

Optimization of operational
parameters for current
injection detectors

by

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(selected results of RD39 collaboration)

RD50 collaboration

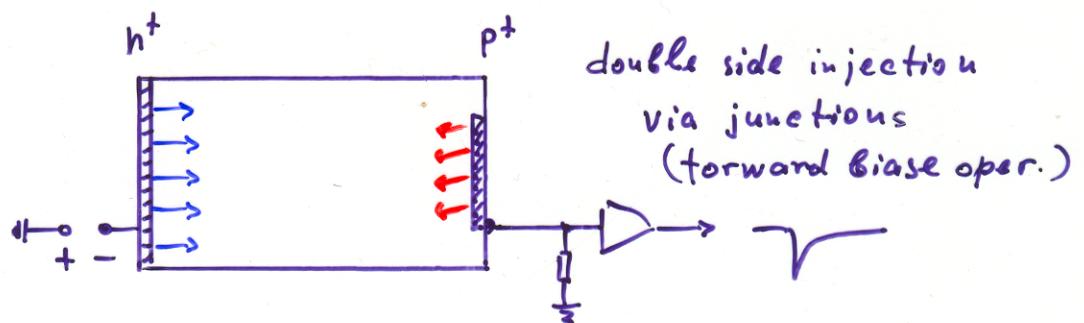
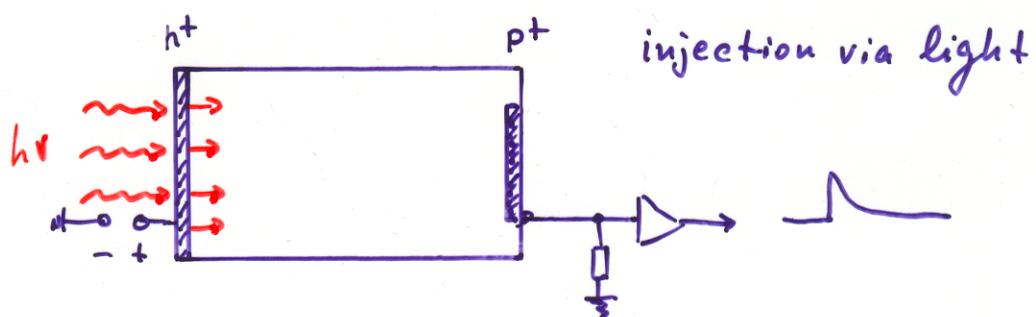
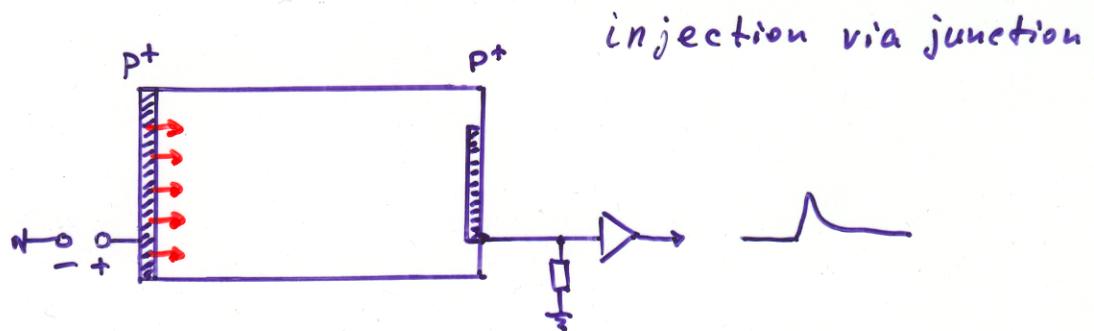
May 5, 2004

