Conductivity Study of CVD-diamond detectors

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Contributing...

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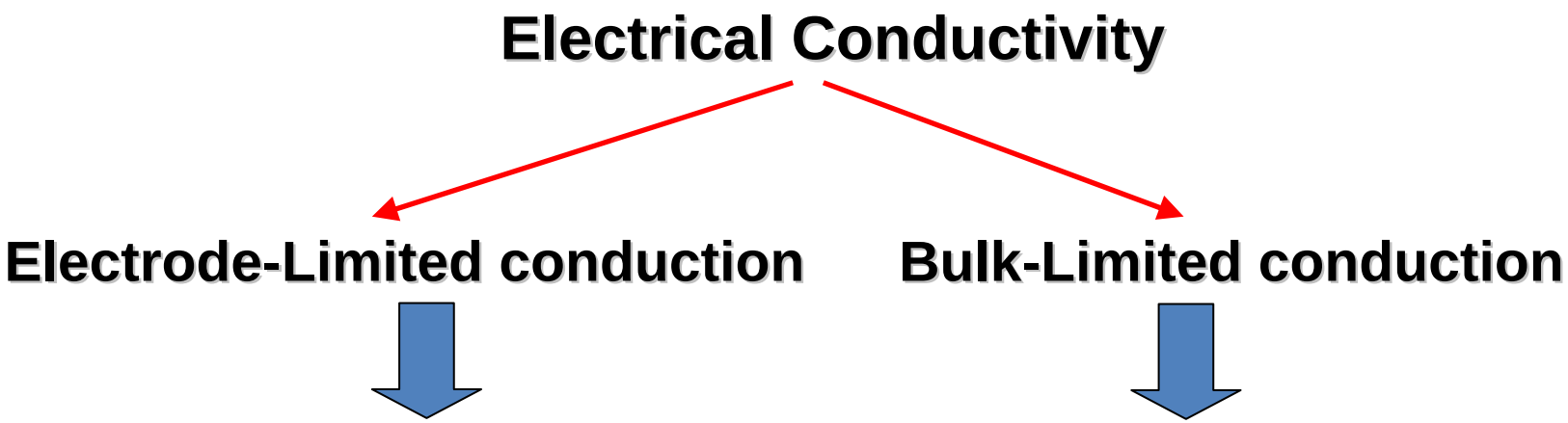
- S. Dunst
- M. Pomorski
- Detector Laboratory, GSI
- Target Laboratory, GSI

Outlines

- Introduction
- *I-V* characteristics of CVD Diamond Detectors
- Dark conductivity study of CVD Diamond materials
  1. Homoepitaxial CVD Diamonds, both sc and sc coating with DLC
  2. Heteroepitaxial quasi sc CVD Diamond on Ir (DoI)
- Summary

Introduction

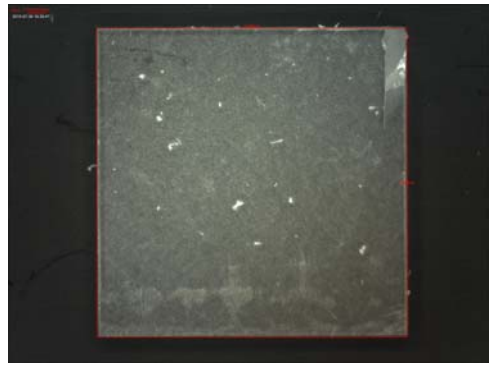


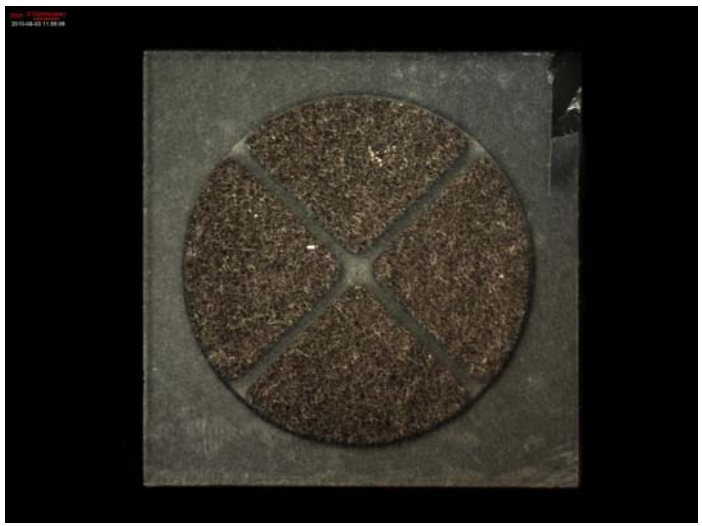
1. Schottky (Thermionic) emission
2. Tunneling
   (i) Direct Tunneling (DT)
   (ii) Fowler Nordheim (FN)

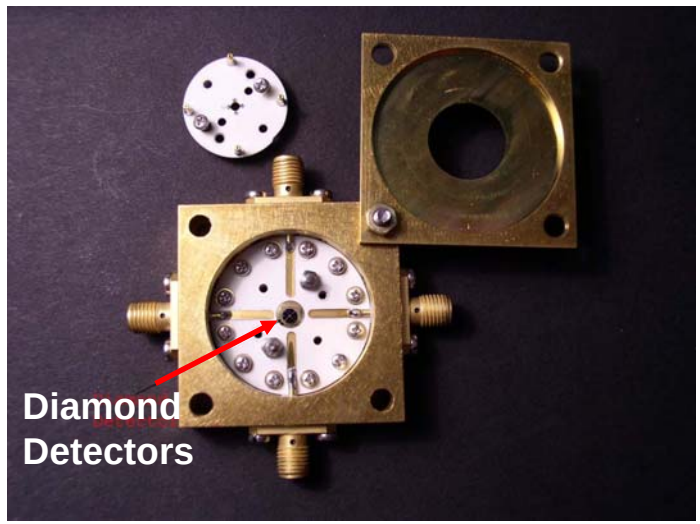
1. Space-charge limited conduction (SCLC)
2. Poole-Frenkel (P-F) conduction
3. Trap Assisted Tunneling (TAT)

