New results on the annealing behaviour of the $E4/E5$-defect

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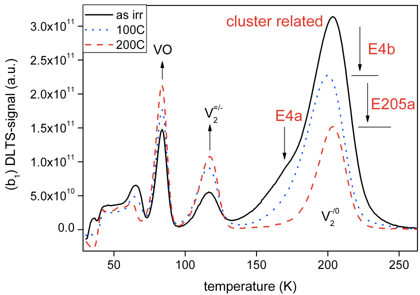
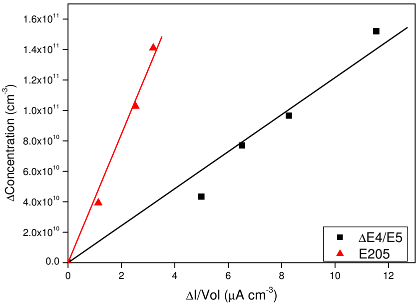
What is the origin of high leakage current?

Crystal defects in the silicon bulk create leakage current

⇒ Combine microscopic and macroscopic measurements



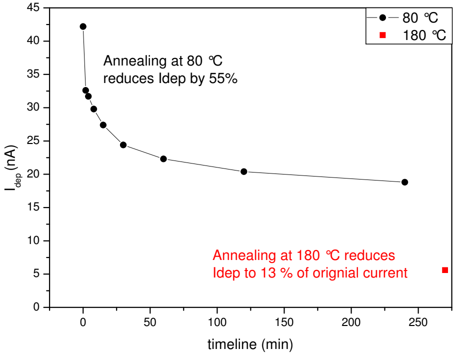
DLTS measurements show defect concentrations...



... revealing the correlation of defects and LC

Impact of *E*4/*E*5 and *E*205*a*

- 55 % of the total LC anneals out during 80 °C annealing
- After annealing at 180 ℃ only 10 % of the LC is left



Annealing of crystal defects

- The *E*4/*E*5 defect anneals at 80 ℃
- *E*205*a* anneals between 140 ℃ to 200 ℃

$E4/E5$ is one bistable configuration of V_3

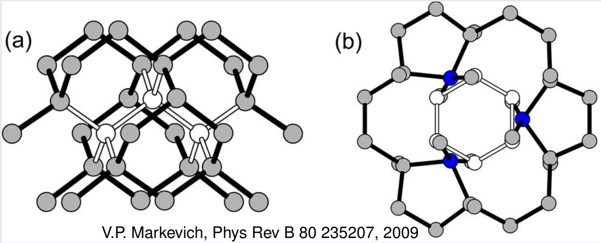
Three silicon vacancies in two configurations

Planar configuration

- 2 acceptor levels $E4$ & $E5$

Four-fold configuration (ffc)

- 1 acceptor level $E75$



V.P. Markevich, Phys Rev B 80 235207, 2009

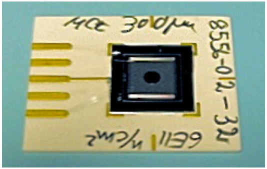
Change of configuration *(recovery)* possible by

- annealing at 80 ℃ $\Rightarrow$ produces $E75$
- injection of high current $\Rightarrow$ produces $E4/E5$

Materials & measuring techniques

Materials

MCz & FZ
Neutron irradiated
$\Phi_{eq} = 1 - 6 \times 10^{11}$



Capacitance/current-voltage characteristics (CV-IV)

Measurement of diode characteristics stabilised at 20 ℃
⇒ Endcapacitance, depletion voltage and leakage current

Deep level transient spectroscopy (DLTS)

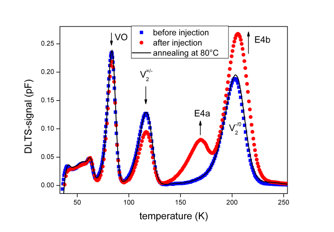
Measurement of capacitance transients due to emission of charge carriers
⇒ Defect concentrations

