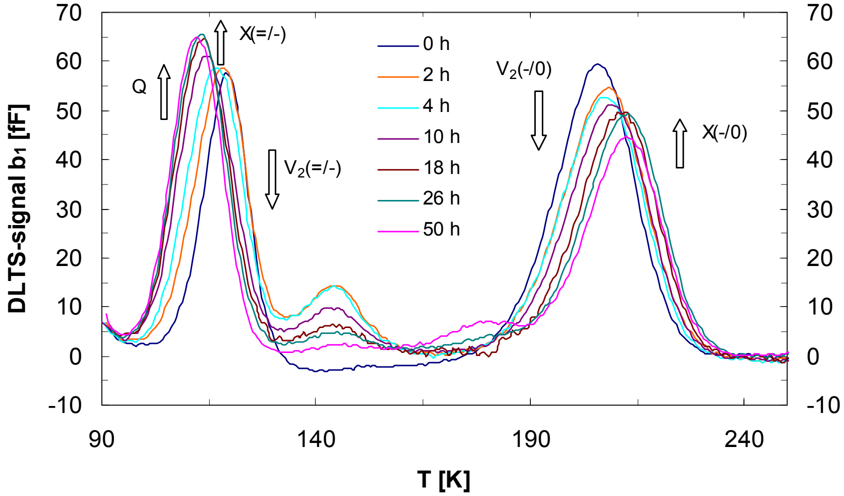


In DO-EPI and MCZ $[IO_2]$ is almost homogeneous like [O]

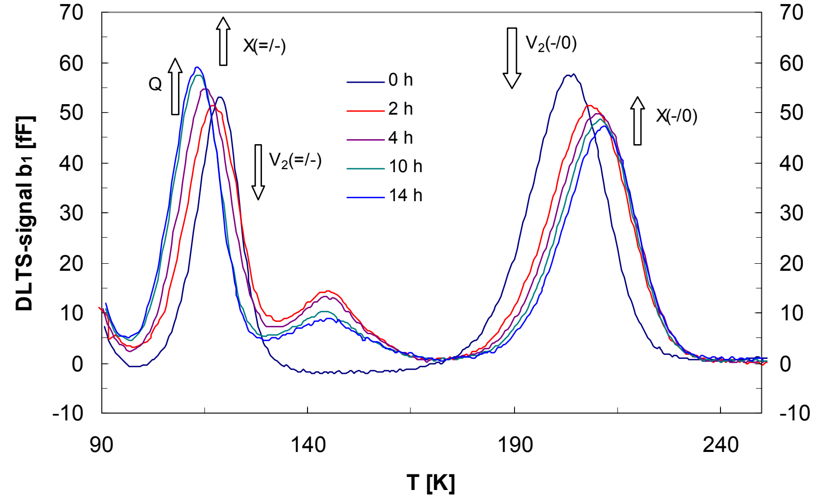
In EPI standard $[IO_2]$ is strongly inhomo-geneous like [O]

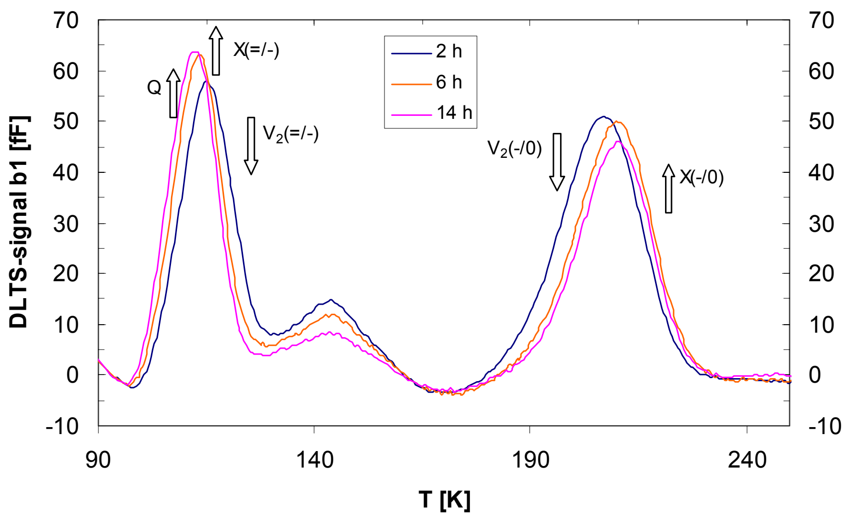
X-defect – different oxygenation time (DOFZ technology)