Diamond Detectors

Diamond

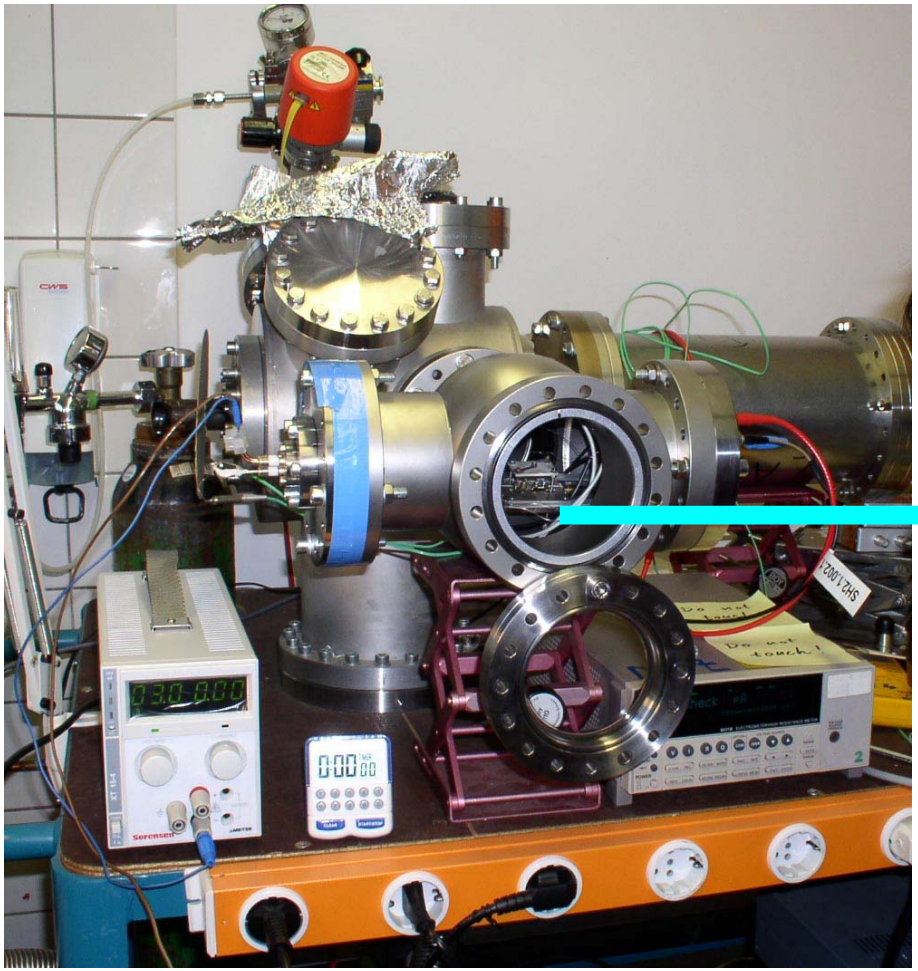




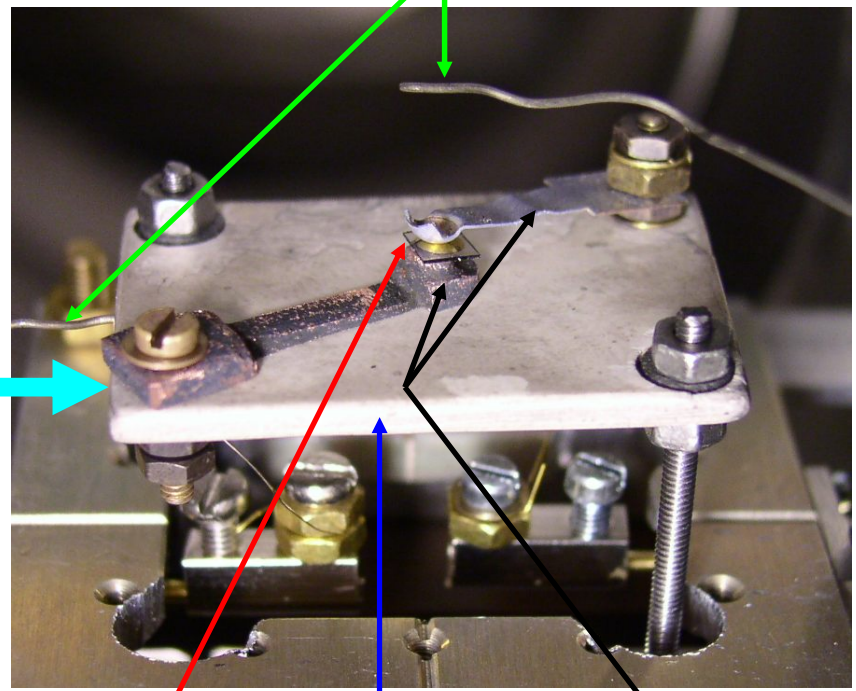


Diamond Detectors

Measurement setups



Temperature Sensors

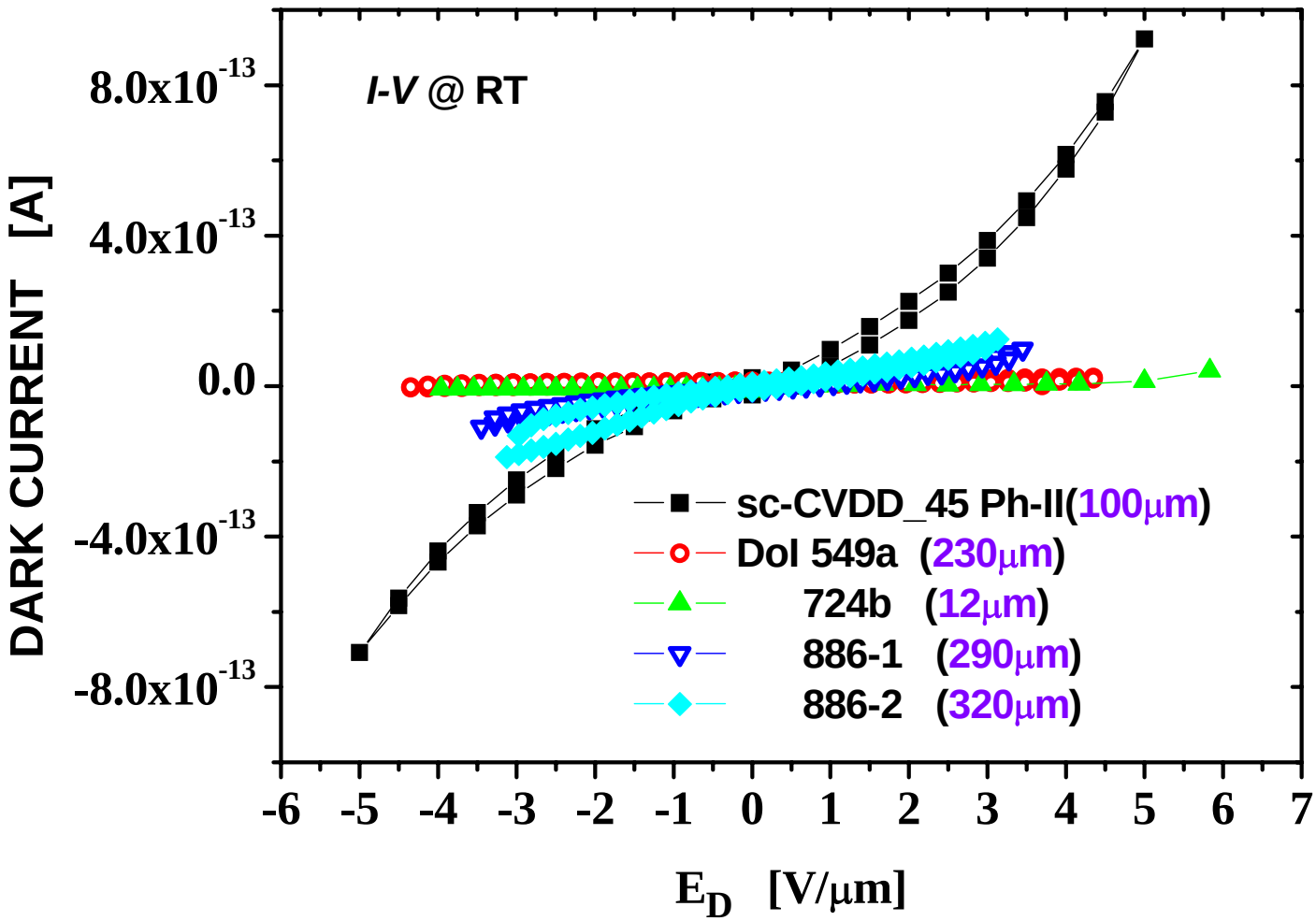


Diamond Detector

Electrodes

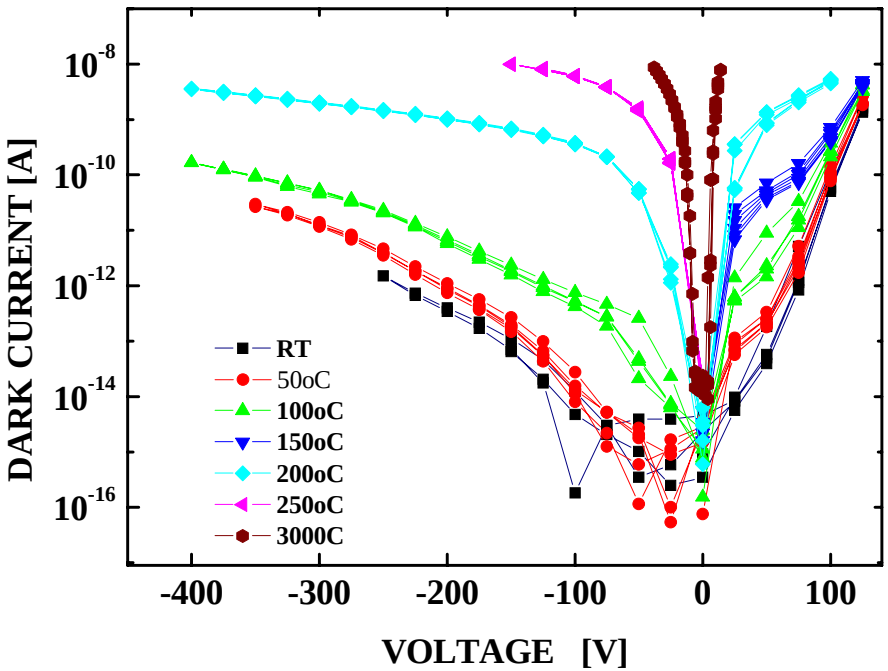
Ceramic

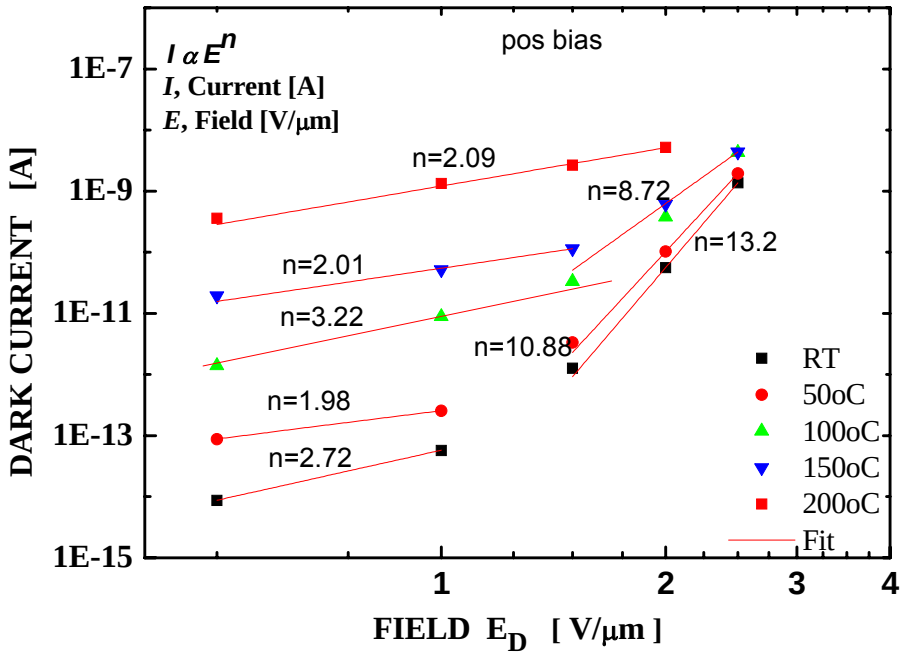
I-E characteristics CVDD Detectors



Electrical conduction of scCVDD

scCVDD 10B50 (50μm)
(Al-Dia-Al)

