Early Diamond-on-Iridium (DoI) samples

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Contributing to these studies

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- MD Shahinur Rahman
- Carmen Simons
- Michael Träger
- EBe

GSI – ACCELERATOR HF

- Peter Moritz

GSI – TARGET LABORATORY

- Annett Hübner
- Birgit Kindler
- Bettina Lommel
- Willy Hartmann

UNIVERSITY OF AUGSBURG

- Stefan Dunst
- Stefan Gsell
- Matthias Schreck
- Christian Stehl

Outline

- Introduction
- Bulk and surface structure
- Electronic properties
  - Dark conductivity
  - Timing signals
  - Charge Collection Efficiency (CCE)
  - Homogeneity of the signal response
- Summary and conclusions

Introduction

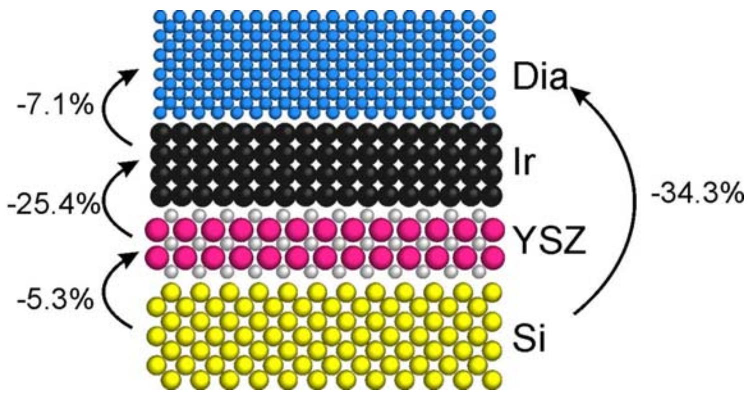
- **Motivation**
  - Radiation hard, ultra-fast, large-area diamond tracking and ToF sensors of better homogeneity than pcCVDD

- **Requirements**
  - Homogeneous, high-mobility detector material
    - δx, $\delta y \approx 3 - 100\ \mu m$; $\sigma_{ToF} \leq 50$ ps; SPR $\approx 10^7 - 10^8$ ions/s
  - High charge-collection efficiency (CCE)
    - good S/N ratio for relativistic light ions and protons

DoI material(s) - Post processing

Dia/Ir/YSZ/Si(001): (cube on cube)

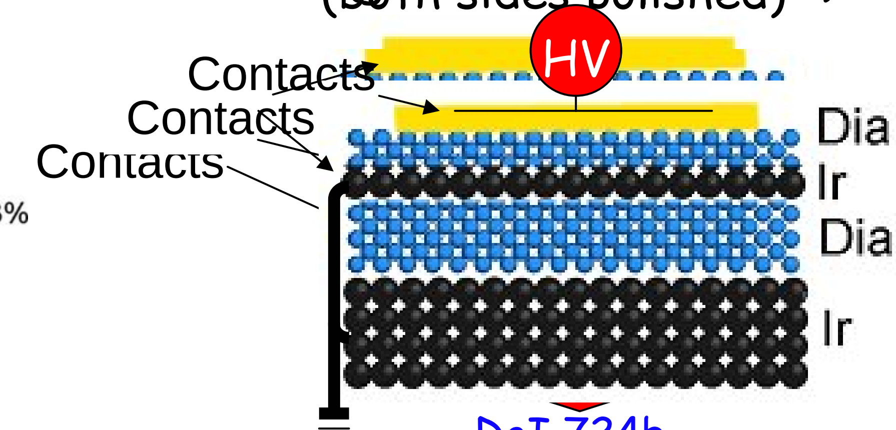
ORIGINAL
STRUCTURE



Iridium substrates:
4 inch wafers routinely realized

M. Schreck et al, Uni Augsburg

1) IRIDIUM ELECTRODE
(growth side polished)
2) FREESTANDING
IR LAYER
3) ADDITIONAL
(both sides polished)

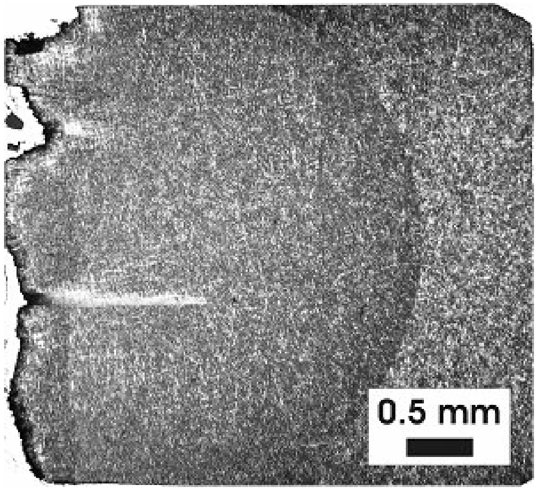


DoI 724b
d = 12 µm
universal
HI sensors
samples

ultra-thin
low-energy HI
sensors

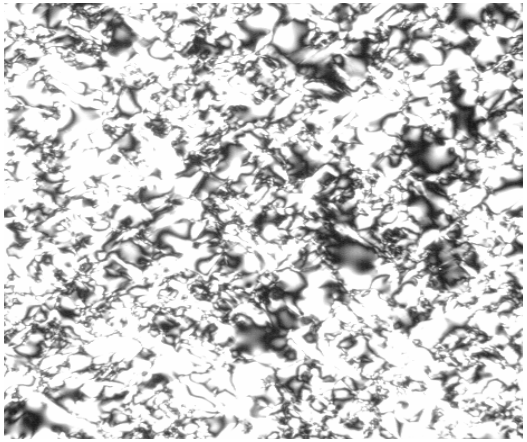
Bulk Structure\Birefringence imaging

Stefan Dunst, Uni Augsburg; Michael Träger, Carmen Simons, GSI (DL)



