Silicon Containing Oxygen Dimer

A radiation hard sensor material?

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Outline

- Status of the Dimer experiment
  - RD50 Wshop1: Dimer Task Force:
    - Veronique Boisvert (CERN)
    - Eckhart Fretwurst (Hamburg)
    - Robert Jones (Exeter)
    - Zheng Li (BNL)
    - Lennart Lindström (Lund)
    - Michael Moll (CERN)
    - Bengt Svensson (Oslo)
- Results of Simulations

Evidence for Oxygen Dimers

- Defect Engineering possibility:
  - Oxygen Dimers: O_2
- How could they help?
  - V_2O_2 and VO_2 : neutral?
  - vs V_2, VO, V_2O: charged?
- How to create them? Pre-irradiation
  - $V+O \rightarrow VO$, $VO+O \rightarrow VO_2$, $I+VO_2 \rightarrow O_2$
- HEP irradiation:
  - $V+O_2 \rightarrow VO_2$
  - $V+VO_2 \rightarrow V_2O_2$

Evidence for Oxygen Dimers

- Lindstrom et.al.:
  - Irradiation using fast electrons (E=2.5MeV)
  - Samples:
    - n-Cz Si (P), 50Ωcm
    - Carbon-lean
    - High [O]~10^{18}cm^{-3}
  - [O_2]=
    - Before: ~1x10^{15}cm^{-3}
    - After: ~5x10^{16}cm^{-3}>>[VO]

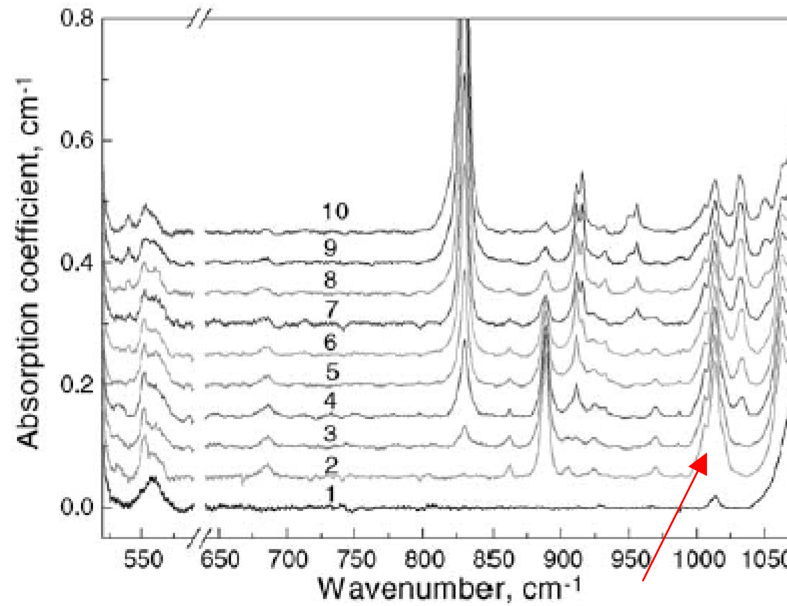


Fig. 1. Room temperature absorption spectra for C-lean n-
Si (ρ = 50 Ωcm): (1) as-grown; (2) after electron irradiatio
350°C, $F = 8 \times 10^{17}$ cm^{-2}; (3–10) after RT irradiation. F(cm
(3) 1×10^{16}, (4) 5×10^{16}, (5) 10^{17}, (6) 2×10^{17}, (7) 4×10^{17},
7×10^{17}, (9) 1.1×10^{18}, (10) 6×10^{18}.

Summary of Experiment

- 1) Dimering Process on bulk material and diodes
  - Different samples: Cz, (DO)FZ
  - Use 10MeV e at 350C up to $1x10^{18}$ fluence
- 2) IR measurements for evidence of O_2 presence
- 3) p^+ irradiation to LHC+ fluences
- 4) Characterization of diodes

Status of Experiment

- Received bulk material from ITME
  - Surface: chemically polished for IR measurements
  - FZ not from ITME
  - Carbon source:
    - residual [C] in polycrystal
    - Carbon heaters in Cz method

Sample		Resist. (ohmcm)	Type	[Oxygen] $x10^{17}$ at/cm^{-3}	[Carbon] $x10^{16}$ at/cm^{-3}	Wafer D. (inch)	Thick. (mm)
CZ-21BII	middle	1.8	n	8.1	6.3	4	2
	edge			7.89	5.7		
CZ-72AI-1	middle	30	n	10.3	nd	4	3
	edge			9.5	nd		
CZ-72AI-2	middle	30	n	10.3	nd	4	3
	edge			8.87	nd		
CZ-60-AII	middle		n	9	14.5	2	2
FZ		3300	n	-	-	?	3

