

# Annealing studies of cluster related defects after neutron irradiation

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# Outline

Motivation

DLTS spectra - survey

Low temperature annealing (60°C)

Studies at high temperatures (200 - 300°C)

Summary

## Motivation

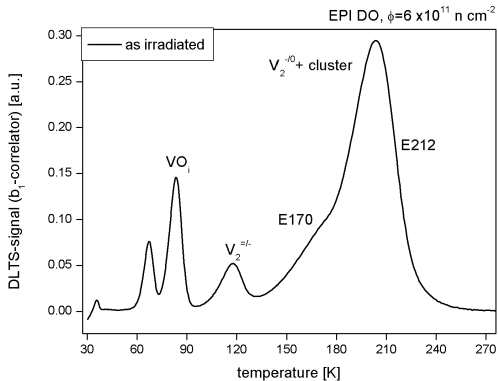
- Clusters as source for damage induced current?  
 $I/V \propto \Phi$  and independent of hadron type
- Neutron damage effects dominated by clusters
- Current annealing correlated with cluster annealing?
- DLTS studies offer signature for cluster annealing

### Used samples

n-type Si	d [ $\mu\text{m}$ ]	$N_{\text{eff}}$ [ $\text{cm}^{-3}$ ]	[O] [ $\text{cm}^{-3}$ ]	$\Phi_n$ [ $\text{cm}^{-2}$ ]
MCz	100	$3.5 \times 10^{12}$	$2.2 \times 10^{17}$	$3 \times 10^{11}$
EPI DO*	74	$2.4 \times 10^{13}$	$2.2 \times 10^{17}$	$6 \times 10^{11}$
FZ	100	$1.3 \times 10^{13}$	$1.8 \times 10^{16}$	$6 \times 10^{11}$

\*Diffusion oxygenated epitaxial layer

# DLTS spectra - survey



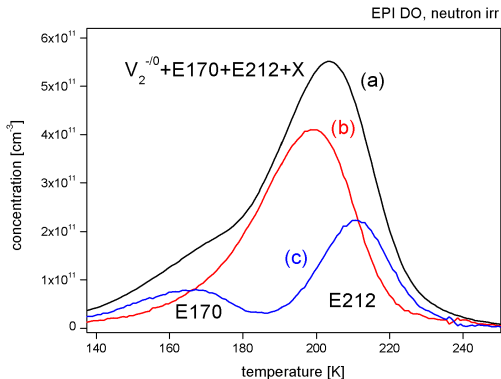
## Point defects

- $VO_i$
- $V_2^{=/-}$
- $V_2^{-/0}$

## Cluster related defects

- E170
- E212

## Evaluation of cluster related defects



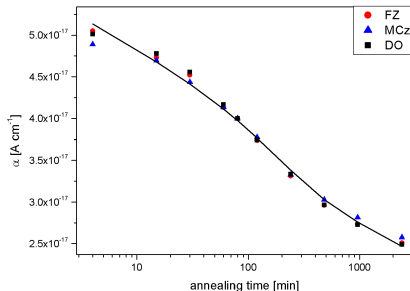
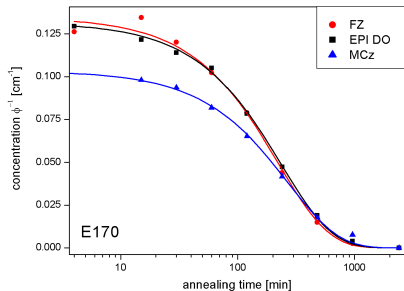
- (a) as irradiated
- (b) 2400 min at 60°C
- (c) difference spectra

$V_2^{-/0}$  not annealing at 60°C



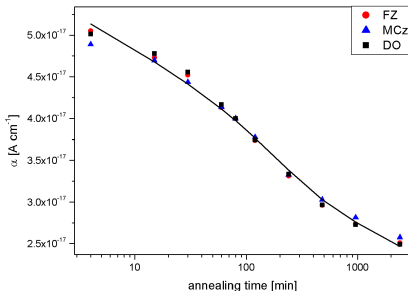
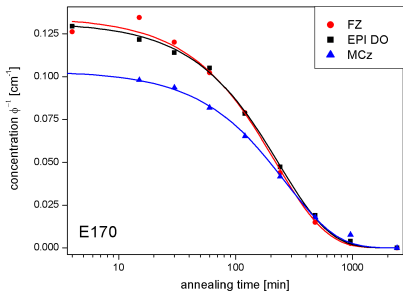
(a)-(b)=(c)  
only E170, E212