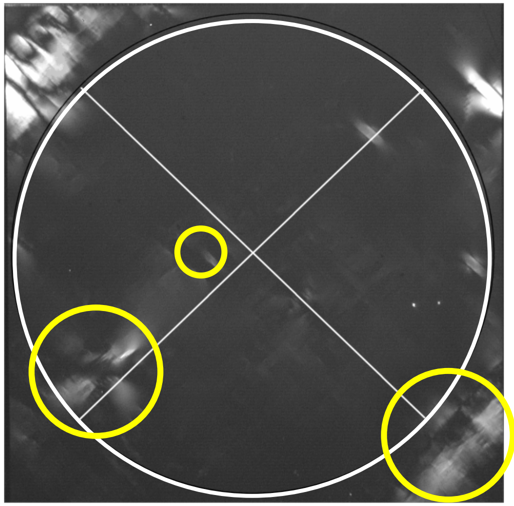
Dia-on-Iridium

'quasi' single-crystal



Dia-on-Silicon

poly-crystal



Dia-on-Dia

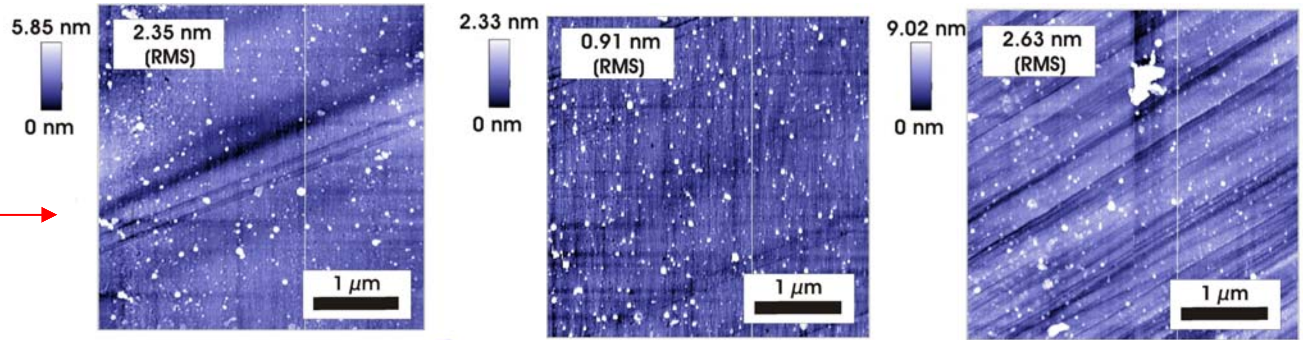
single-crystal

Early Diamond-on-Iridium (DoI) samples

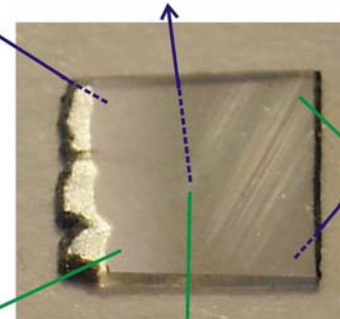
Surface structure – AFM imaging

Stefan Dunst, Uni Augsburg

Nucleation side →

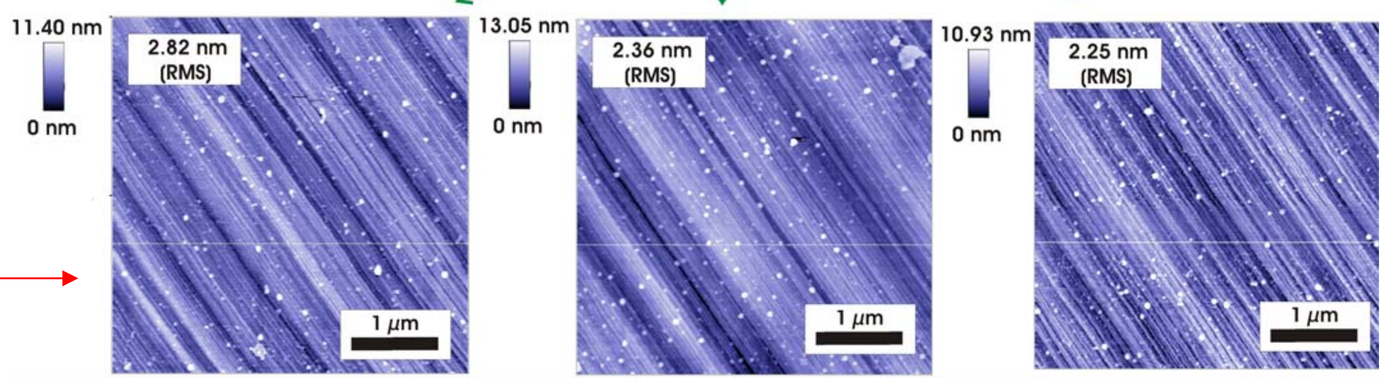


1 DoI 549a,
No add. N2,
free standing
D = 230 μm



scaife polished

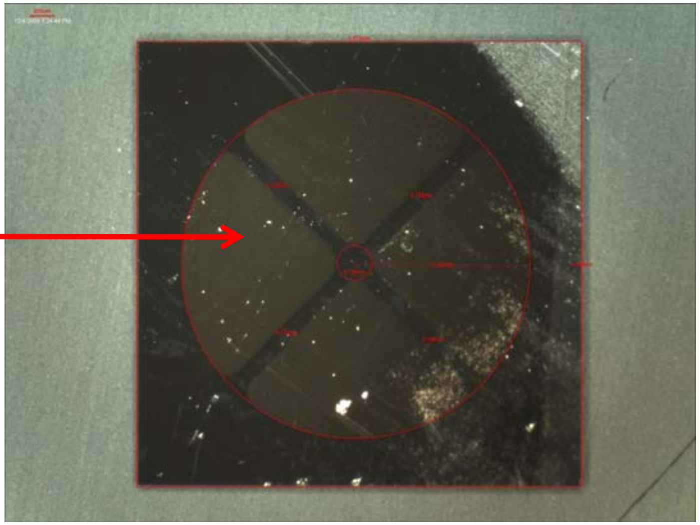
Growth side →



Metallization by sputtering (Ti-Pt-Au)