CERN

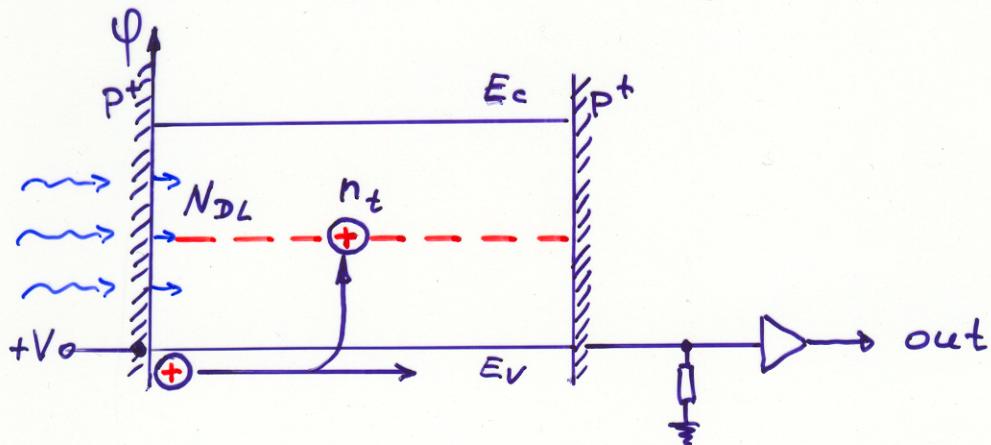
Outline

1. Basic structures of CTDs
2. Physics of operation
3. I-V characteristics
 - SCLC mode
 - Ohmic mode
 - DL saturation effect
4. Temperature effect
5. Preirradiation fluence
6. Conclusions

Basic constructions of CIDs



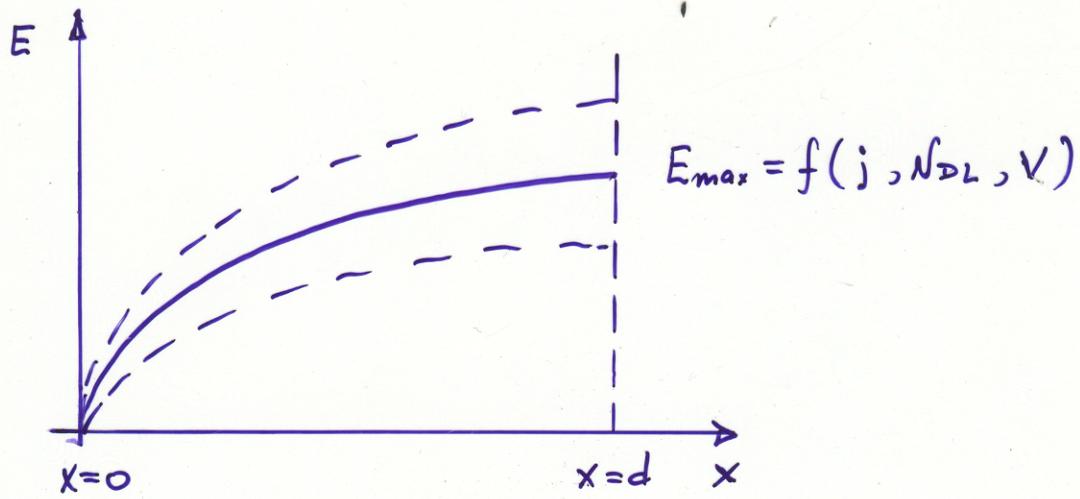
Electric field in CIDS



$$\begin{cases} n_t = F N_{DL} n \\ j = e n M E \\ \frac{\epsilon}{e} \frac{dE}{dx} = n_t \end{cases} \quad F = f(N_e, v, T) [cm^3]$$