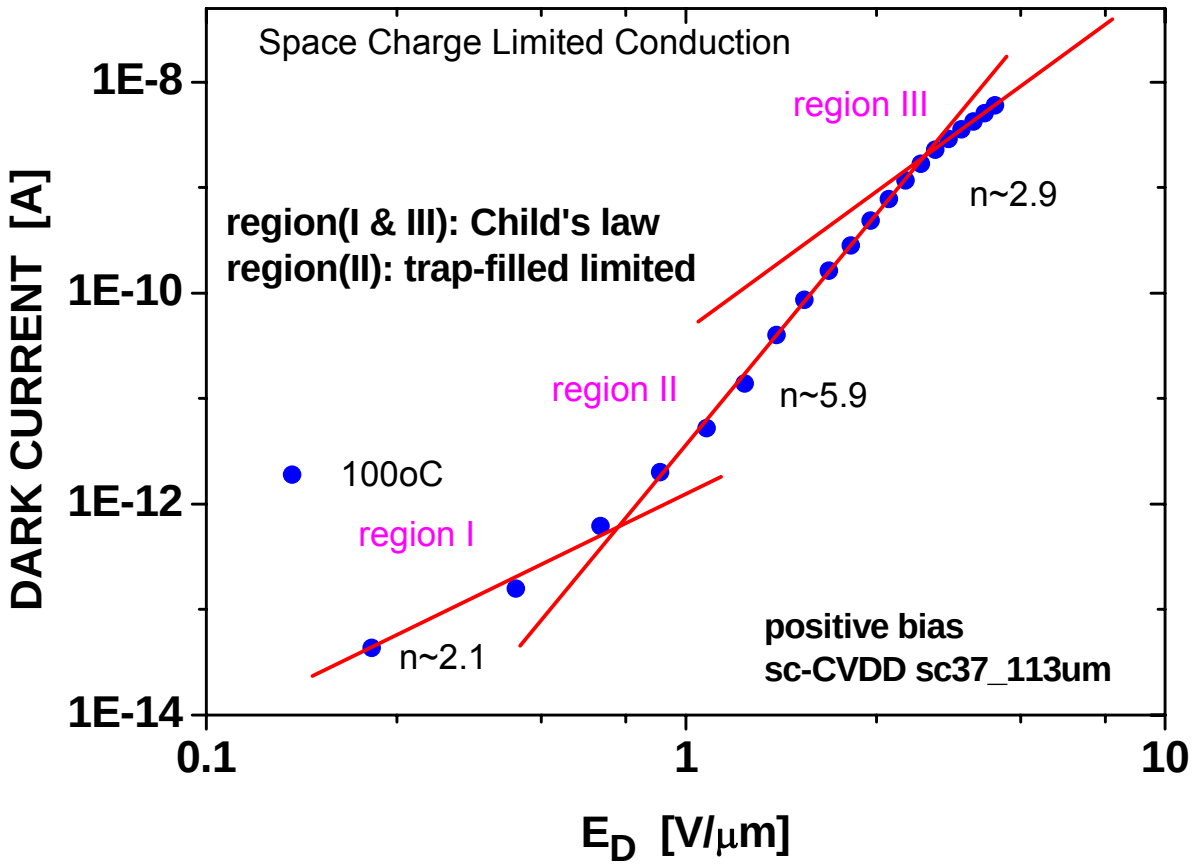




***I-V* characteristics at higher temp** **I-E characteristics, SCLC**

Space Charge Limited Conduction (SCLC)

sc37_113μm (Al/DLC-Dia-DLC/AL)



theory of SCLC

$$I_{Child} = \frac{9}{8}\mu\varepsilon\frac{V^2}{d^3}$$

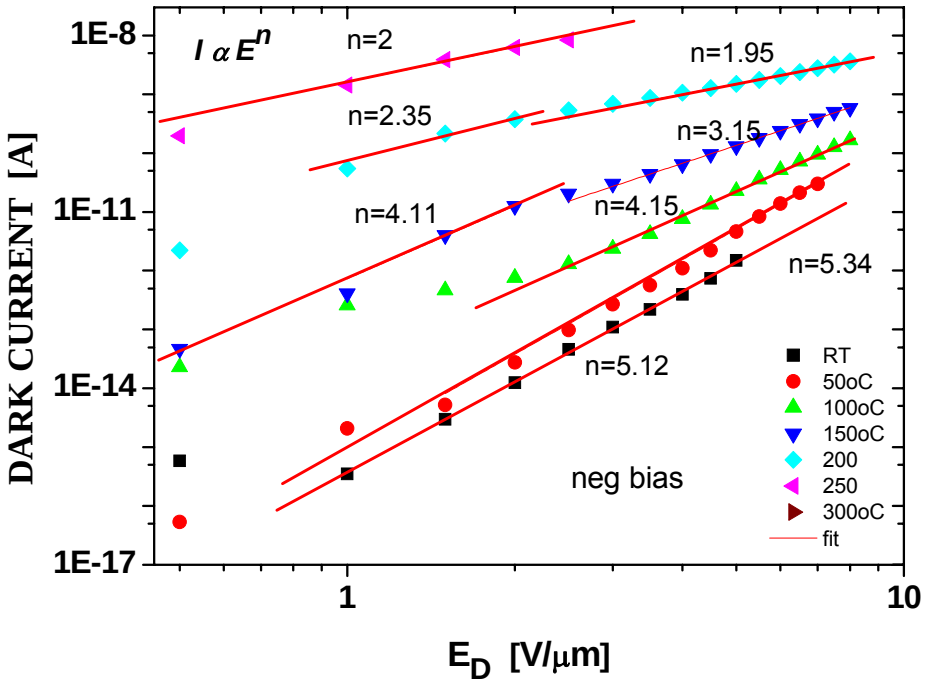
$$I_{TFL} = \frac{9}{8}\mu\varepsilon\theta\frac{V^2}{d^3}$$

Here,
μ electronic mobility
V applied bias
d thickness
ε dielectric constant

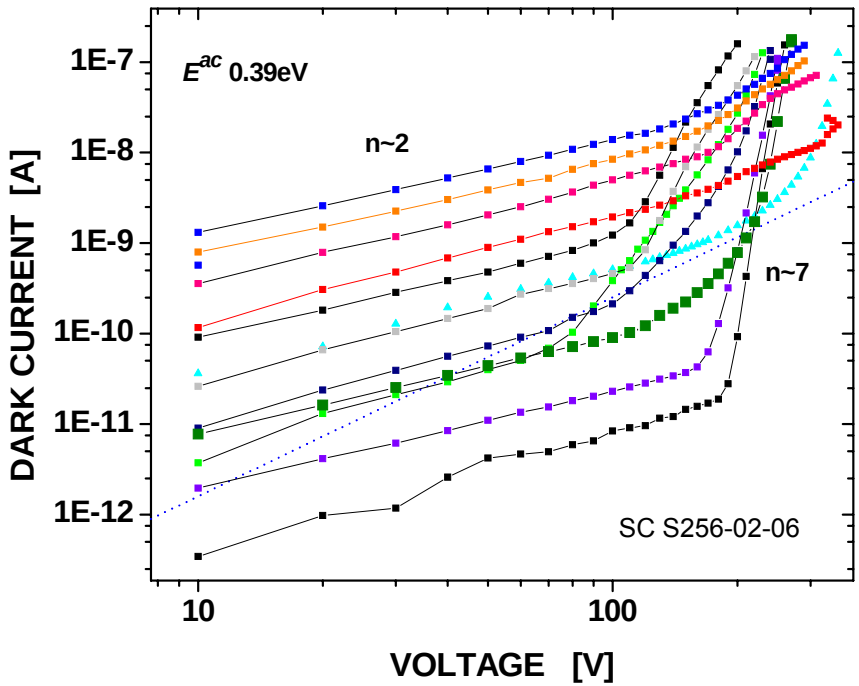
$$\theta = \frac{free\_Carrier\_Density}{Total\_Carrier\_Density}$$

Electrical conduction of scCVDD

scCVDD 10B50 (50μm)
(Al-Dia-Al)



scCVDD s256-02-06

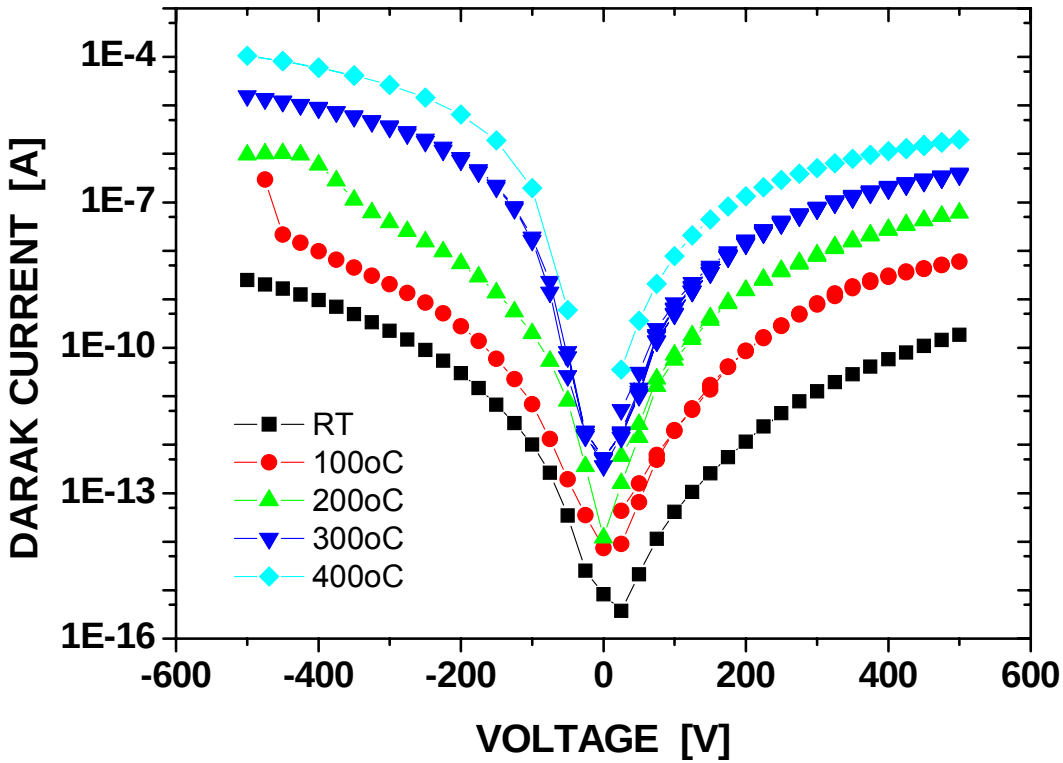


I-E characteristics, SCLC

Michal Pomorski
PhD thesis 2008

I-V characteristics of scCVDD with DLC coating

sc37_113μm
(Al/DLC-Dia-DLC/AL)



I-V characteristics at higher temp.