B. Lommel, A. Hübner et al. GSI (TL)

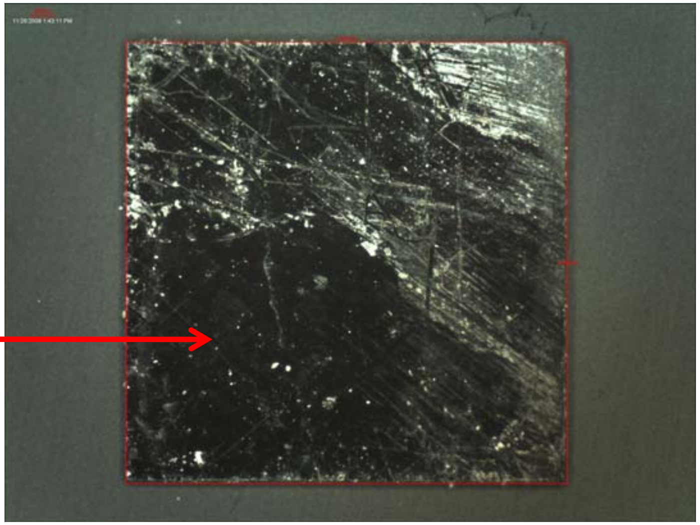
4-sector electrode
on growth side



② DoI 724b

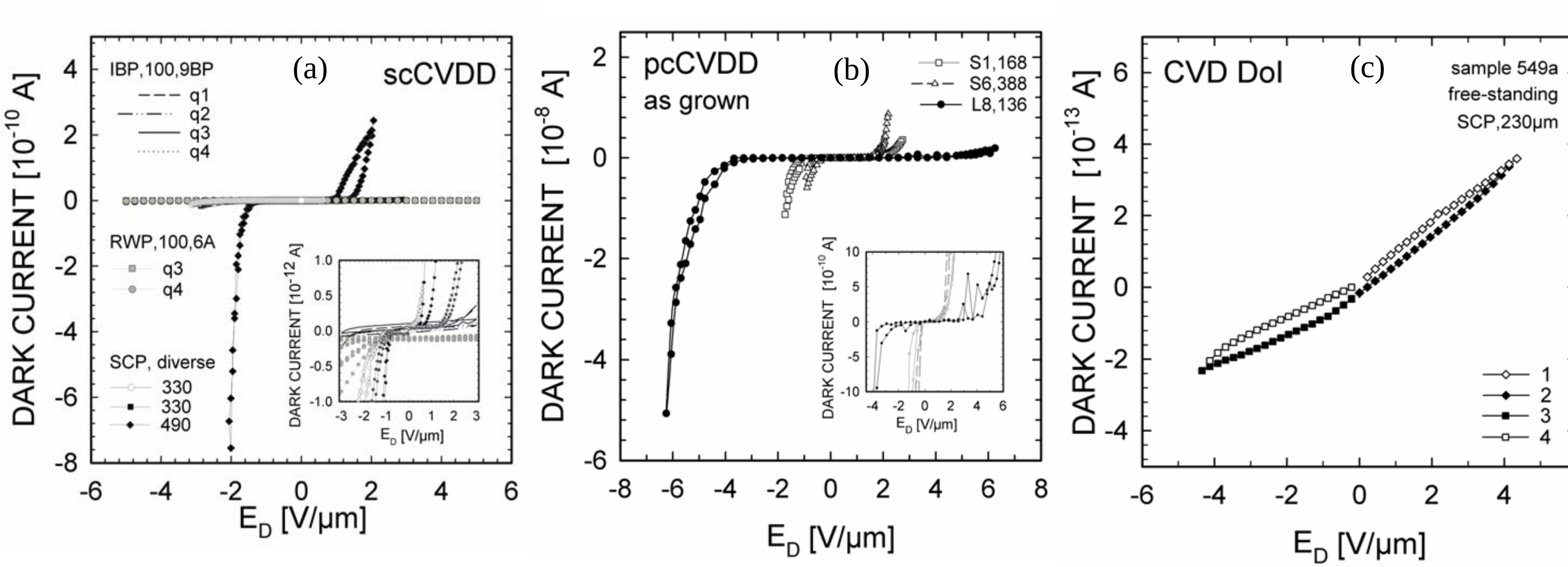
2^{nd} Ir layer defining an
active thickness of 12μm

Bottom view
on '1st' Ir layer



Electronic properties

IV characteristics of the different CVDD types



Dia-on-Dia | Dia-on-Silicon | Dia-on-Iridium

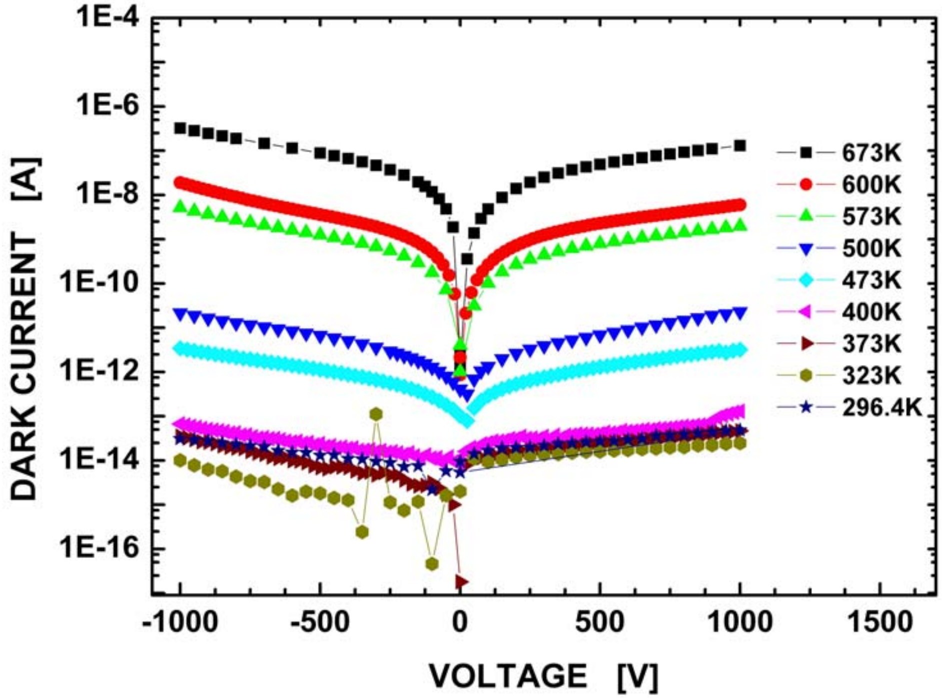
The lowest dark conductivity has been measured for Dia-on-Iridium.

Electronic properties - dark conductivity

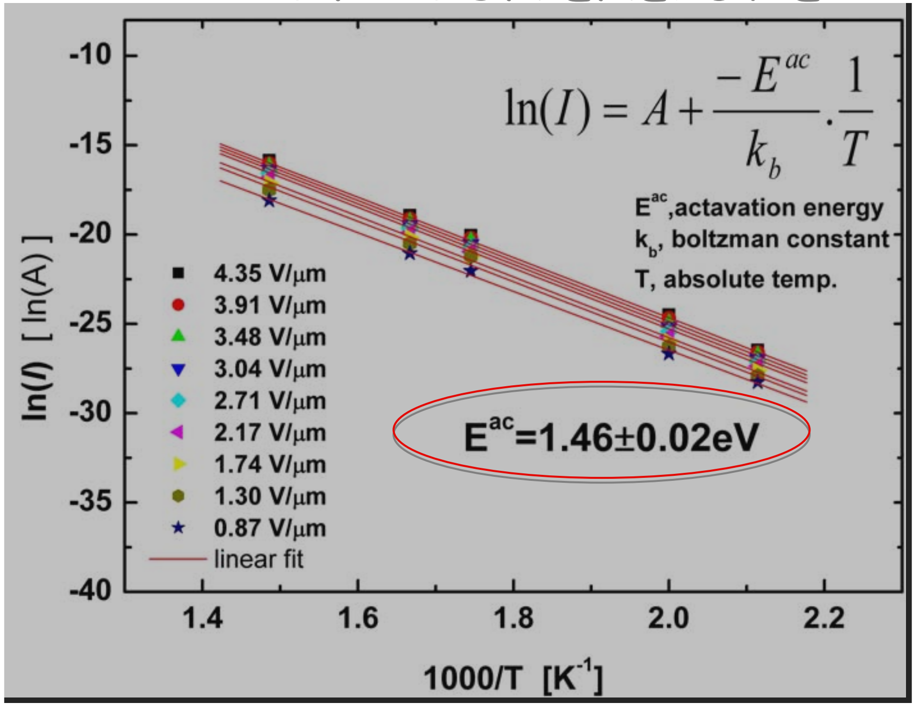
Dark conductivity studies with DoI549a → MD Shahinur Rahman, GSI MC PAD

PRELIMINARY !