at: $E(0) = 0$

$$E(x) = \sqrt{\frac{2F N_{DL} j}{\epsilon M}} \times \frac{1}{2}$$



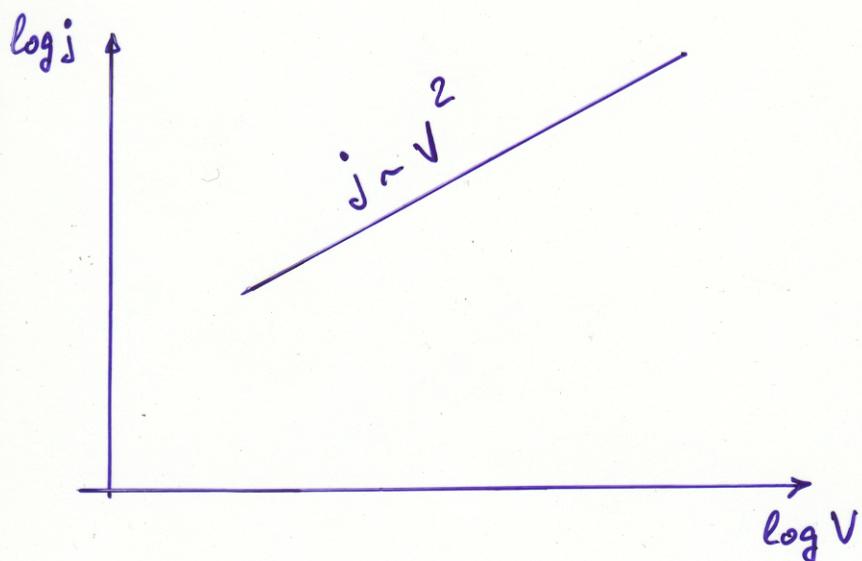
I-V characteristics controlled by
space charge limited current

$$E(x) = \sqrt{\frac{2F N_{DL} j}{\epsilon_m}} \times \frac{1}{2} ; \quad F = f(N_c, T) [cm^3]$$

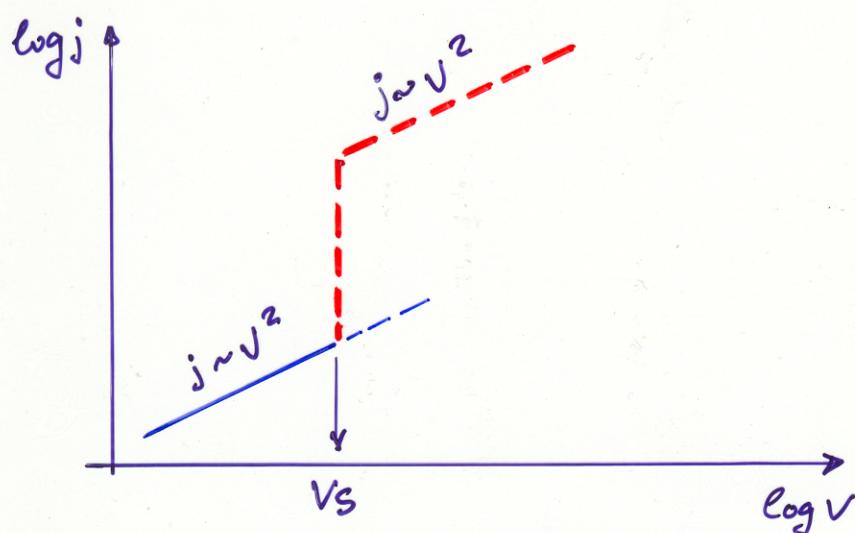
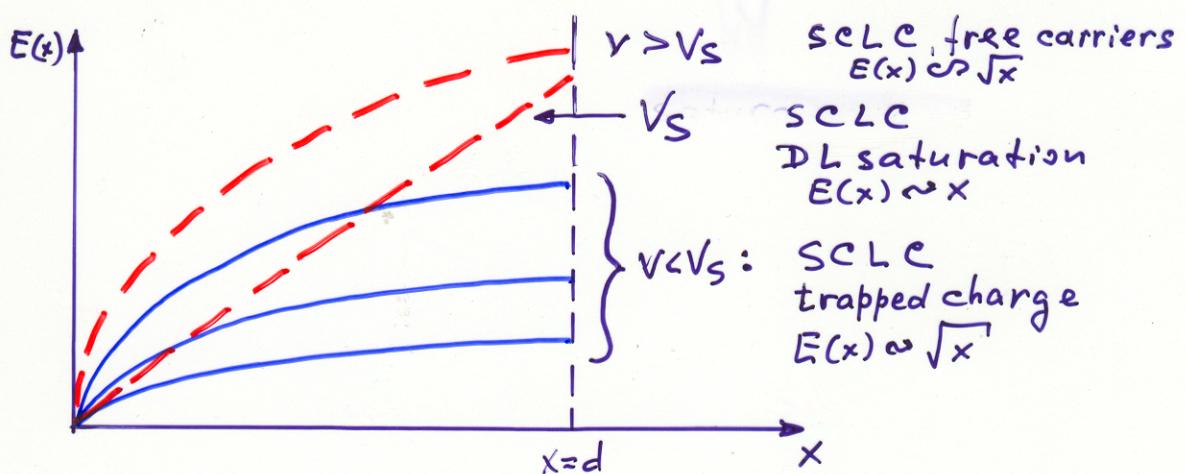
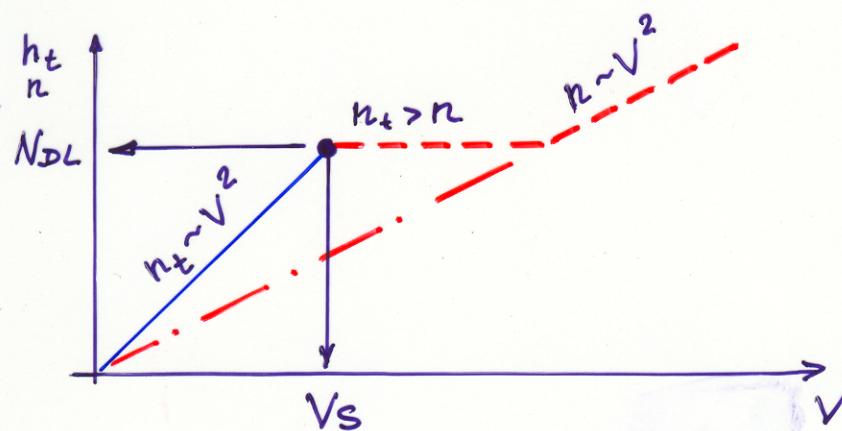
$$V = \int_0^d E(x) dx$$