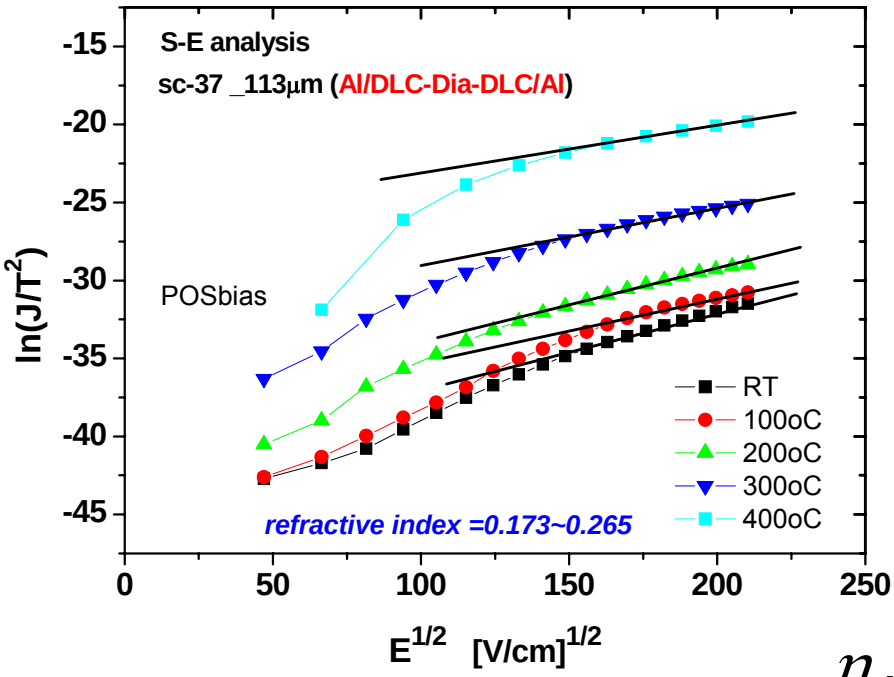
Electrical conduction of scCVDD with DLC coating

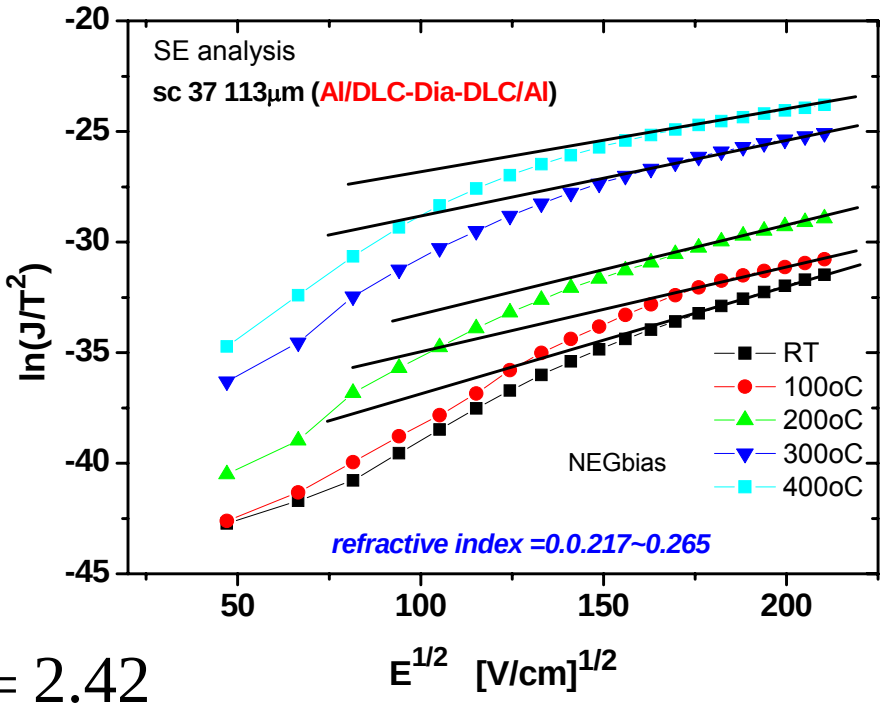
S-E

$$J = A^{*}T^{2}\exp\left[\frac{-q(\phi_b - \sqrt{qE_D/4\pi\kappa_d\varepsilon_o}}{k_bT}\right]$$

$$\ln(J/T^2) \propto E_D^{1/2} \qquad \eta^2 = \kappa_d$$

scCVDD sc37 (113μm)
(Al/DLC-Dia-DLC/AL)





$$\eta_{dia} = 2.42$$

Schottky emission (S-E) conduction ? **NO**

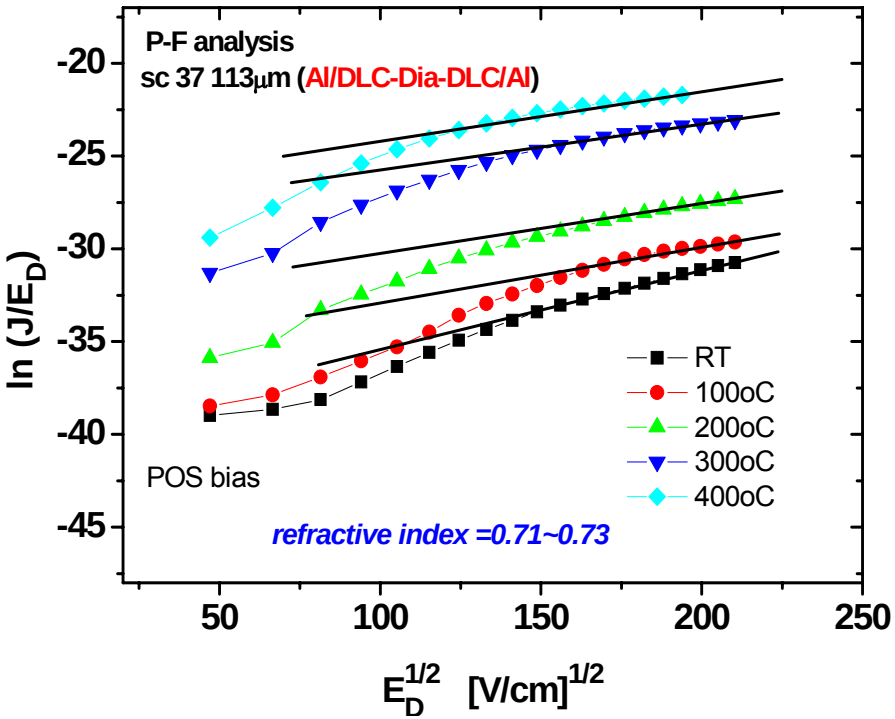
Electrical conduction of scCVDD with DLC coating

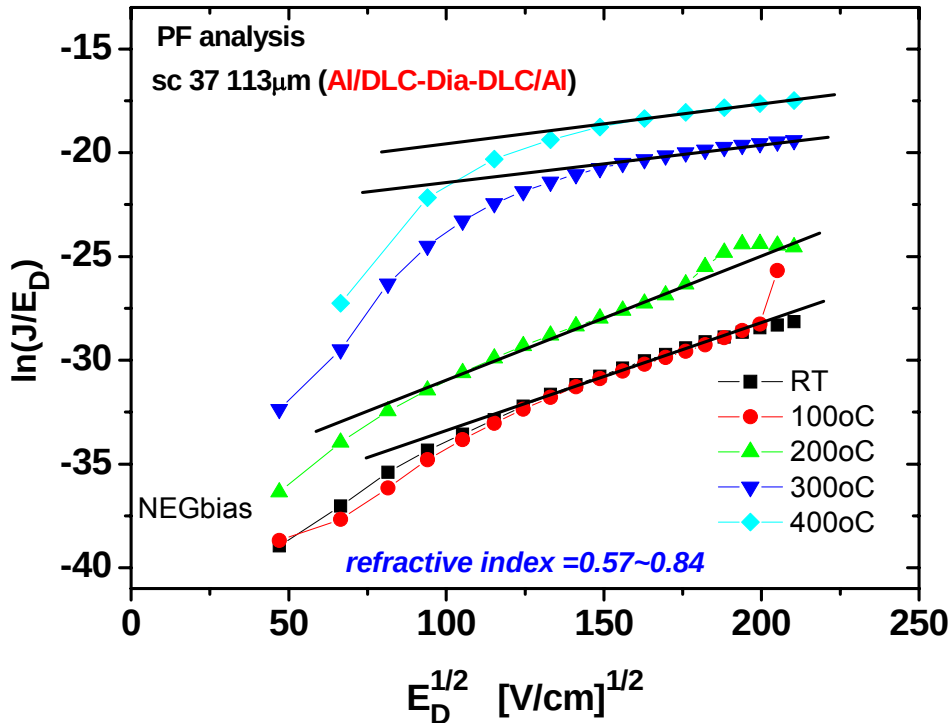
P-F

$$J = C_t E_D \exp\left[\frac{-q(\phi_t - \sqrt{qE/\pi\kappa_d\varepsilon_o}}{k_b T}\right]$$

$$\ln(J/E_D) \propto E_D^{1/2} \qquad \eta^2 = \kappa_d$$

scCVDD sc37 (113μm)
(Al/DLC-Dia-DLC/AL)