IV (T) - DEPENDENCE



ACTIVATION ENERGY E^{ac}



M. Pomorski PhD thesis: $E^{ac}_{SC} \approx 0.35 - 0.39$ eV: B activation

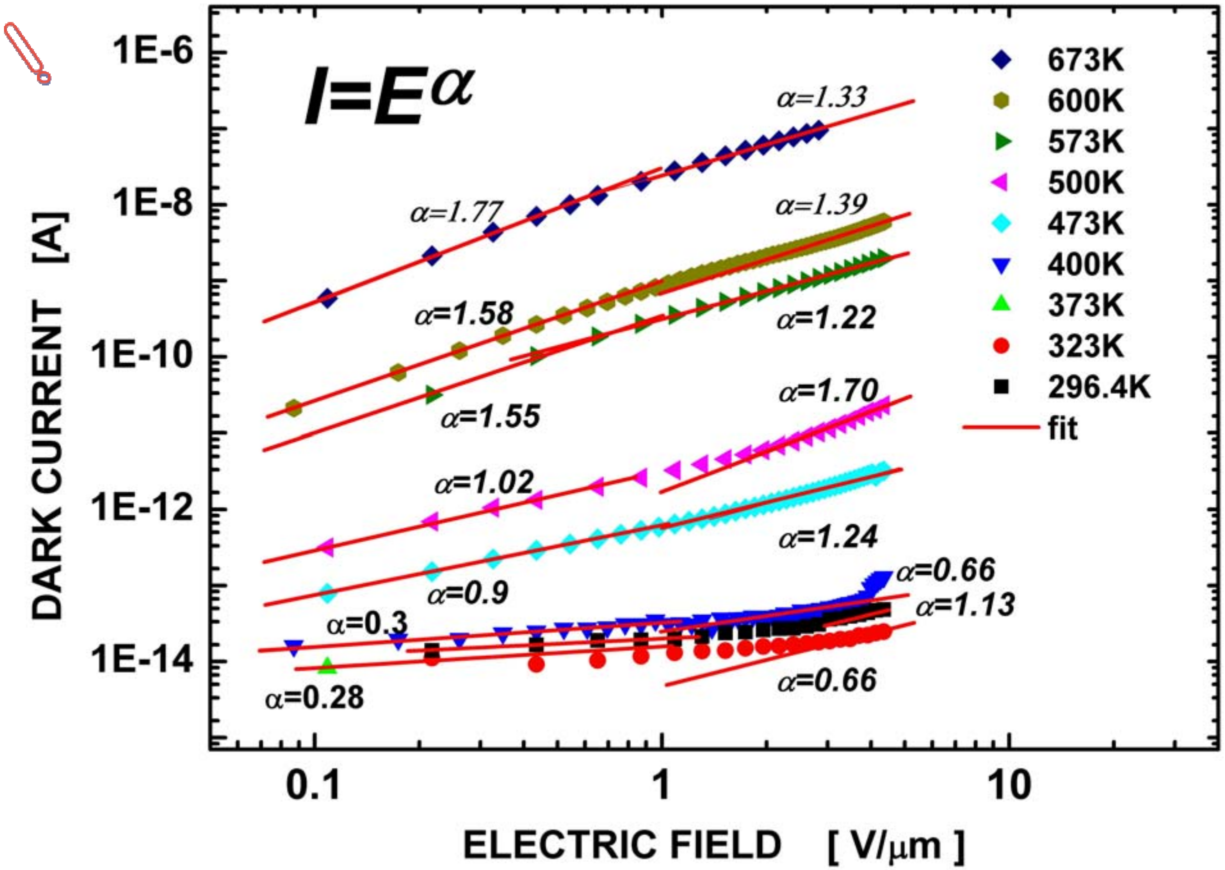
Electronic properties – dark conductivity

Dark conductivity studies with DoI549a

MD Shahinur Rahman, GSI MC PAD

CHECK OHMIC and SCL CONDUCTION

PRELIMINARY !