$$j = \frac{\epsilon_m}{F N_{DL} d^3} V^2$$

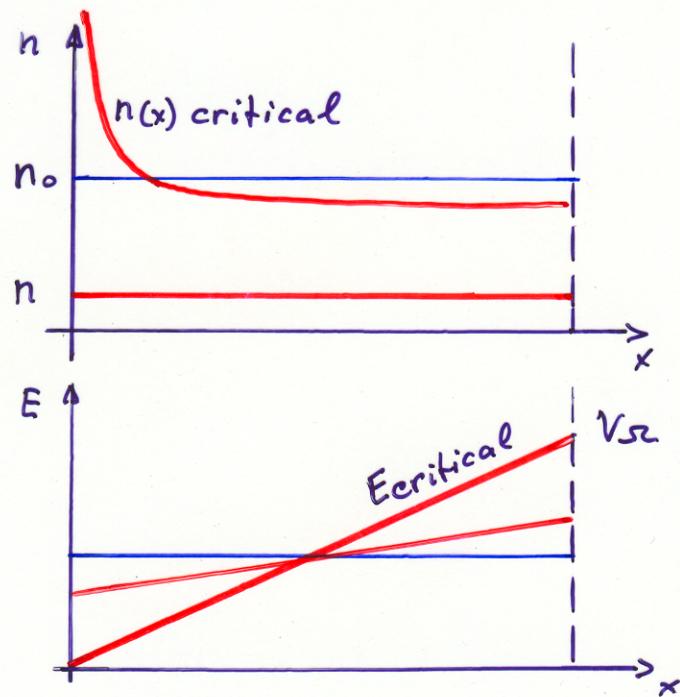


The deep level saturation voltage



$$V_s \approx \frac{e N_{DL} d^2}{\epsilon}$$

Ohmic current mode



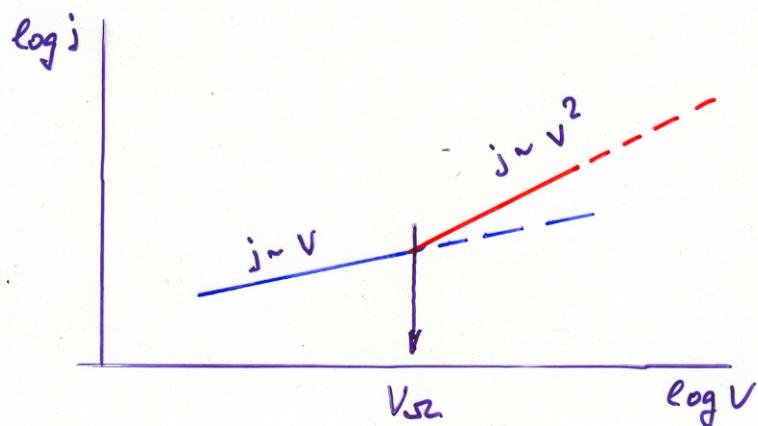
$$j = e n_0 \mu \frac{V}{d} \quad n_0 > n$$