Status of Experiment

- Received diodes from Hamburg
- p^+nn^+ implanted, 300μm, 0.25cm^2

Label	Vdep (V)	I(Vdep) (nA)
Standard FZ <111> CA03-		
3	62.6	1.77
7	61.4	0.61
8	66.9	0.24
9	65.6	0.22
10	66.7	0.21
11	63.1	0.6
DOFZ <111> CD22-		
3	51.2	0.794
4	52	0.676
6	50.6	0.413
7	50.3	0.44
11	51.2	0.457
12	51.6	0.43
CZ 5337-04-		
41	216.2	0.66
43	220.1	0.75
48	198.4	0.12
49	221.3	0.27
53	202.8	0.32
54	193.1	0.16

Status of Experiment

- Ready to do dimer irradiation (L. Lindstrom)
  - LUND 2.5MeV e shut down
  - KTH:
    - 6 MeV e
    - 30-35h to reach $1x10^{18}$ e/cm^2
    - Diameter: 50mm, 350C hot plate
    - Cost: 5000CHF
    - Soon
  - May be Aarhus
    - 2-3 $x10^{17}$e/cm^2
    - Not before mid-August
  - Other places? (~20Grad of γ)

Simulation of dimer irradiation

- Kinetic reactions

$$P(V,O)=\frac{R(V,O)[O]}{R(V,V_2)[V_2]+R(V,O)[O]+R(V,VO)[VO]}$$

$$[VO]=f\eta P$$

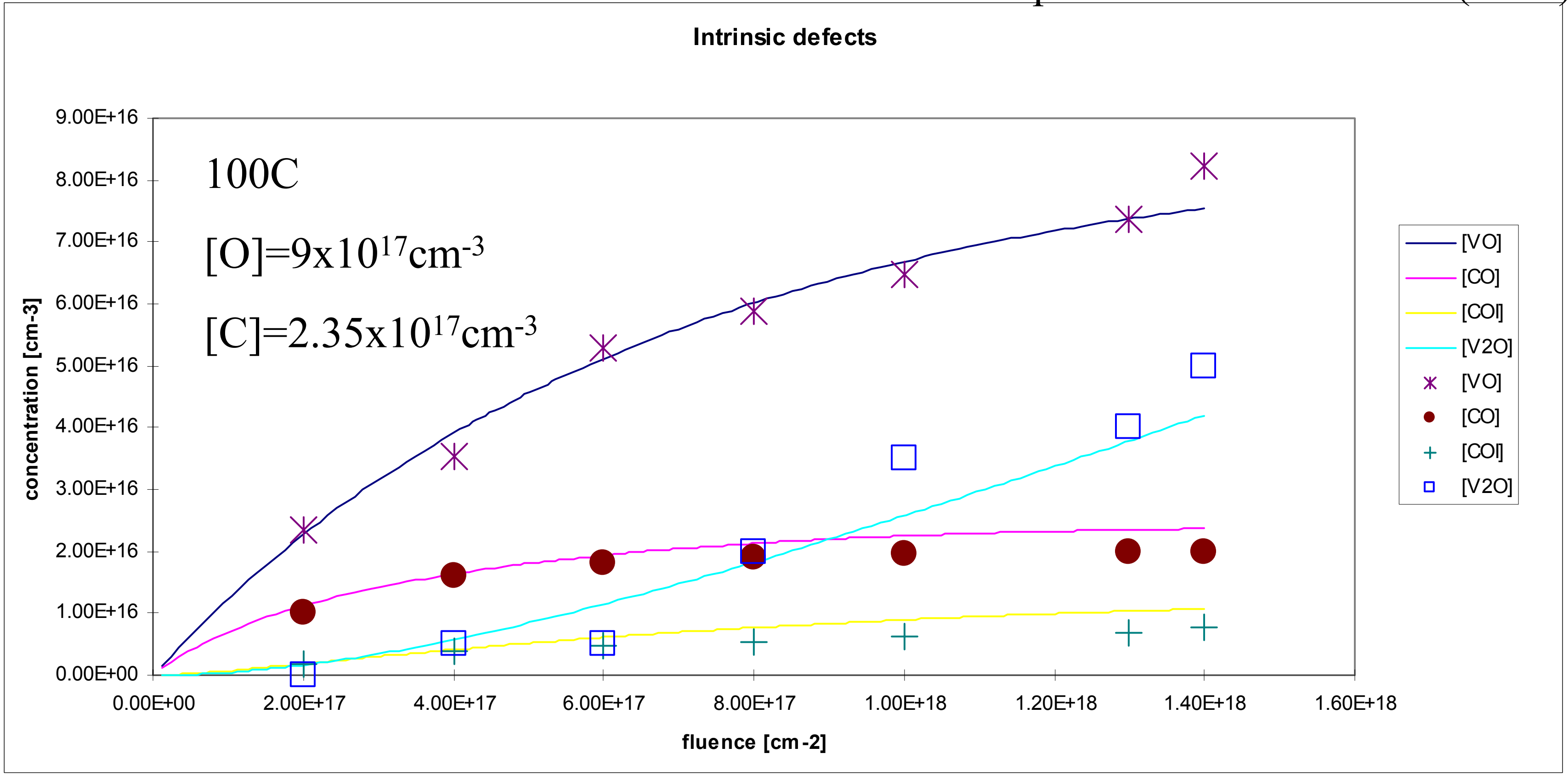
- 1^{st} step: 100C reactions:

I	V	C_i
$I+C_s \rightarrow C_i$	$V+V_2 \rightarrow V_3$	$C_i+C_s \rightarrow CC$
$I+CC \rightarrow CCI$	$V+O \rightarrow VO$	$C_i+O \rightarrow CO$
$I+CCI \rightarrow CCII$	$V+VO \rightarrow V_2O$	
$I+CO \rightarrow COI$		
$I+COI \rightarrow COII$		
$I+V_2 \rightarrow V$		
$I+VO \rightarrow O$		

Simulation of dimer irradiation

- Needed ingredients:
  - Introduction rates: I,V,V_2
  - All the trapping radius ratios

Data points from: NIMA 374(1996)12-26



Simulation of dimer irradiation

- 2nd step: Simulation at 350C
  - VO is moving! Additional reactions:

VO	I	V	C_i
$VO+O \rightarrow VO_2$	$I+VO_2 \rightarrow O_2$	$V+VO_2 \rightarrow V_2O_2$	$C_i+VO_2 \rightarrow C_sO_2$
	$I+O \rightarrow IO$	$V+O_2 \rightarrow VO_2$	
	$I+IO \rightarrow I_2O$	$V+IO_2 \rightarrow O_2$	
	$I+O_2 \rightarrow IO_2$	$V+I_2O_2 \rightarrow IO_2$	
	$I+IO_2 \rightarrow I_2O_2$		
	$I+V_2O_2 \rightarrow VO_2$		

Simulation of dimer irradiation

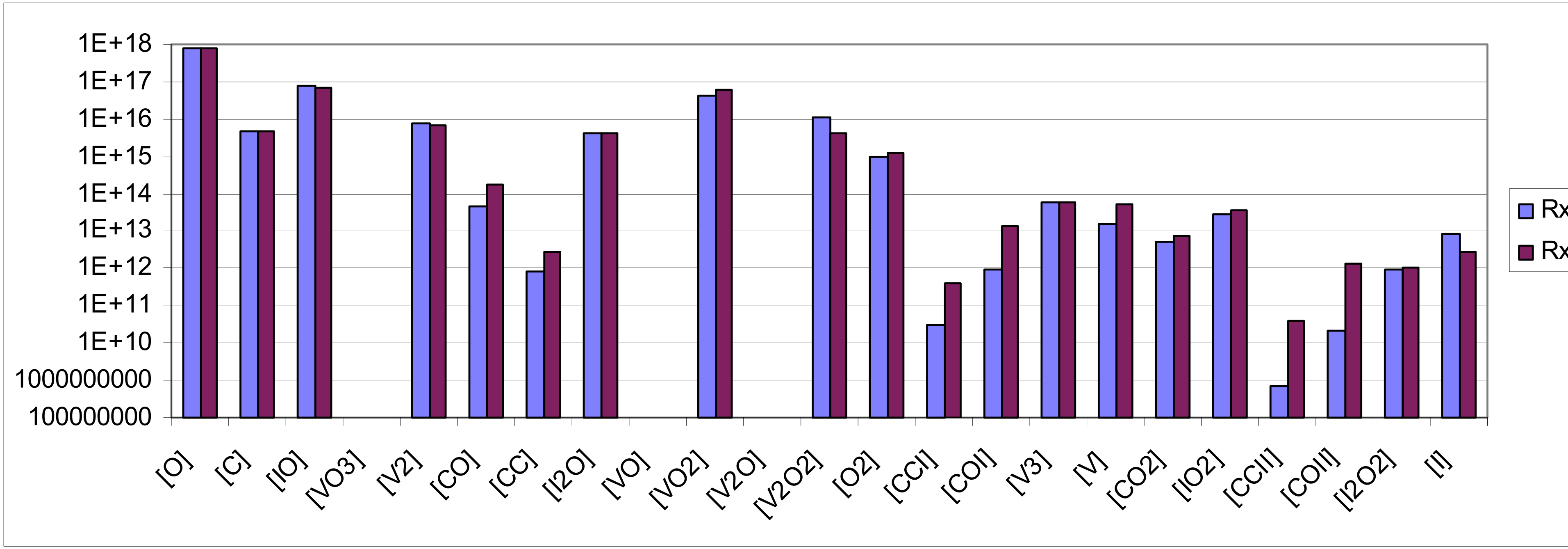
- Fluence: 1×10^{18} e/cm^2
- $[O]=1 \times 10^{18}$ cm^{-3}
- $[C]=5 \times 10^{15}$ cm^{-3}