$\alpha = 1$ ➔ OHMIC

$\alpha \geq 2$ ➔ SCL

Electronic properties - dark conductivity

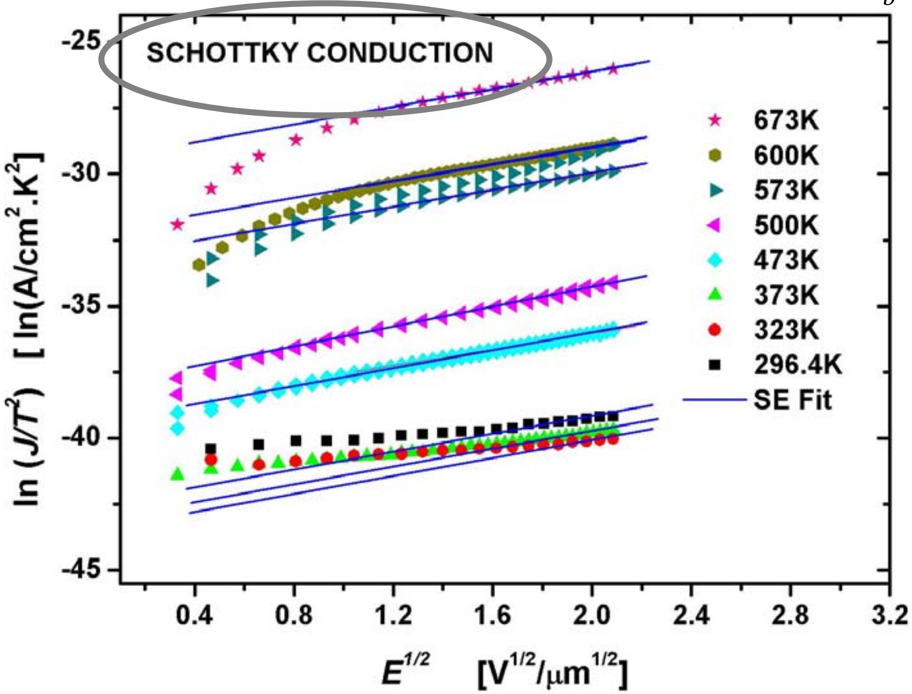
Dark conductivity studies with DoI549a

MD Shahinur Rahman, GSI MC PAD

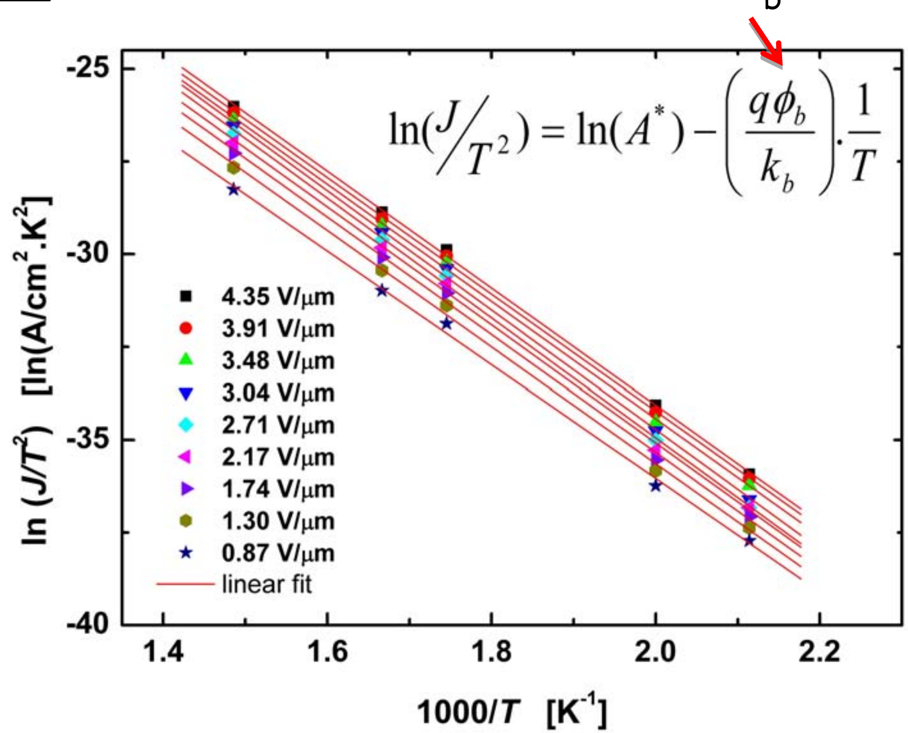
PRELIMINARY !

Φ_b = 1.8 -1.9 eV

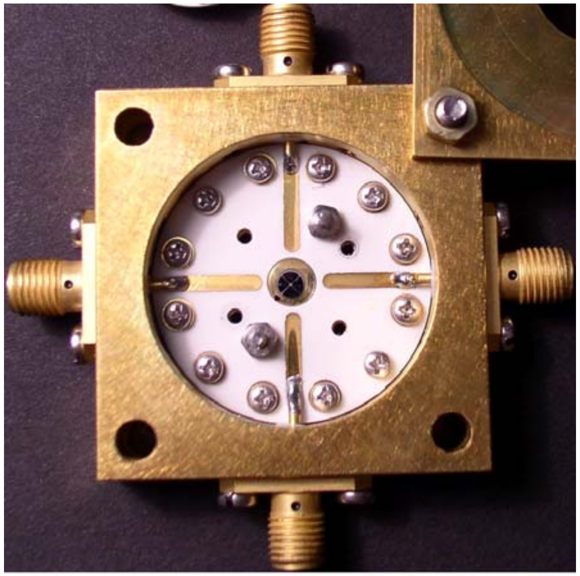
$$\ln(J/T^2) = \ln(A^*) + C.\sqrt{E} \quad \text{with} \quad C = \frac{\sqrt{q/4\pi.\varepsilon.k_d}}{k_b}$$