$$E(x) = \frac{V}{d}$$

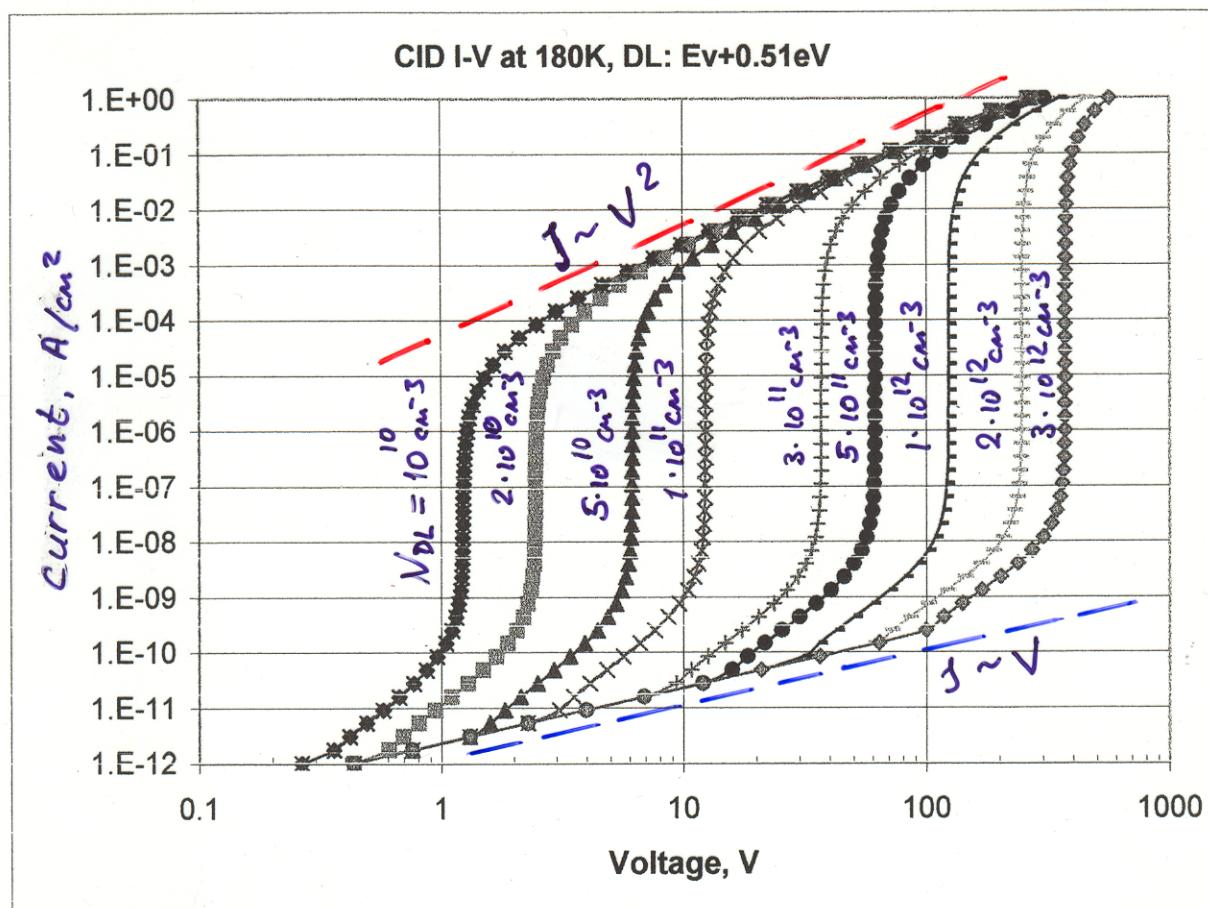
Transition from Ohmic to SCLC mode

$$Q_{inj} = n_0 \cdot d$$

$$V_{S2} = \frac{e F N_{DL} n_0 d^2}{\epsilon}$$



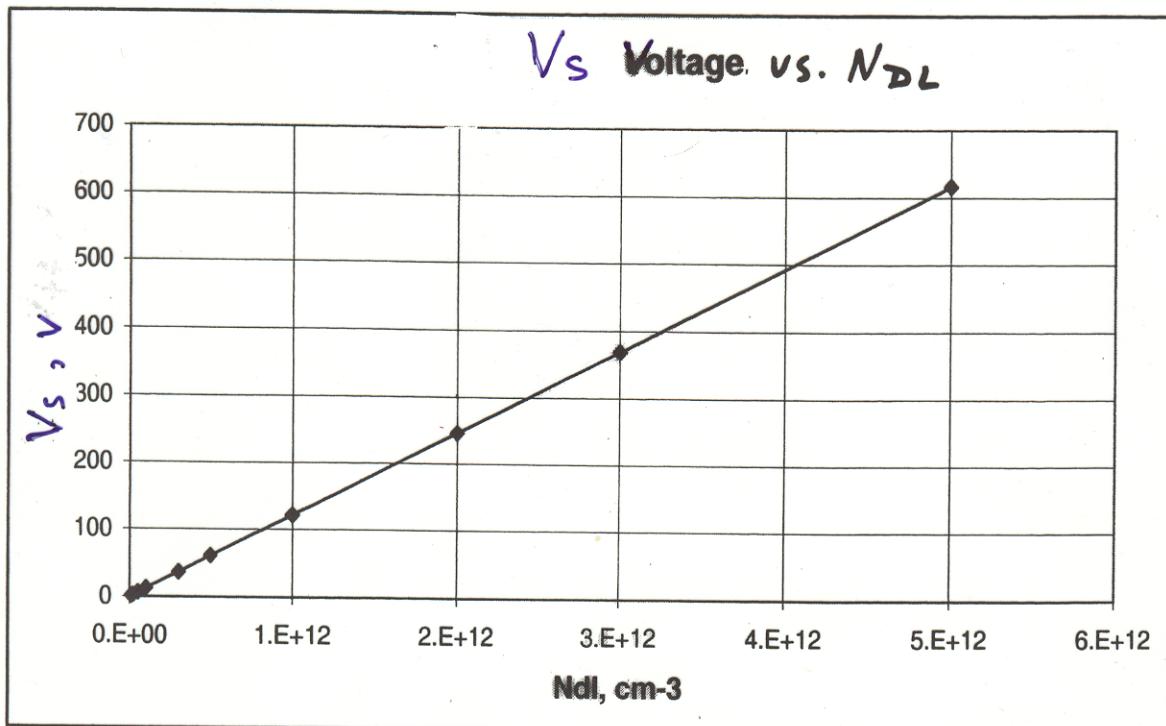
I-Vs simulation result



DL parameters: T=180K, Ev+0.51, d = 400 μm

DL #	Ci-Oi	V-V	3	4
$h/e, 0/1$	0	1	0	1
	electrons	electrons	electrons	electrons
Et=Edl-Ev	0.4	0.7	0.51	0.61
sig/e[cm²]	1.00E-15	1.00E-17	1.00E-15	5.00E-15
sig/h[cm²]	1.00E-15	1.00E-15	1.00E-15	5.00E-15
Ndl[cm⁻³]	0.00E+00	0.00E+00	3.00E+12	0.00E+00
Sig*Vth	1.61E-08	1.22E-08	1.61E-08	1.22E-08
detrap.prob.	1.54E-09	4.19E-01	3.81E-03	1.70E-09