- Lindstrom et.al.:
  - $[O_2] \sim 5 \times 10^{16}$ cm^{-3}
  - $\rightarrow$Might need to tune Capture Radii Ratios

Defect	Conc (cm-3)
[O]	8.02E+17
[IO]	7.31E+16
[VO2]	5.33E+16
[V2]	7.57E+15
[V2O2]	6.93E+15
[C]	4.90E+15
[I2O]	4.08E+15
[O2]	1.15E+15
[CO]	9.45E+13
[V3]	5.99E+13
[IO2]	3.17E+13
[V]	2.80E+13
[CO2]	6.32E+12
[I]	4.96E+12
[COI]	3.56E+12
[CC]	1.56E+12
[I2O2]	9.95E+11
[COII]	1.73E+11
[CCI]	1.15E+11
[CCII]	5.52E+09

Simulation of dimer irradiation

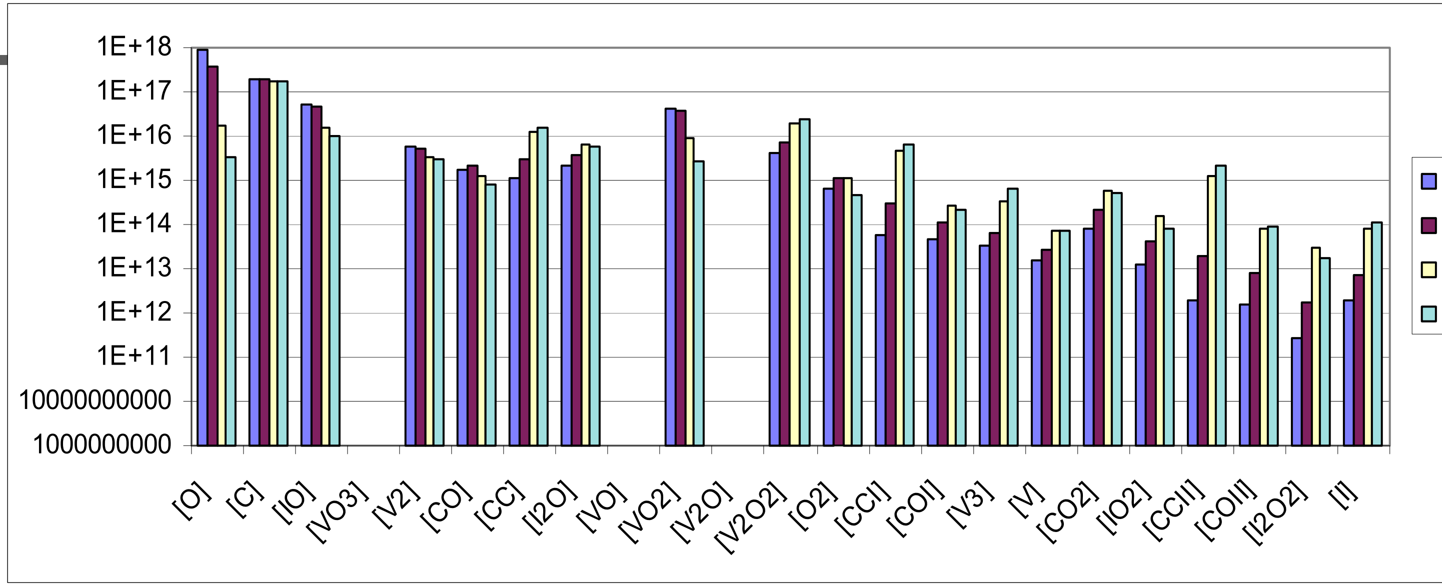
- Dependency on the Capture Radii Ratios