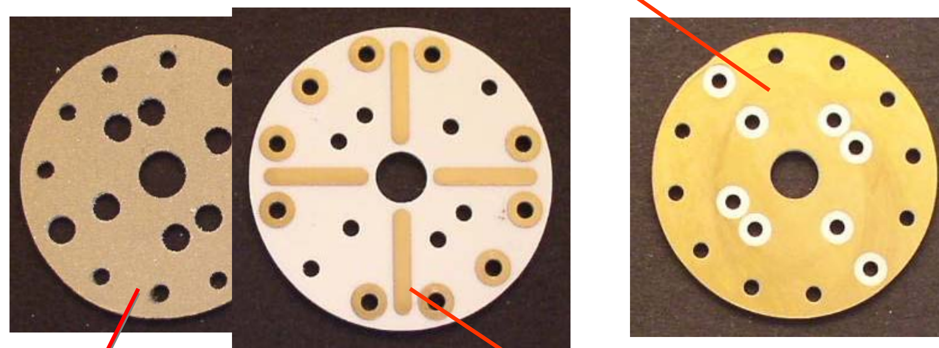
SCHOTTKY BARRIER Φ_b



Detector setup for α-ToF measurements

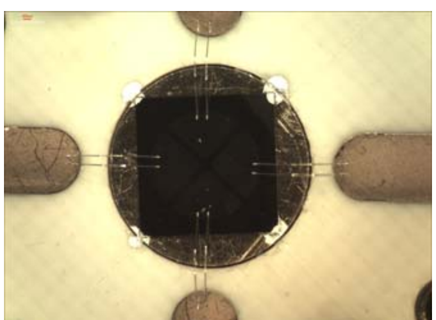


main pcb back side



conductive rubber

main pcb front side

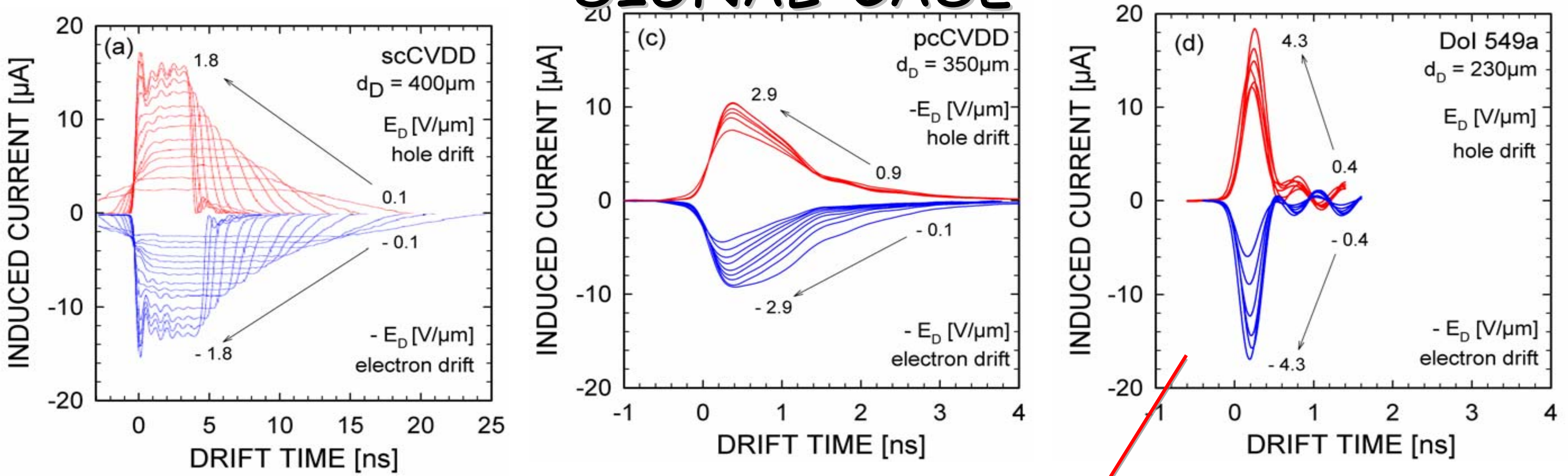


No α-collimator in this case

DoI 724b

^{241}Am-α-induced transient current signals

'SINGLE-CARRIER' DRIFT IN THE 'SMALL-SIGNAL' CASE



Dia-on-Dia

Dia-on-Silicon

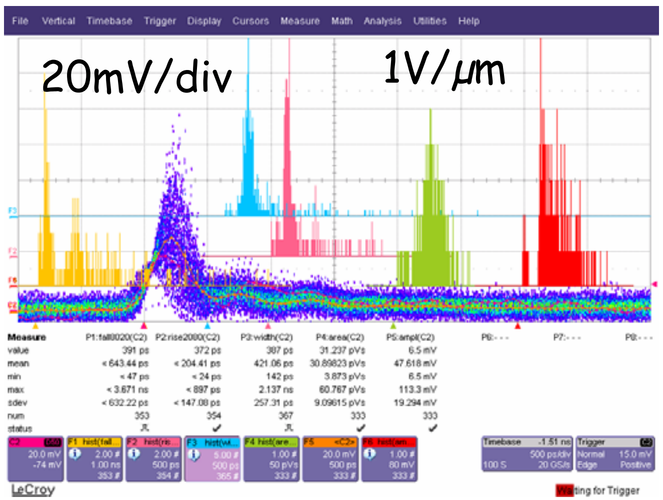
Dia-on-Iridium

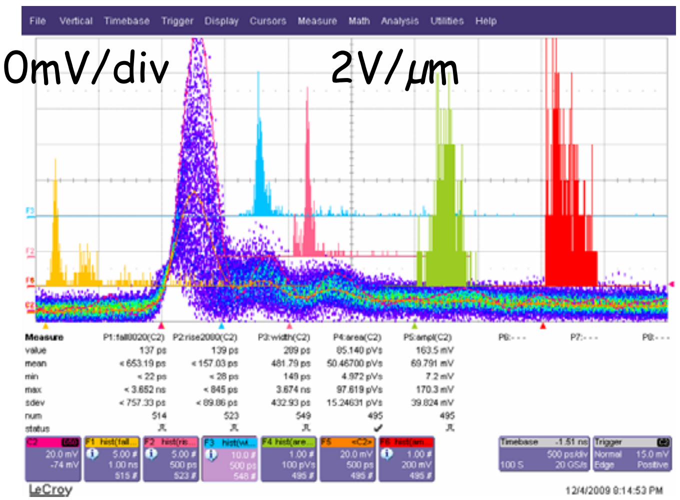
The TC signals of DoI sensors show narrowest FWHM (< 500ps) and amplitudes (on 50Ω) comparable to homoepitaxial diamond.

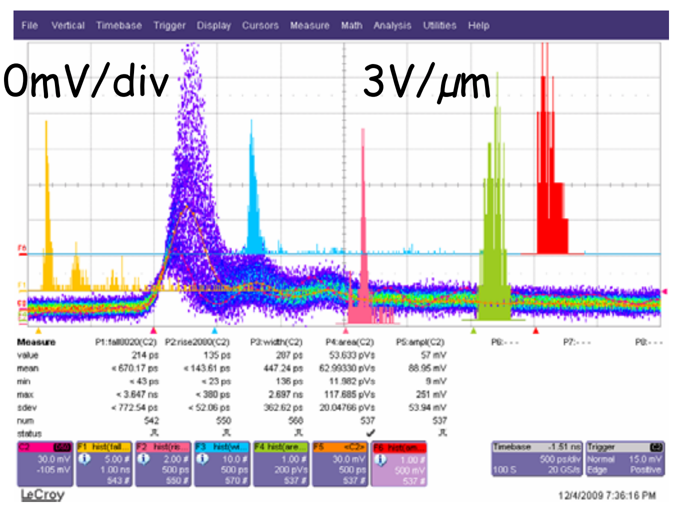
Timing signal characteristics – DoI 724b