$[O_i] = 6 \cdot 10^{16}\ cm^{-3}$



$[O_i] = 1 \cdot 10^{17}\ cm^{-3}$





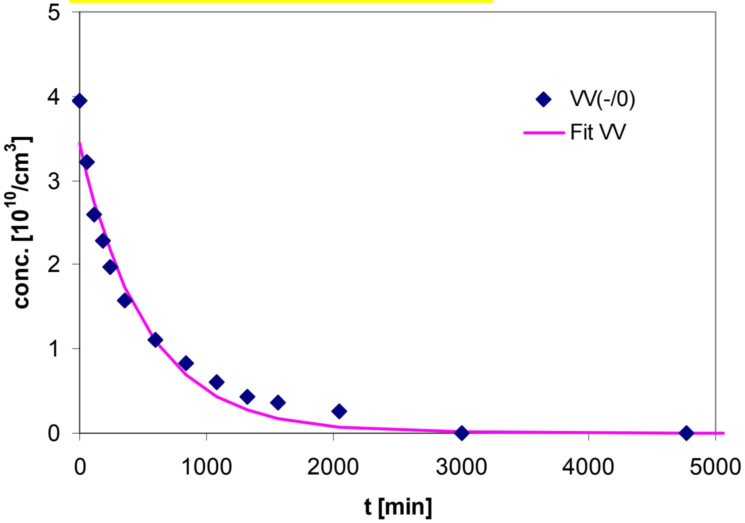
spectra after electron injection of DOFZ – diodes irradiated with 4 Mrad annealed at 250°C.