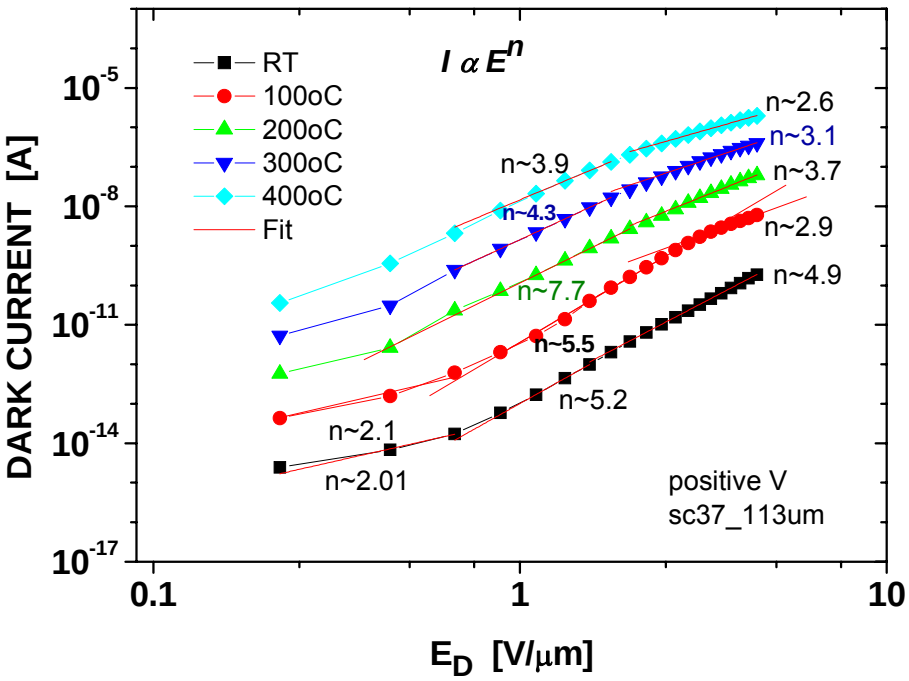


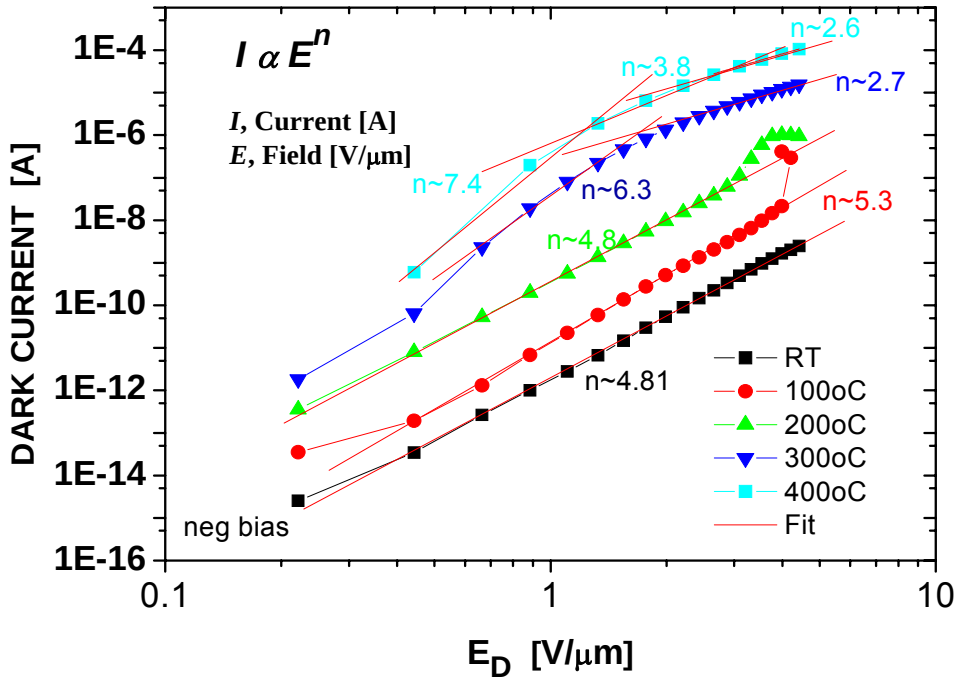


Poole-Frenkel (P-F) conduction ? **NO**

Electrical conduction of scCVDD with DLC coating

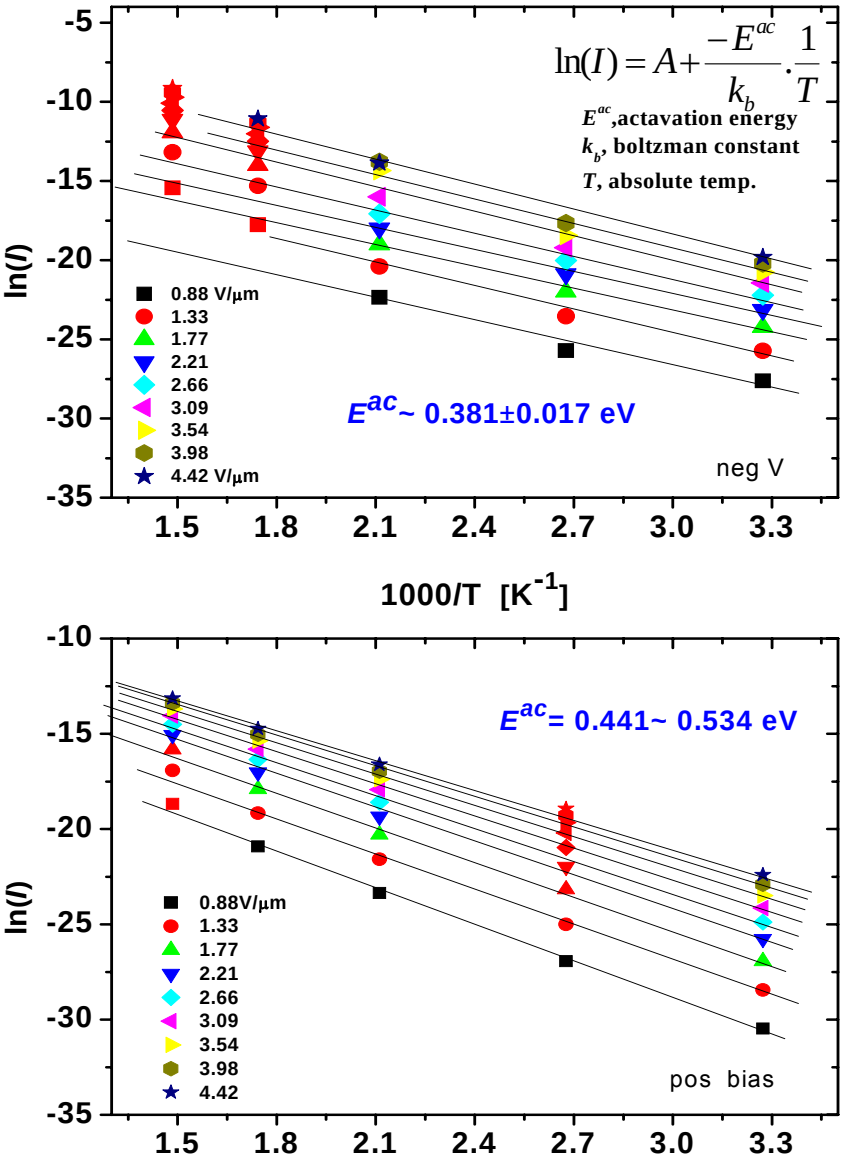
scCVDD sc37 (113μm)
(Al/DLC-Dia-DLC/AL)