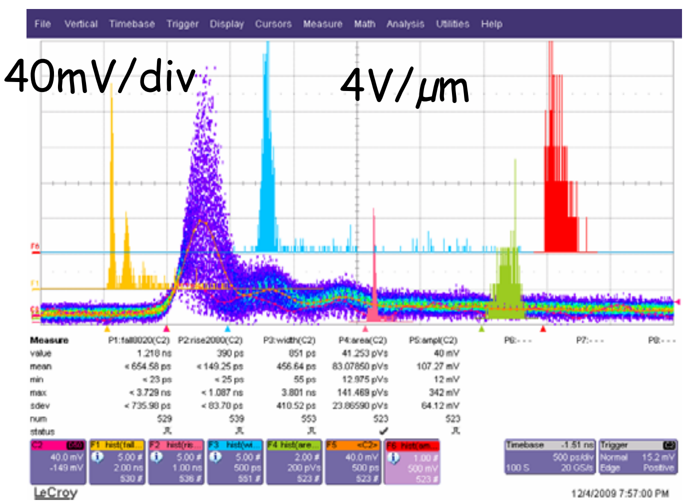
α-source, DBAII, and +HV on growth side

HOLE DRIFT SIGNALS









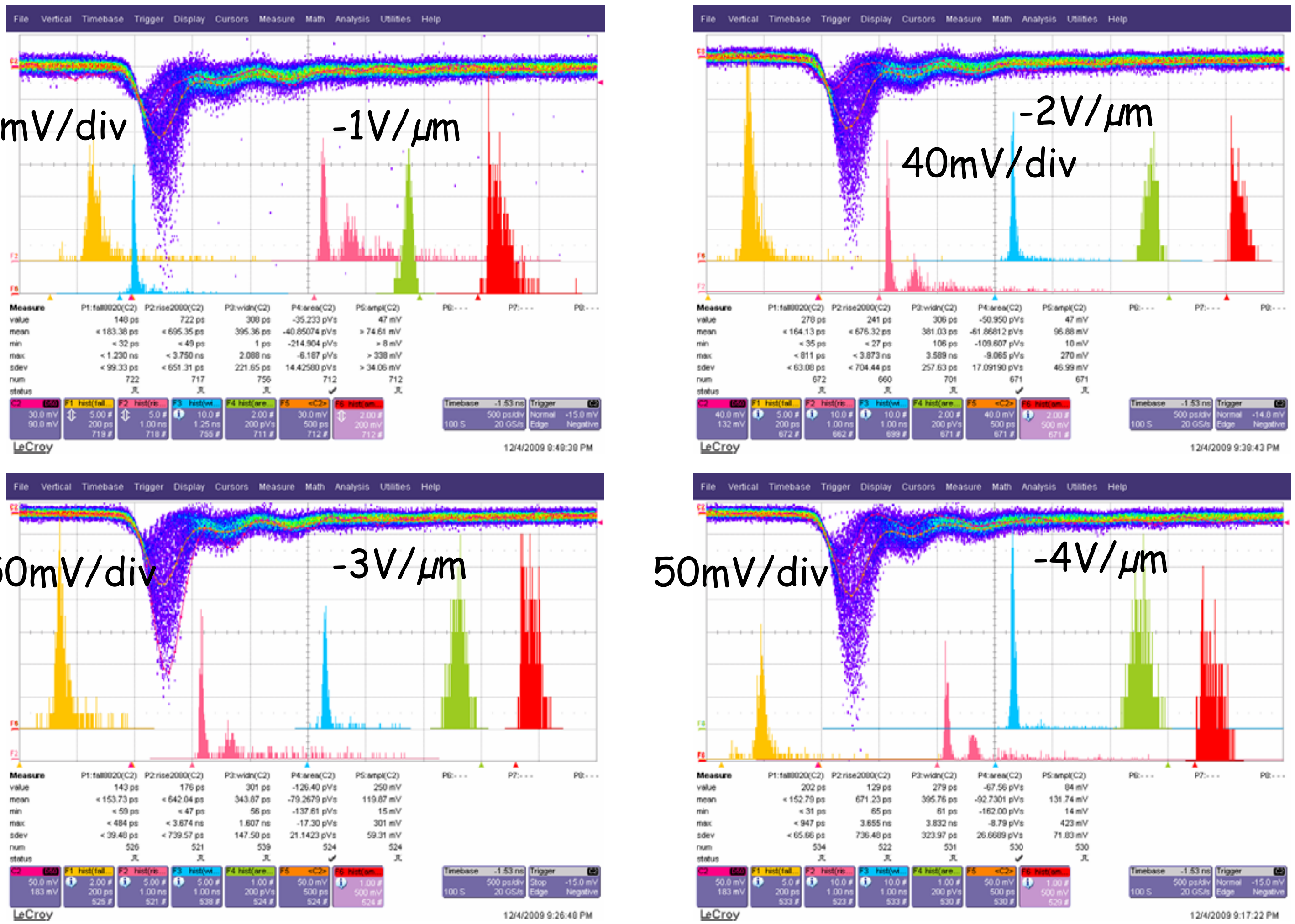
16 μA ≈ 100 mV on 50Ω (at DBA gain 122.5)