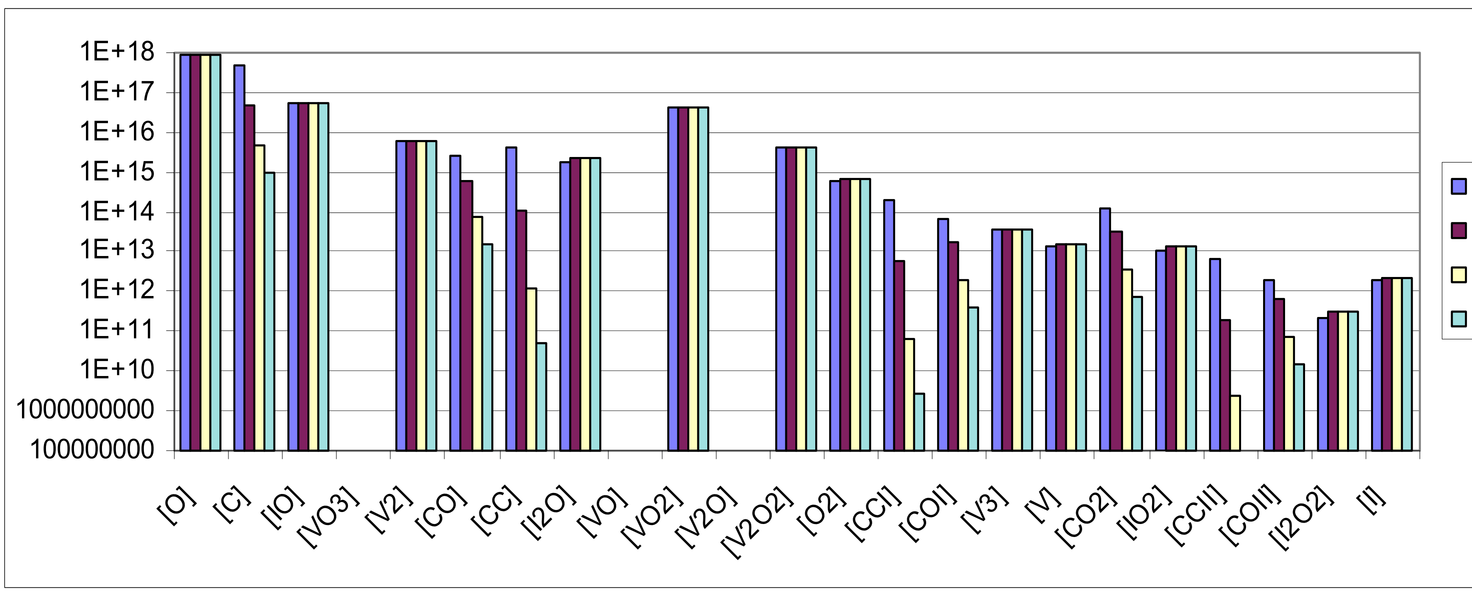


Simulation of dimer irradiation

Dependency on [O] and [C]

	[O]	[C]
1C	1.00E+18	2.00E+17
2C	5.00E+17	2.00E+17
3C	1.00E+17	2.00E+17
4C	7.00E+16	2.00E+17
C1	1.00E+18	5.00E+17
C2	1.00E+18	5.00E+16
C3	1.00E+18	5.00E+15
C4	1.00E+18	1.00E+15





Simulation of dimer irradiation

- Representative of DOFZ
- [O]=4×10^{17} cm^{-3}
- [C]=5×10^{15} cm^{-3}

Defect	Conc (cm-3)
[O]	2.25E+17
[IO]	5.92E+16
[VO2]	3.88E+16
[V2O2]	1.45E+16
[I2O]	9.50E+15
[V2]	6.29E+15
[C]	4.76E+15
[O2]	2.22E+15
[CO]	2.04E+14
[IO2]	1.60E+14
[V3]	1.40E+14
[V]	6.52E+13
[CO2]	3.64E+13
[I]	2.87E+13
[COI]	1.97E+13
[I2O2]	1.37E+13
[CC]	9.40E+12
[COII]	2.64E+12
[CCII]	2.22E+11
[CCI]	1.71E+12

Conclusion

- Dimer experiment progressing
  - Need to find funds
  - Contact us if interested in sharing this irradiation
- Simulation needs some fine tuning
  - Could contain a lot of interesting info!