Can we make use of $E4/E5$ bistability

Bistability used to find origin of LC

- If defect switched *on/off* LC should follow

DLTS after injection

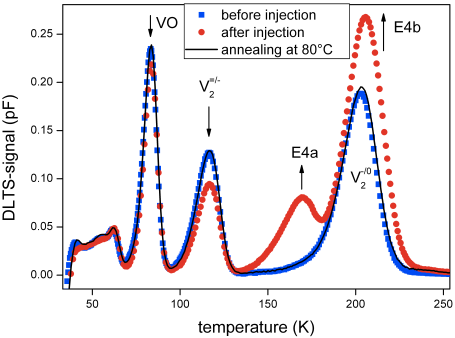


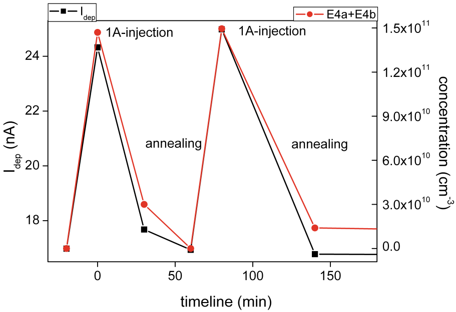
Annealing procedure

1. Isochronal annealing step
2. Injection of current at 0 ℃
3. Isothermal annealing

Measurements: CV/IV, DLTS/TSC, charge capture

Correlation of LC and *E4*/*E5*

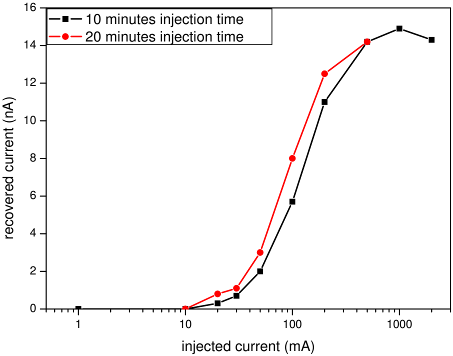




Direct correlation found

- Which mechanism leads to change of configuration?
- How much current do we need to inject?

Variation of the injected current



10 minutes injection:

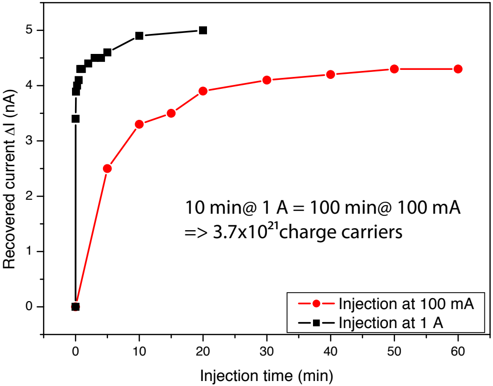
- Saturation reached at 1 A
- Annealing effects very high at 2 A (≈15 W at 0 ℃)

20 minutes injection:

- No change of saturation value

I (A)	charge density ($s^{-1}cm^{-3}$)	accumulated charge (cm^{-3})
1	4.5×10^{17}	3.7×10^{21}
0.5	1.8×10^{16}	1.9×10^{21}

Variation of injection time



- LC not fully recovered even after 100 minutes at 100 mA
- Charge carrier density leads to change of configuration
- Charge need to overcome potentials in cluster defects

Speculation: cluster core shielded by potentials

$\Rightarrow$ High charge densities needed

How can I imagine clustering effects?

Play ***Chargeball***

- Balls represent charge carriers
- Semi circles are charge trapping positions

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- Multi Ball represents high current injection
- With high injection also the shielded core can be reached

Summary & Outlook

Summary

- Correlation of $E4/E5$ with LC nicely seen
- Bistability used to recover LC
- Charge density important for recovery of LC

Outlook - Electrons or holes responsible?

- Red laser from front ⇒ electron injection
- Red laser from rear ⇒ hole injection
- Diode window allows 12 % of LC recovery