## Time constants for the annealing



$$\alpha(t) = \alpha_I \cdot \exp\left(-\frac{t}{\tau_I}\right) + \alpha_0 - \beta \cdot \ln(t/\tau)$$

## Time constants for the annealing

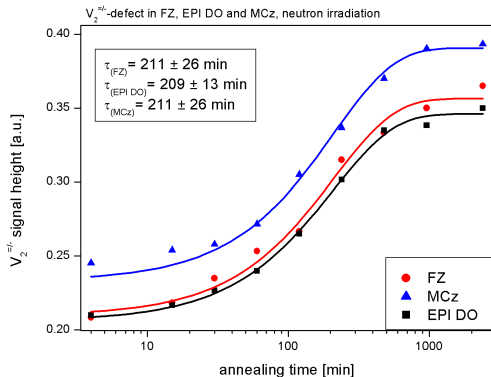


- No 100% correlation between E170, E212 as after e<sup>-</sup>-irr
- $\tau_{\alpha}$  shorter

	FZ	EPI	MCz
$\tau_{(E170)}$ [min]	$222 \pm 13$	$238 \pm 7$	$270 \pm 10$
$\tau_{(E212)}$ [min]	$291 \pm 31$	$224 \pm 23$	$161 \pm 16$

Global fit for  $\tau_{\alpha} = 180 \pm 30$  min

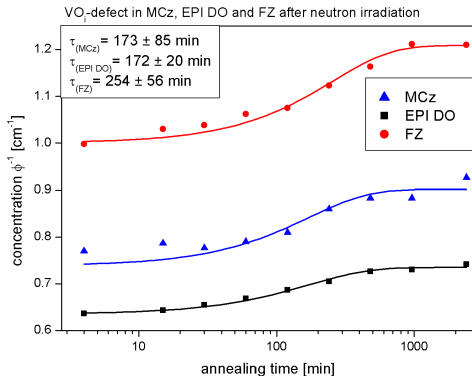
# Increase of $V_2^{\equiv/-}$ -signal



- $\tau$  is nearly the same for all diodes
- Increase of the signal due to lattice strain
- No increase of concentration