CID operational voltage limit
related to DL saturation effect

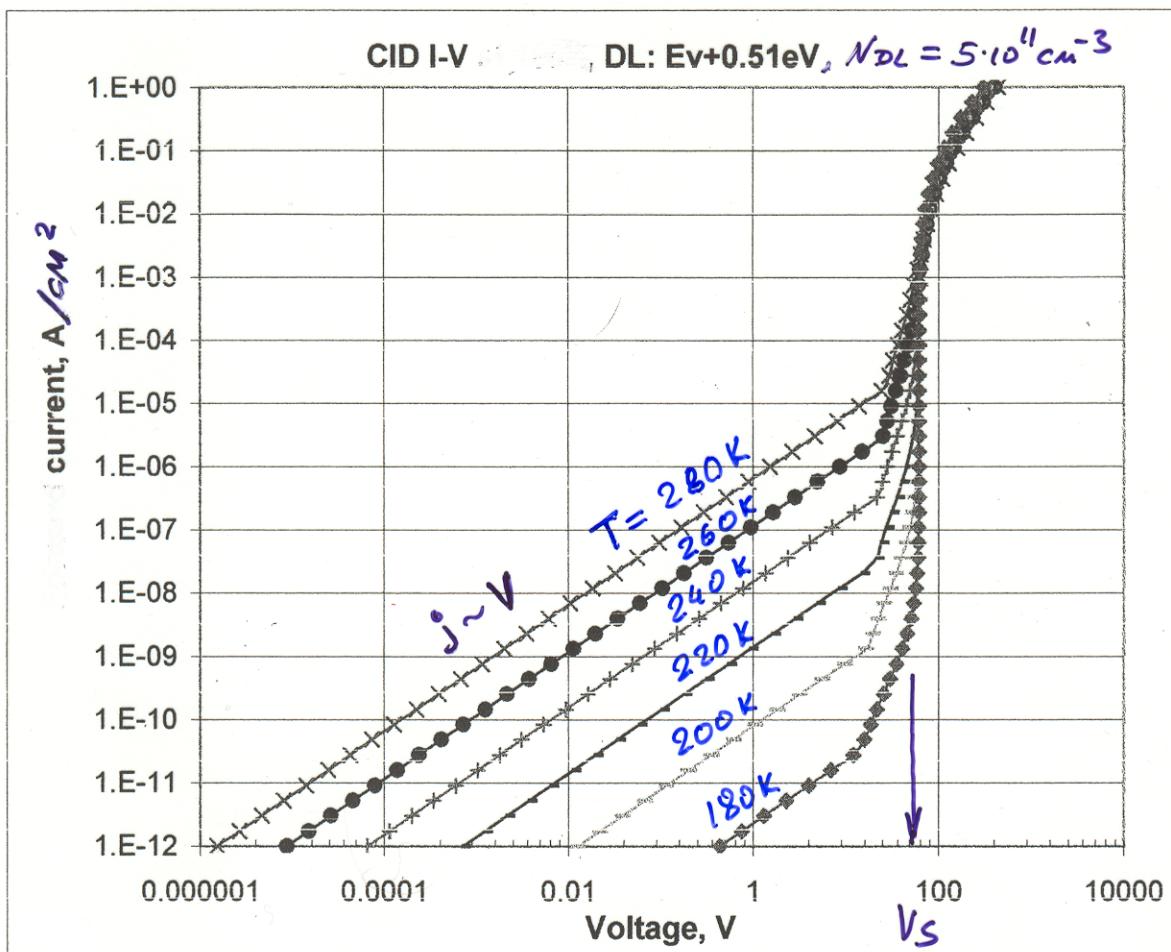


$$V_{max} \sim N_{DL}$$

Note !