t-axis: 500ps/div

Timing signal characteristics - DoI724b

α-source, DBAII, and - HV on growth side

ELECTRON DRIFT SIGNALS

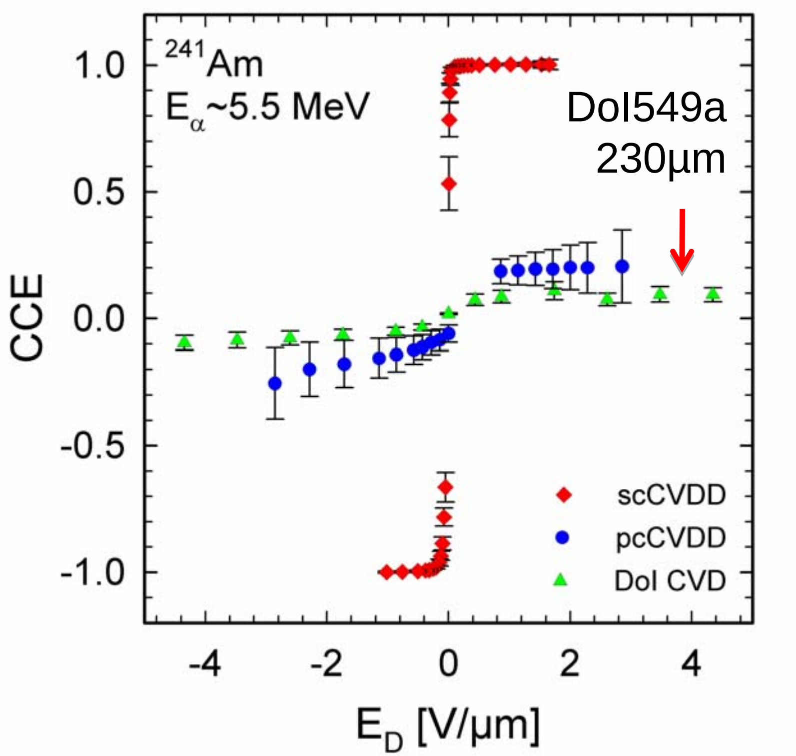


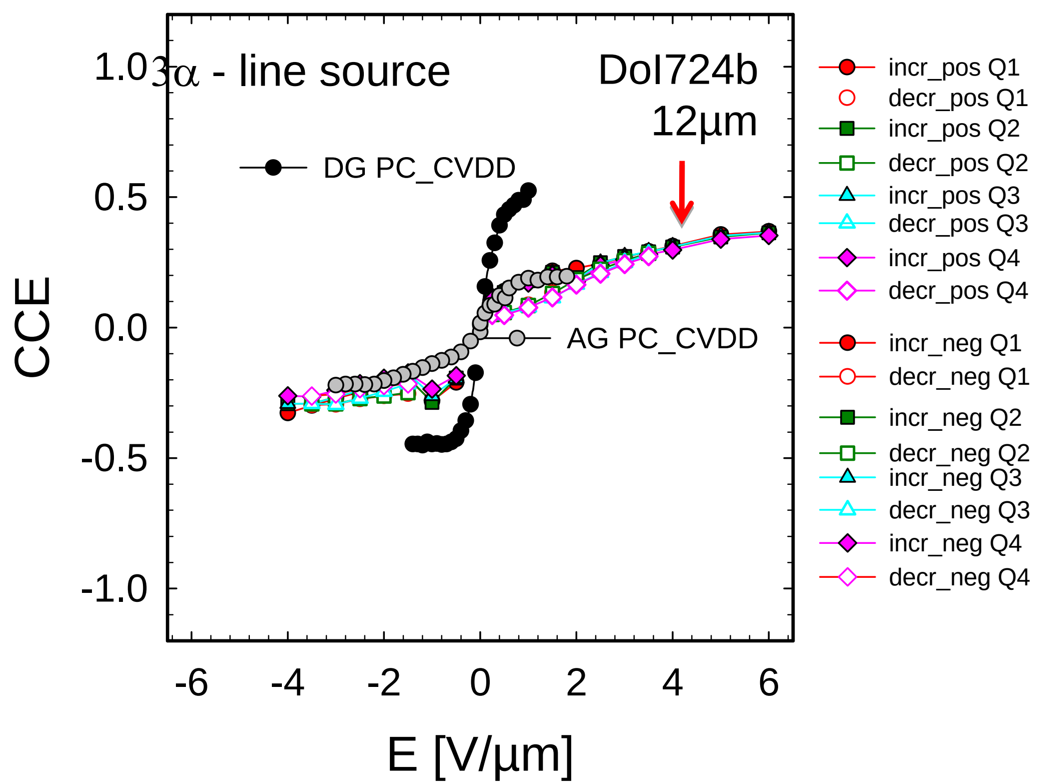
16 μA ≈ 100 mV on 50Ω (at DBA gain 122.5)

t-axis: 500ps/div

Charge collection efficiency (CCE)

Stopped ions → STRONG POLARIZATION



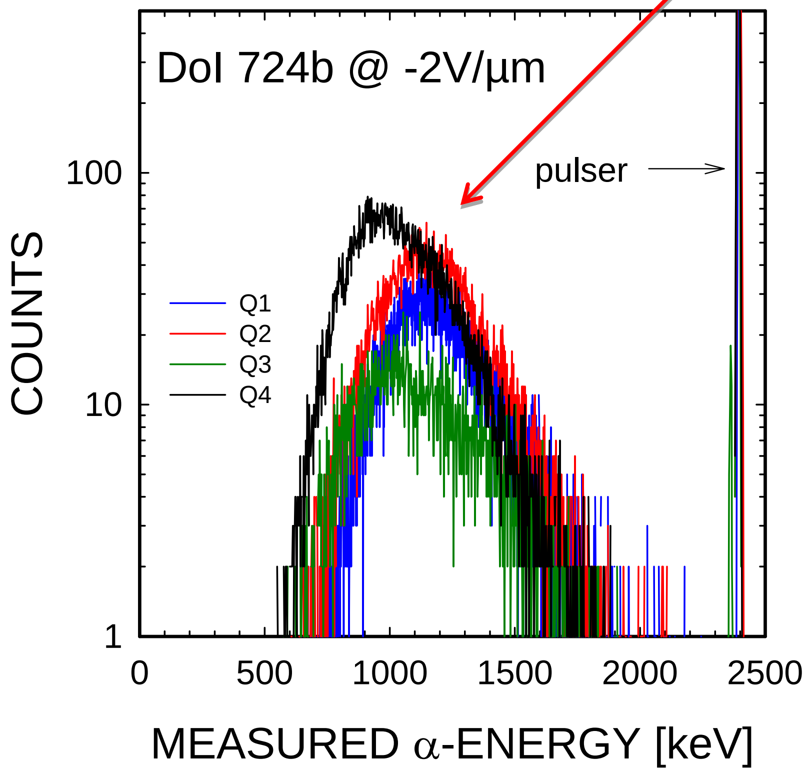


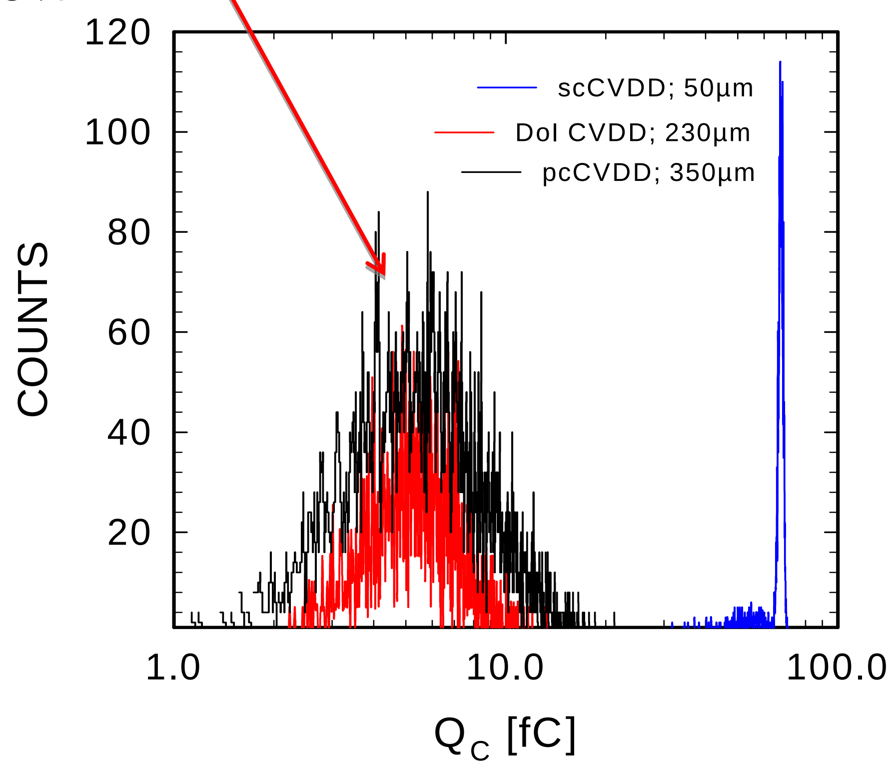
Homogeneity of the sensor response

Energy resolution (α's): 'Thin' DoI ➔ δE/E ≤ 20%

'Thick' DoI ➔ δE/E ≤ 40%

Poly CVDD ➔ δE/E >> 60%





Summary and conclusions

- Very low dark conductivity; order of 10^{-13}A at 4V/μm
  - High activation energy E^{ac} = 1.6eV
  - Schottky conduction
- $CCE_{\alpha} \approx 40\%$
- Extremely fast timing signals; FWHM << 500ps; rt< 200ps

  no really suitable electronics available for
- Timing α-amplitudes as high as of best single-crystals
- Energy resolution $\delta E/E < 20\%$

NEXT STEPS

➔ Signal simulations and FEE developments

➔ Heavy-ion beam tests in spring 2010

➔ Preparation of tools and assembly techniques for large-area strip sensors

MERRY CHRISTMAS and HAPPY NEW YEAR !!!