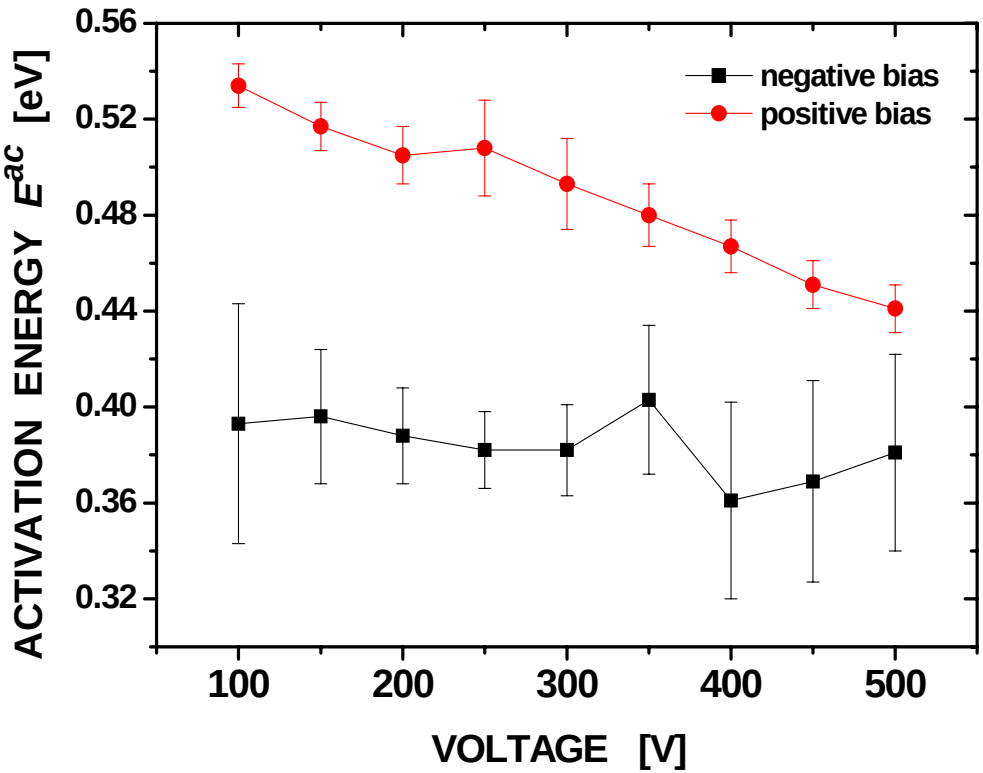


I-E characteristics, SCLC

E^{ac} of scCVDD with DLC coating

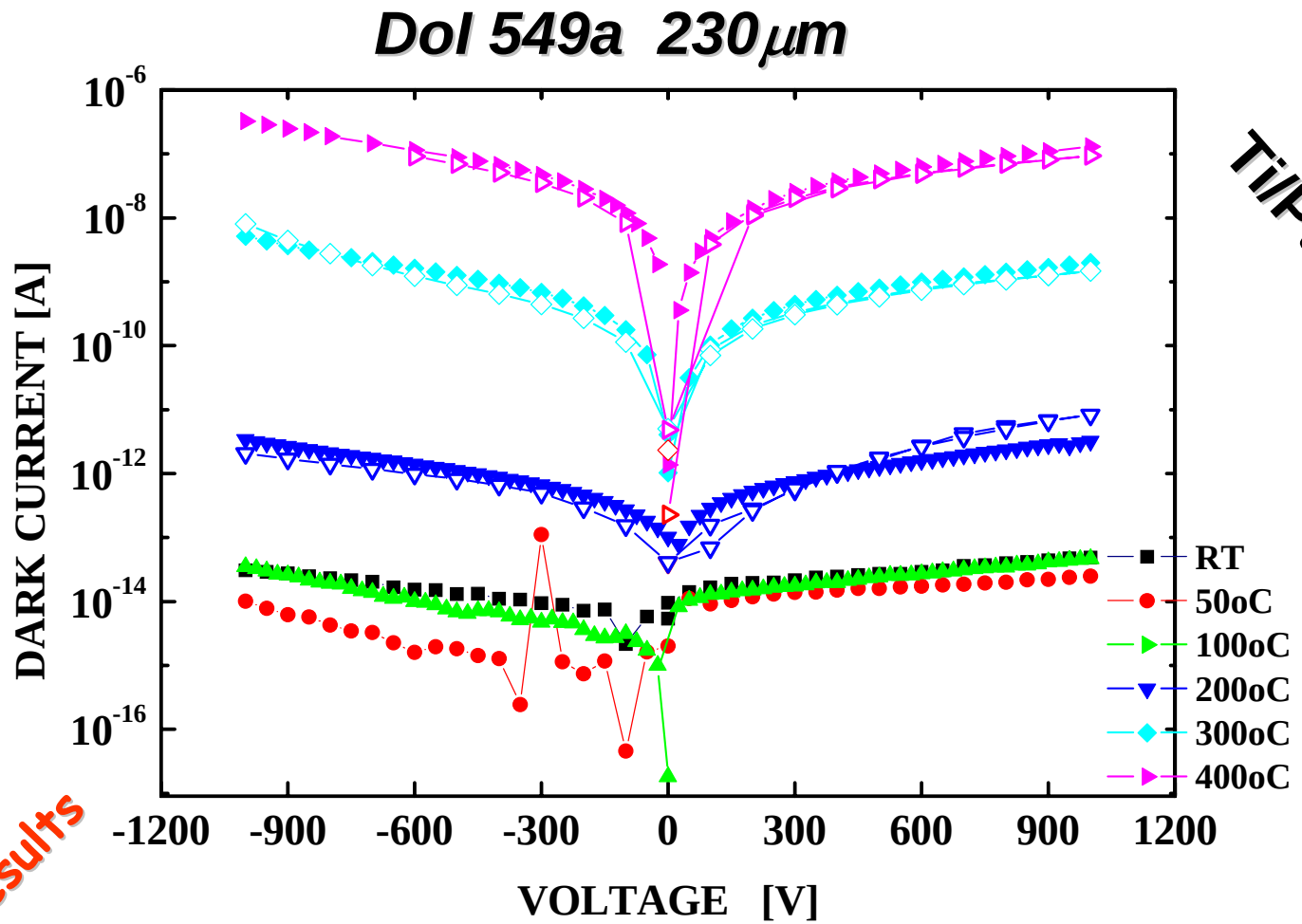


scCVDD sc37 _ 113mm (Al/DLC-Dia-DLC/Al)



Activation Energy of the trap

I-V characteristics of Early DoI

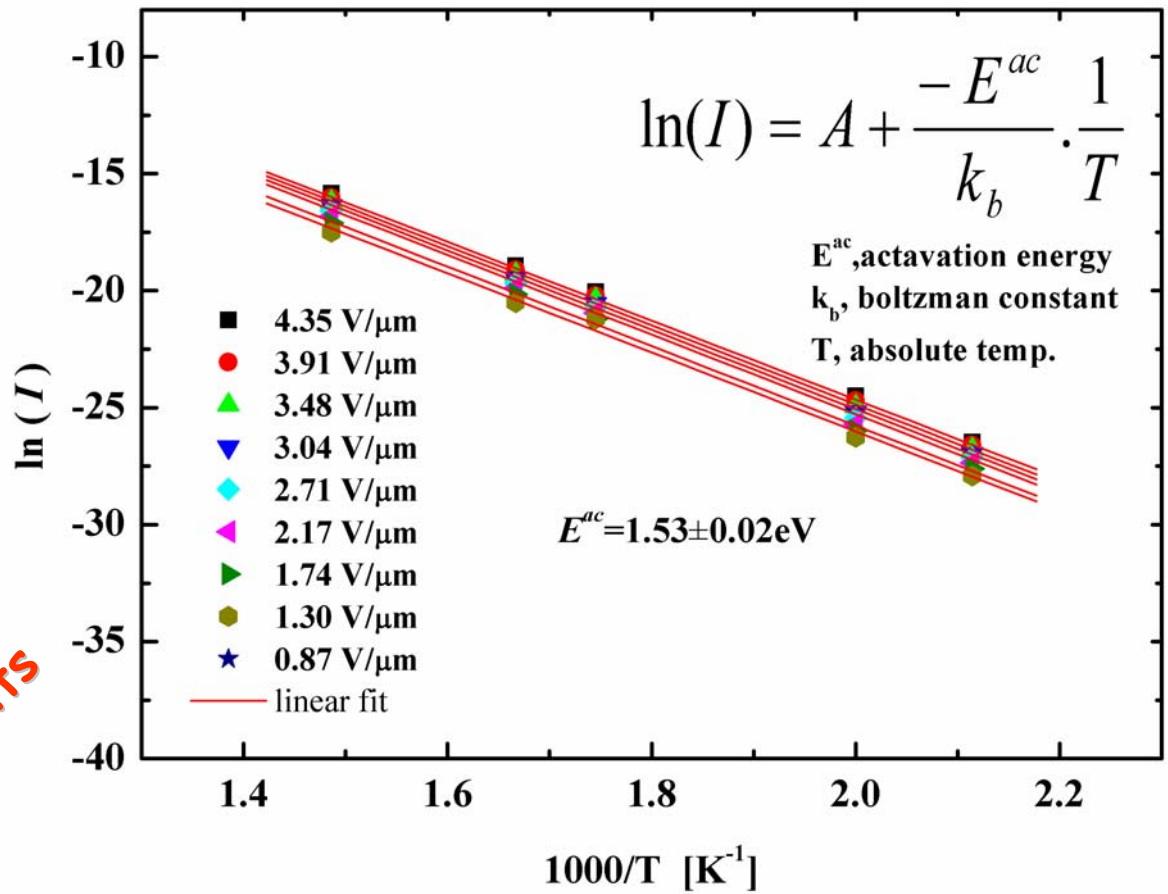


Early Results

I-V characteristics at higher temp.