annealing out of V_2 and formation of X

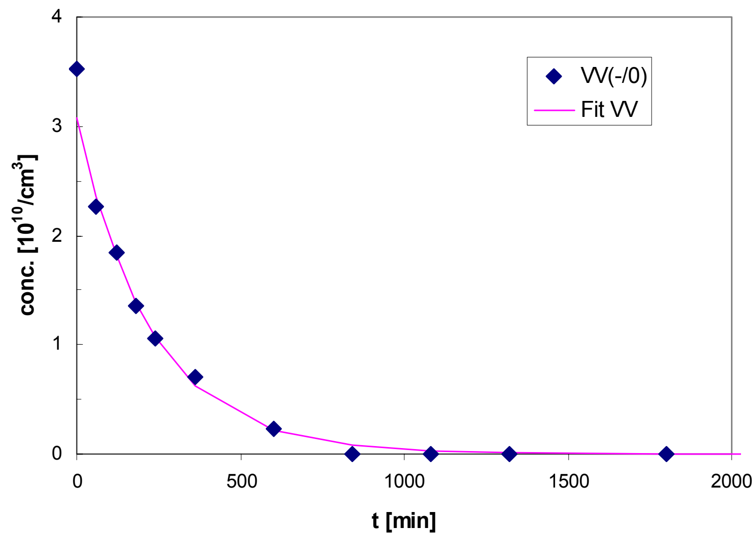
$[O_i] = 1.2 \cdot 10^{17}\ cm^{-3}$

X - Defect

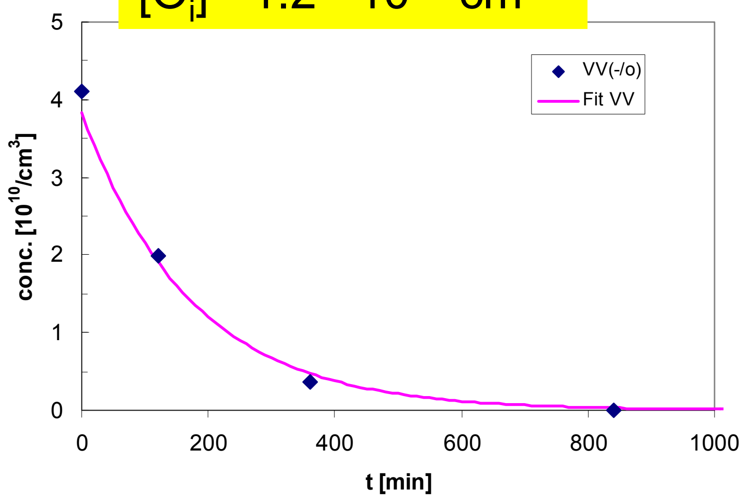
[O_i]= $6 \cdot 10^{16}$ cm^{-3}



[O_i]= $1 \cdot 10^{17}$ cm^{-3}



[O_i]= $1.2 \cdot 10^{17}$ cm^{-3}



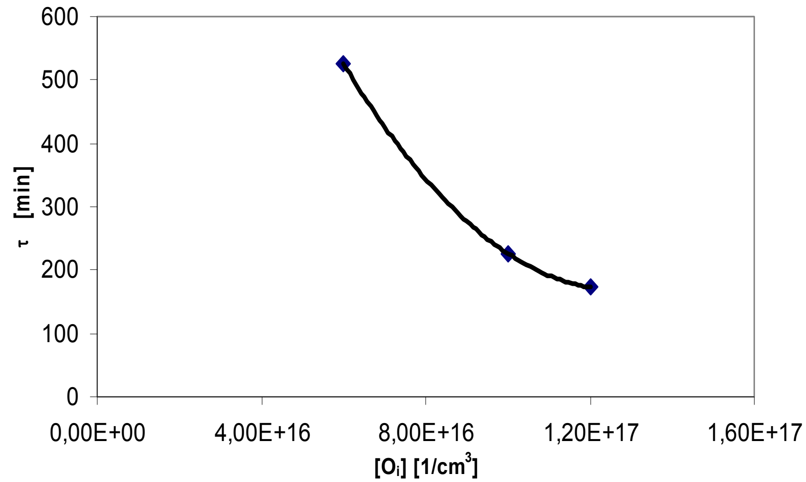
Time dependence of $\mathbf{V_2}$ concentration in DOFZ-diodes during annealing at 250°C.

annealing of V_2

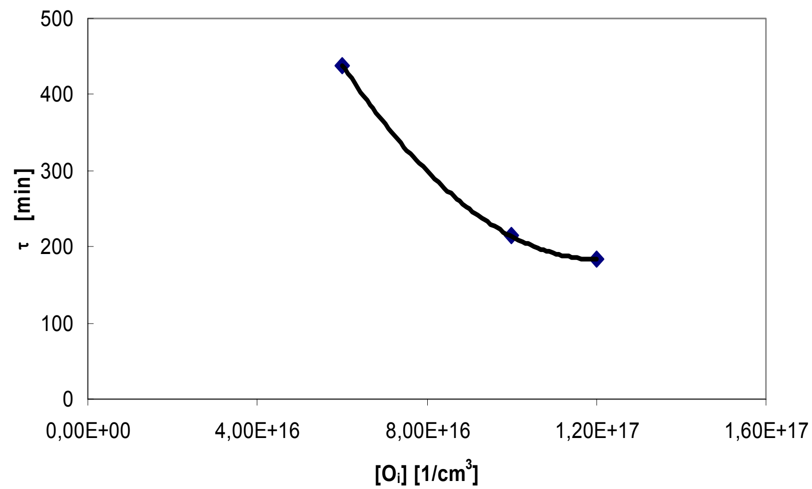
$$N_t = N_0 \bullet \exp\left(-\frac{t - t_0}{\tau}\right)$$

X - Defect

annealing of V_2



formation of X



For $k = 1/\tau$ ⟶ $k = a \cdot x^b$ with $b \approx 1.5$

$\Rightarrow$ Non linear dependence of [X] on $[O_i]$

X - Defect

Summary

- I center is one of the most important defects responsible for macroscopic performance of the detectors
- IO_2-defect gives an indirect hint on dimer concentration of the material
- X-defect shows a non linear dependance on [Oi]
- In combination with other results (TSC) X defect can be associated with V_2O_2