The N_{DL} is an "active" fraction
of the total concentration of DL

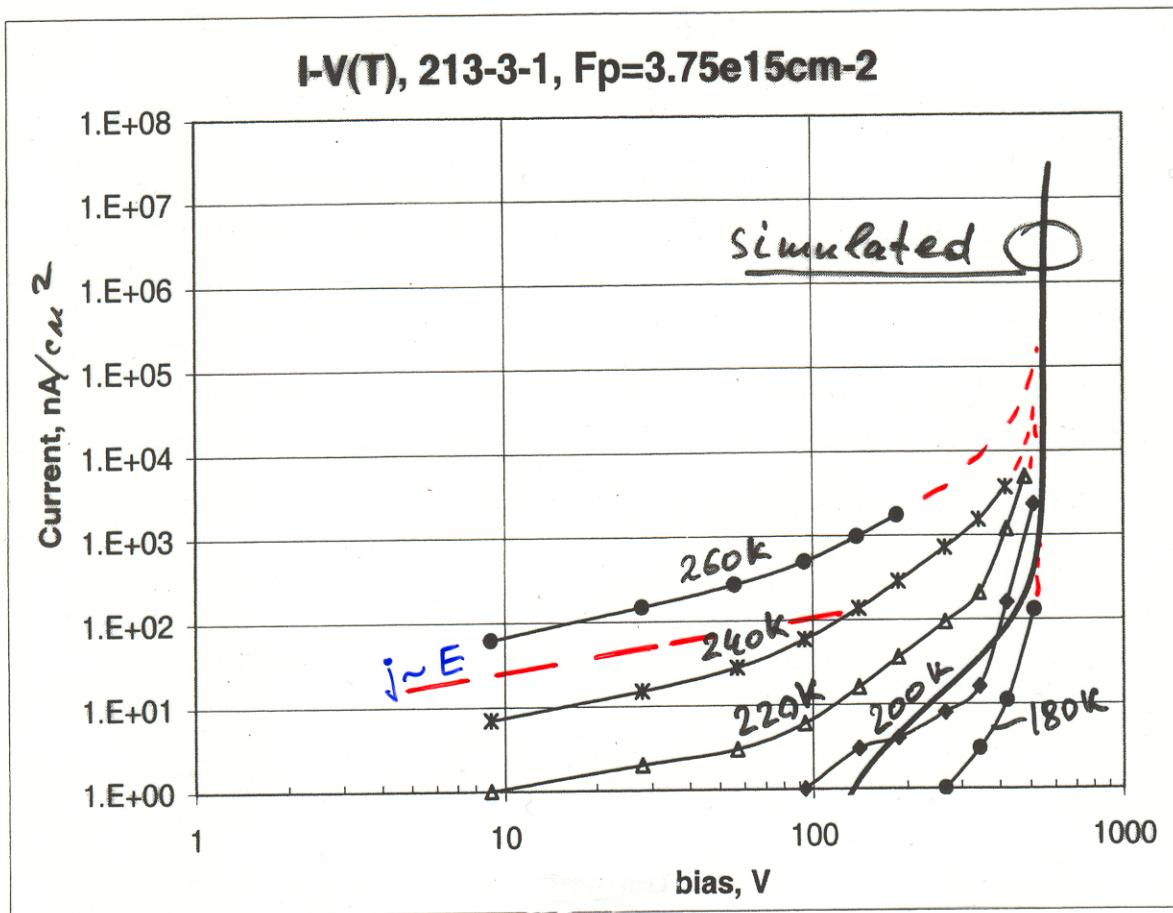
CID I-Vs at different temperature



Notes:

1. $V_s \neq f(T)$
2. Smoothed transition between Ohmic and SCLC parts

Experimental I-Vs treatment



Parameters for simulation:

DL: h⁺-trap, $\bar{N}_n = \bar{N}_p = 10^{15} \text{ cm}^{-3}$, $E_V + 0.537 \text{ eV}$

$$N_{DL}^+ = 4.5 \cdot 10^{12} \text{ cm}^{-3}$$

$$T = 200 \text{ K}$$

$$d = 400 \mu\text{m}$$

Observed correlations:

1. DL saturation is observed.
2. $V_s \neq f(T)$
3. At low $V \rightarrow j \sim E$ (Ohmic current)
4. Transition from Ohmic \rightarrow SCLC \rightarrow DL saturation

Conclusions

1. CIDs I-V curves are well predicted in the frame of SELC model
2. The maximal CID operational voltage is limited by DL saturation voltage
3. The Vs is a linear function on NDL
4. The operational temperature does not effect on Vs and can be optimize for appropriate S/N ratio