Activation energy of Early DoI

DoI 549a 230μm



Early Results

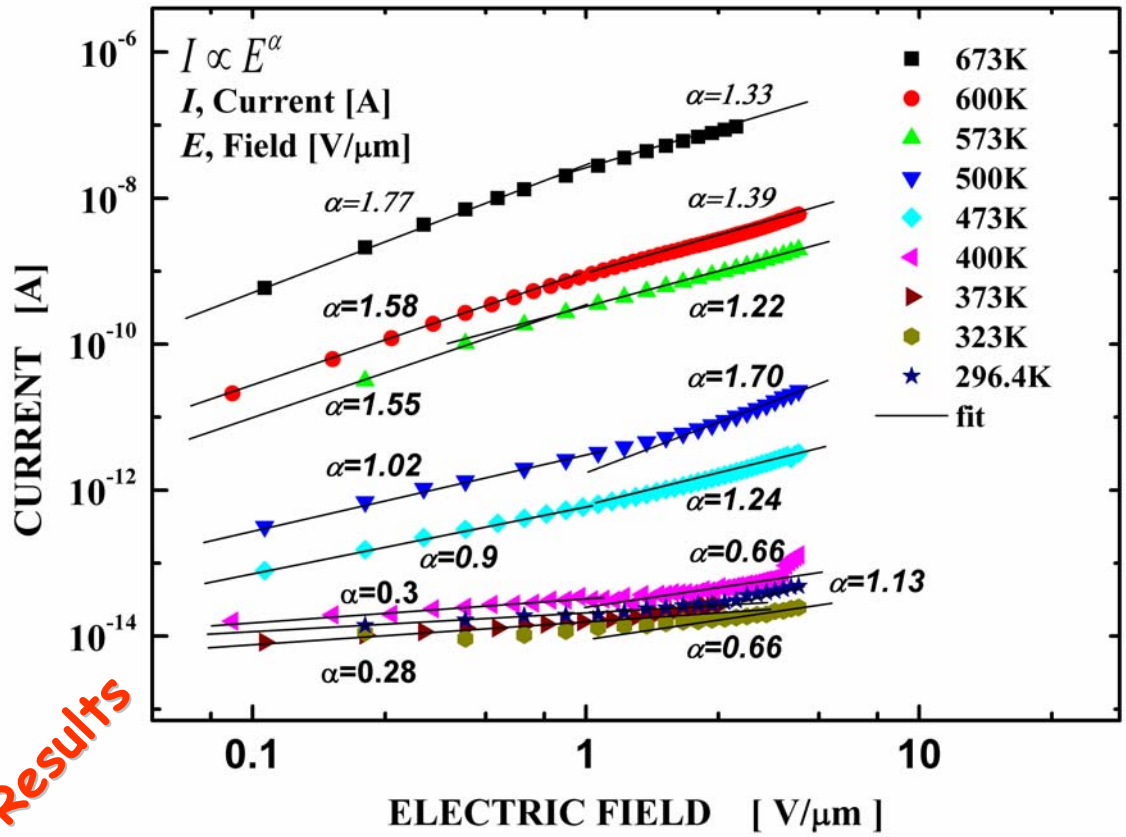
Ti/Pt/Au & Al

Activation Energy of traps E^{ac}=1.53±0.01 eV

Ref. Eac=1.4eV; A. Stolz, et al.,DRM 2006

Electrical conduction of early DoI

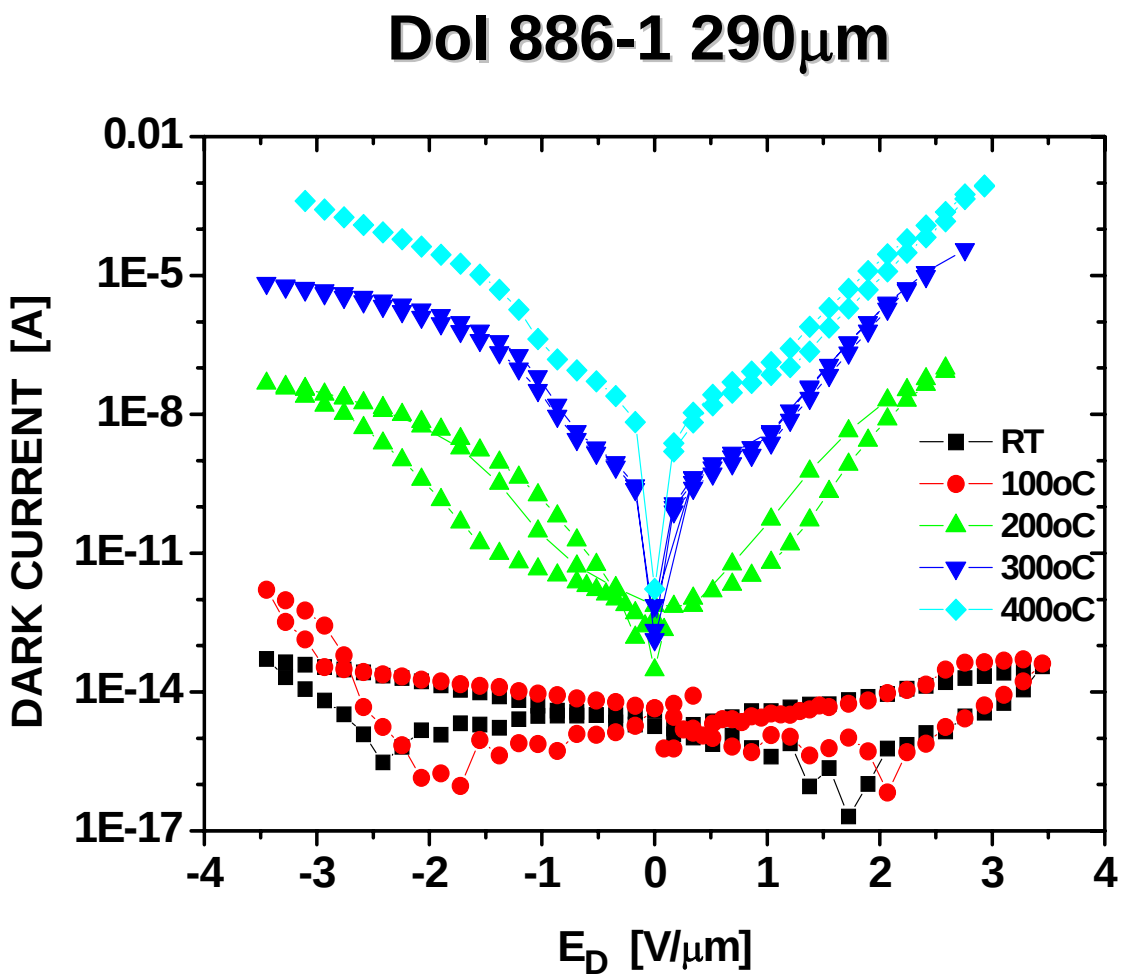
DoI 549a 230μm



Early Results

I-E characteristics Dark conductivity ??

Electrical (I-E) Characteristics of DoI



I-V characteristics at higher temp.

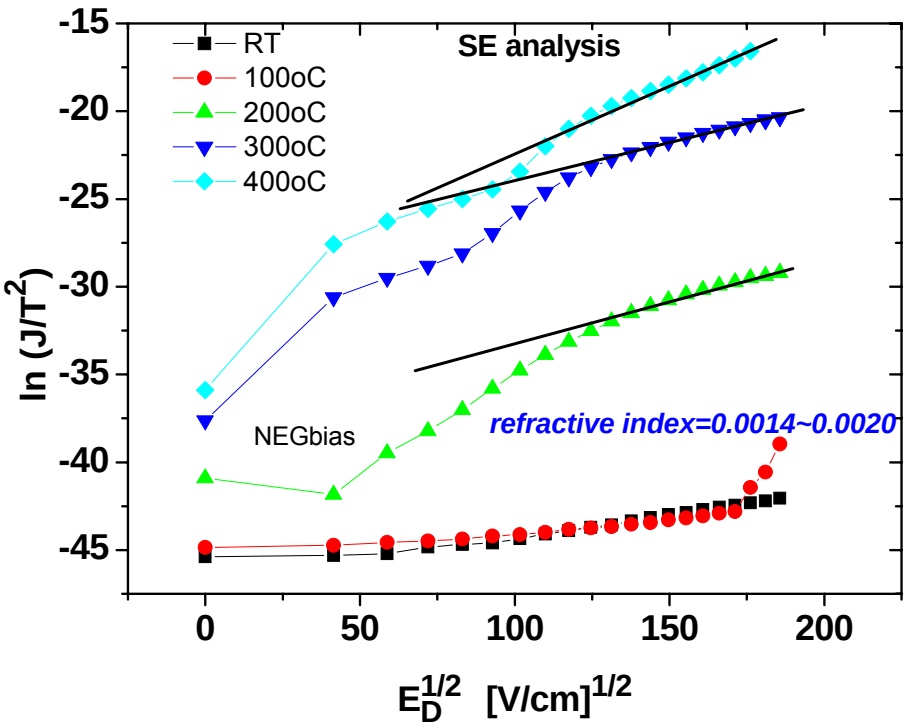
Electrical conduction of DoI

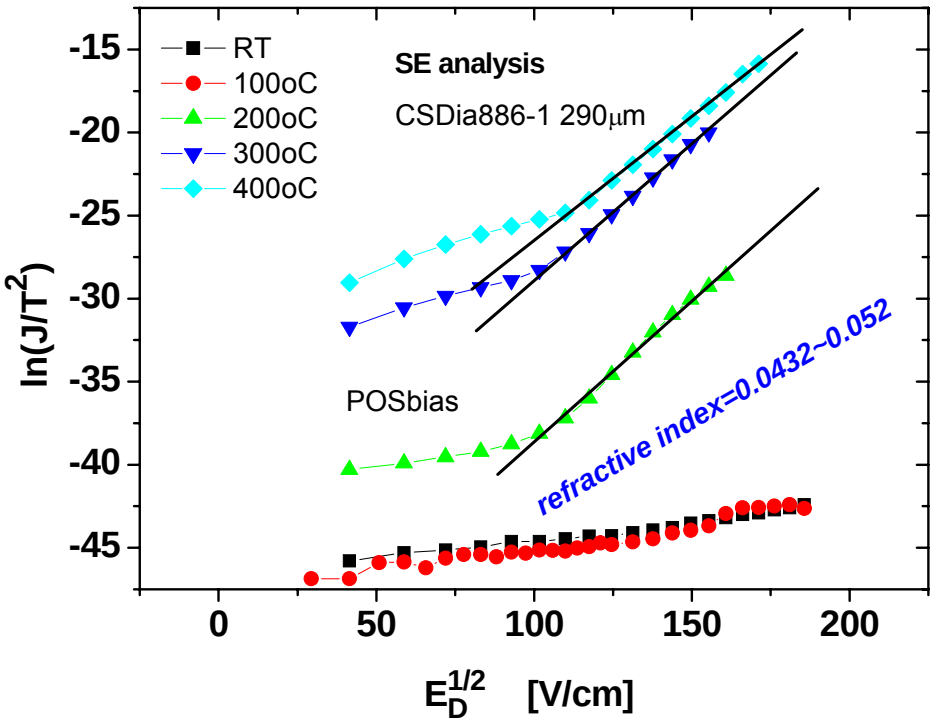
S-E

$$J = A^{*}T^{2}\exp\left[\frac{-q(\phi_b - \sqrt{qE_D/4\pi\kappa_d\varepsilon_o}}{k_bT}\right]$$