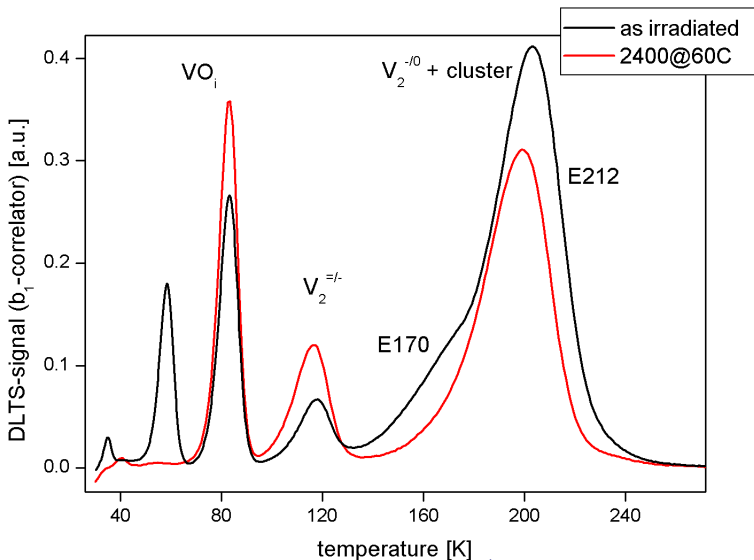


## Increase of $VO_i$ -concentration

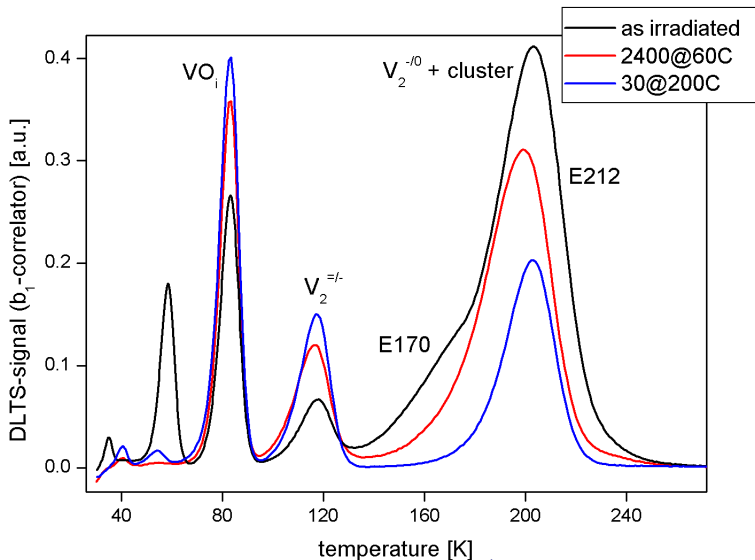


- $\tau$  in FZ due to  $G_i C_s$
- $\tau$  is nearly equal in MCz and EPI DO
- Increase of the concentration due to the release of single vacancies

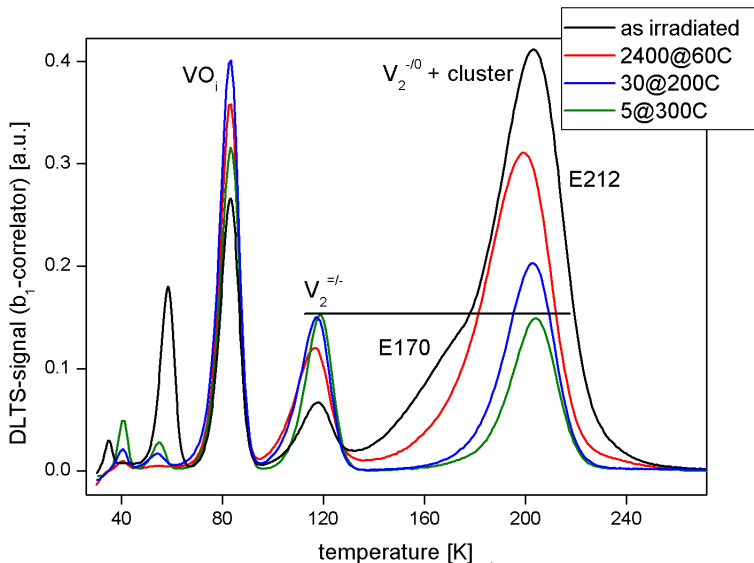
## Further annealing of clusters



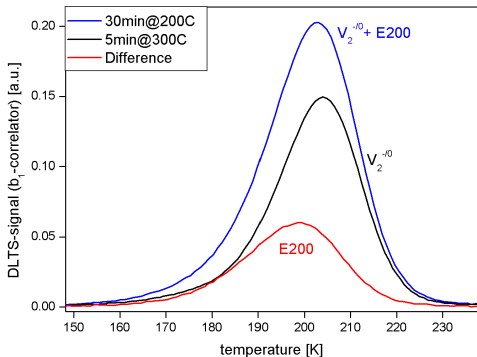
## Further annealing of clusters



## Further annealing of clusters



## Defect at 200K



- Cluster annealing between 200°C and 300°C
- $E_a = -0.405$  eV
- $\sigma_n = 1.7 \times 10^{-15}$

## Summary

- No 100% correlation of E170 and E212  
⇒ this can be an effect of the lattice strain, or these levels do not belong to the same defect, as it is suggested by other groups
- While a very good correlation between E170 and E212 and the leakage current was obtained previously for 6 MeV electron irradiation, after 1 MeV neutron irradiation this correlation does not hold fully  
⇒ this has to be further investigated
- Cluster annealing up to 300°C