$$\ln(J/T^2) \propto E_D^{1/2} \qquad \eta^2 = \kappa_d$$

DoI 886-1 290μm





Schottky emission (S-E) conduction ? **NO**

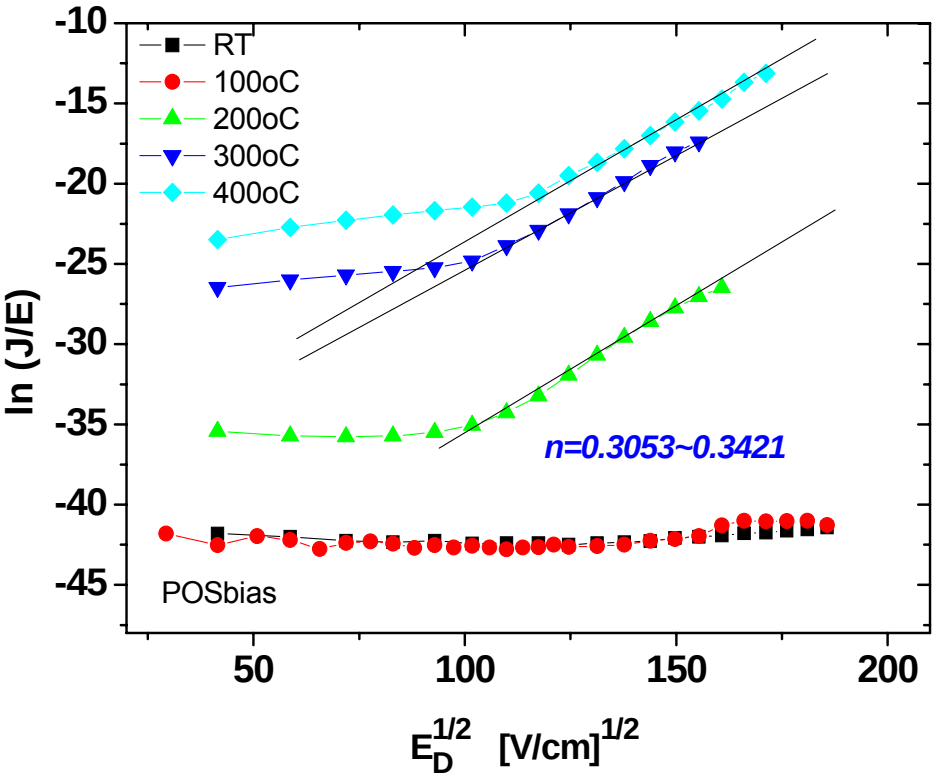
Electrical conduction of DoI

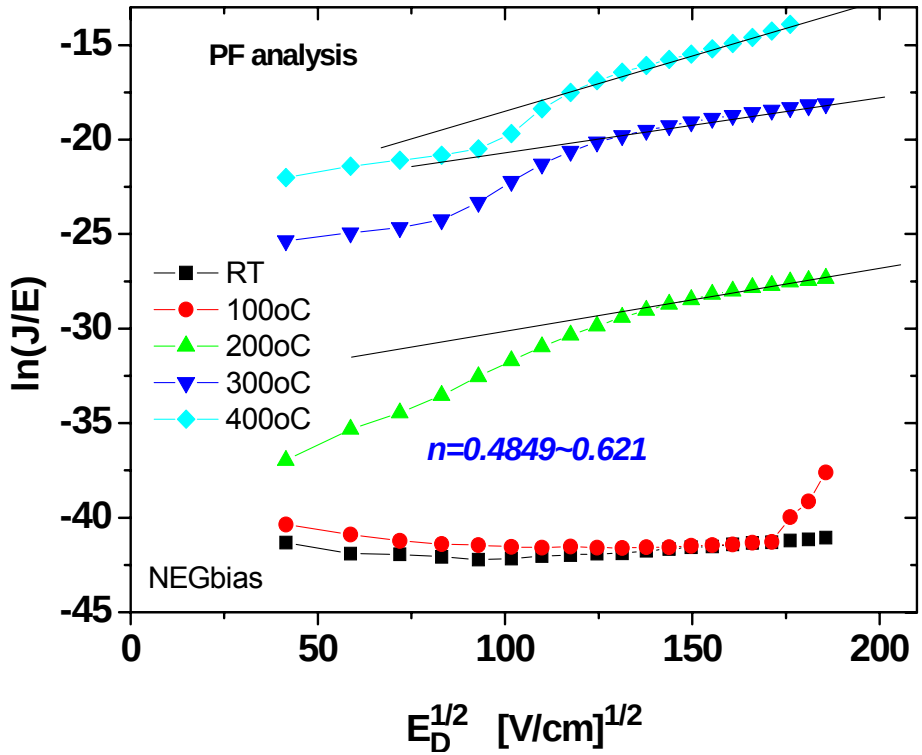
P-F

$$J = C_t E_D \exp\left[\frac{-q(\phi_t - \sqrt{qE/\pi\kappa_d\varepsilon_o}}{k_b T}\right]$$

$$\ln(J/E_D) \propto E_D^{1/2} \qquad \eta^2 = \kappa_d$$

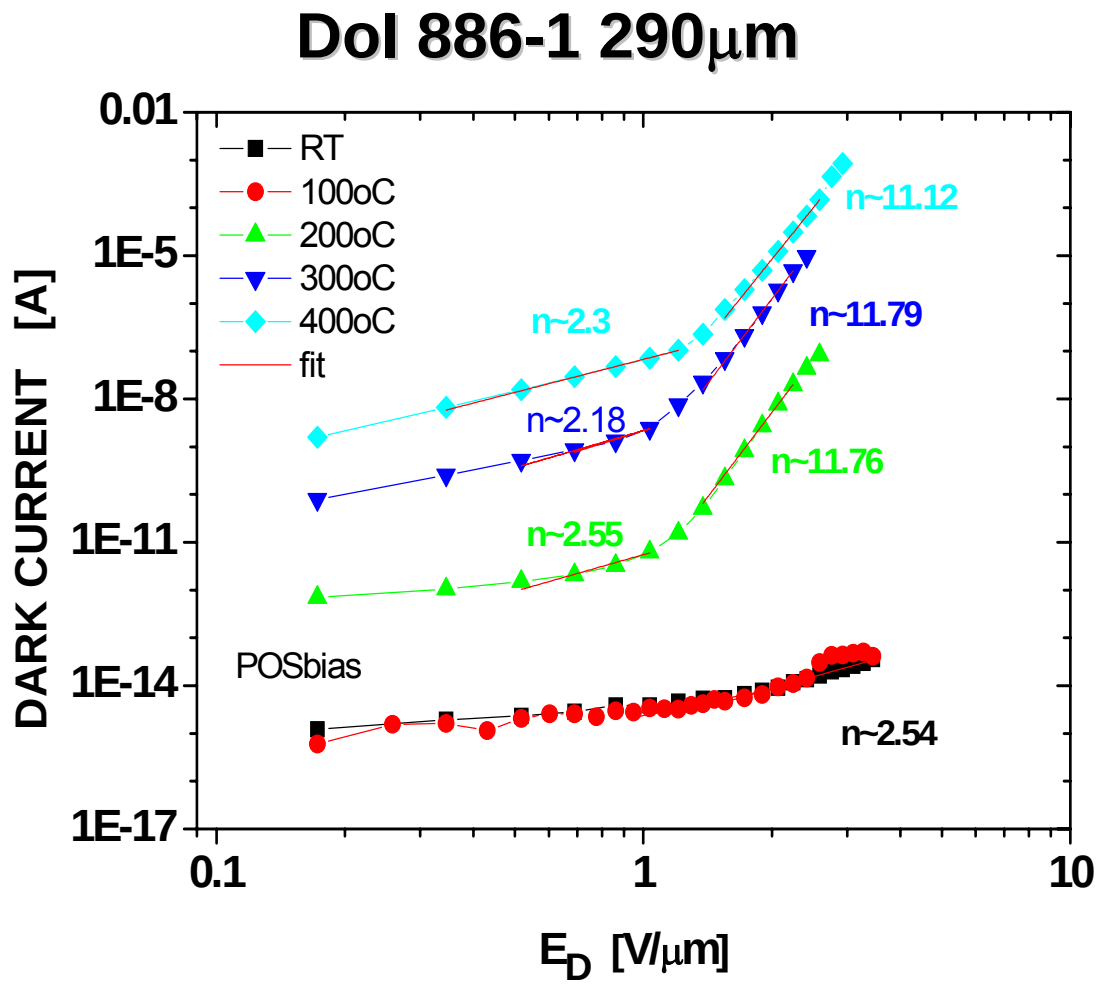
DoI 886-1 290μm





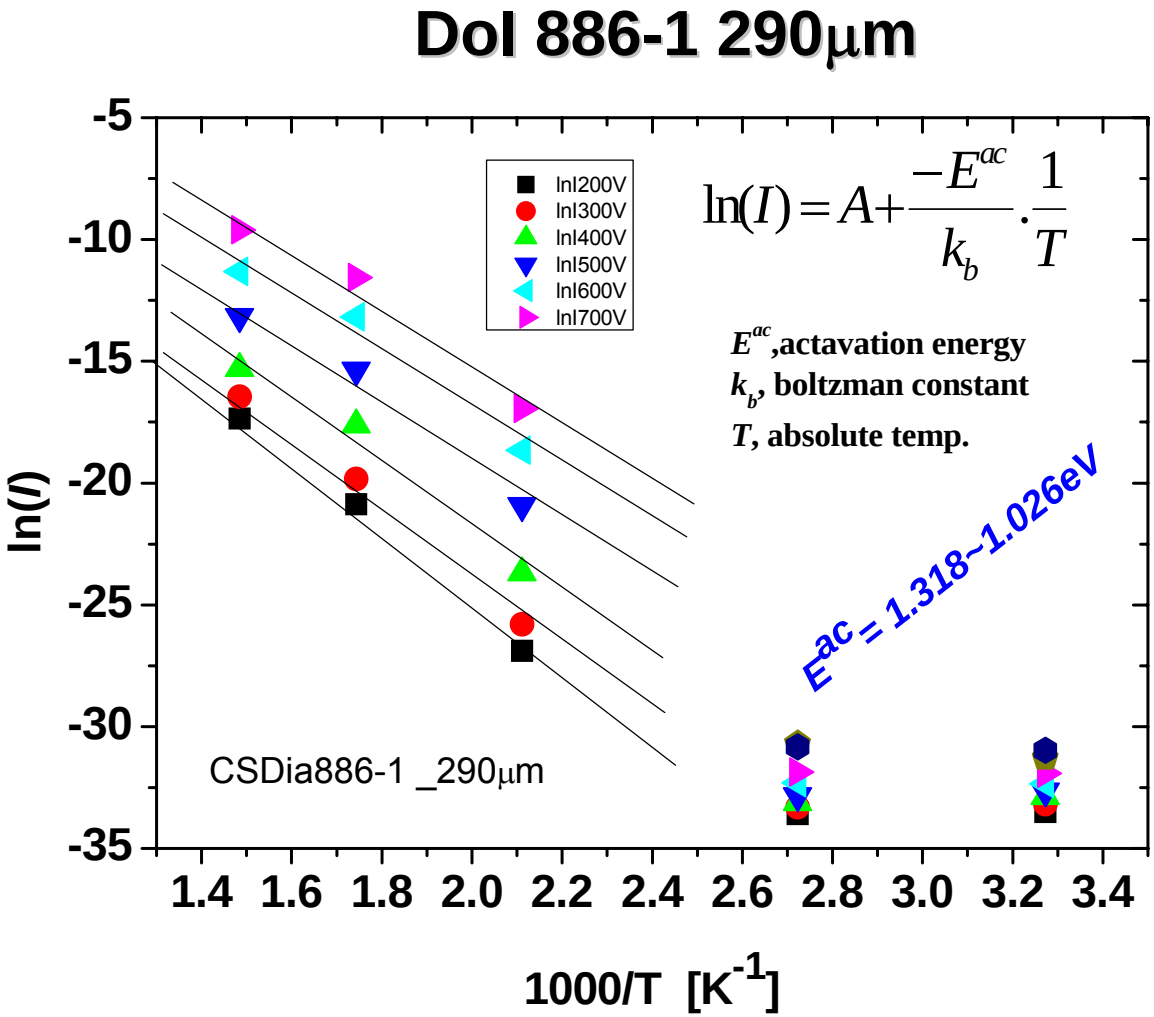
Poole-Frenkel (P-F) conduction ? **NO**

Electrical conduction of DoI



I-E characteristics, SCLC

Electrical conduction of DoI



Activation Energy of the trap level

Summary

- Electrical (*I-V*) characteristics of scCVDD detector are analyzed
- The dominant dark current conductivity of scCVDD detector is SCLC
- The activation energy level of the trap is 0.37~0.39eV
- After coating scCVDD with DLC the conductivity remains the same , *i.e*, SCLC and the activation energy is (0.38 ± 0.017)eV at negative bias while at positive bias E^{ac}=0.44~0.54eV
- The DoI show SCLC mechanism with an activation energy of E^{ac}=1.32~1.026eV

Thank you for your attention