Early Diamond-on-Iridium (DoI) samples

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Contributing to these studies

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CARAT – Advanced Diamond Detectors
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, δy ≈ 3 - 100 µm ; σ_{ToF} ≤ 50 ps; SPR ≈ 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)

1) IRIDIUM ELECTRODE (growth side polished)

2) FREESTANDING (both sides polished)

3) ADDITIONAL (growth layer polished)

Iridium substrates:
4 inch wafers routinely realized

M. Schreck et al, Uni Augsburg

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Early Diamond-on-Iridium (DoI) samples
Bulk Structure\Birefringence imaging

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

Dia-on-Iridium
'quasi'
'quasi'
'single-crystal'

Dia-on-Silicon
poly-crystal

Dia-on-Dia
single-crystal

Early Diamond-on-Iridium (Dol) samples
Surface structure \ \textbf{AFM imaging}

Stefan Dunst, Uni Augsburg

Nucleation side

DoI 549a, No add. N2, free standing \( D = 230 \mu m \)

Growth side

scaife polished

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Early Diamond-on-Iridium (DoI) samples
Metallization by sputtering (Ti-Pt-Au)

B. Lommel, A. Hübner et al. GSI (TL)

4-sector electrode on growth side

② DoI 724b
2nd Ir layer defining an active thickness of 12µm

Bottom view on '1st' Ir layer

Early Diamond-on-Iridium (DoI) samples
Electronic properties

IV characteristics of the different CVDD types

(a) scCVDD
(b) pcCVDD as grown
(c) CVD Dol

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

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

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Early Diamond-on-Iridium (Dol) samples
Electronic properties - dark conductivity

Dark conductivity studies with DoI549a

MD Shahinur Rahman, GSI MC PAD

Preliminary!

IV (T) - Dependence

Activation Energy $E_{ac}$

$\ln(I) = A + \frac{-E_{ac}}{k_B} \cdot \frac{1}{T}$

$E_{ac} = 1.46 \pm 0.02$ eV

M. Pomorski PhD thesis: $E_{ac,SC} \approx 0.35 - 0.39$ eV: B activation

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Early Diamond-on-Iridium (DoI) samples
Electronic properties - dark conductivity

Dark conductivity studies

with DoI549a

MD Shahinur Rahman, GSI MC PAD

CHECK OHMIC and SCL CONDUCTION

$\alpha = 1 \Rightarrow$ OHMIC

$\alpha \geq 2 \Rightarrow$ SCL

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Early Diamond-on-Iridium (DoI) samples
Electronic properties – dark conductivity

Dark conductivity studies

with DoI549a

MD Shahinur Rahman, GSI MC PAD

PRELIMINARY!

\[ \Phi_b = 1.8 \pm 1.9 \text{ eV} \]

\[ \ln \left( \frac{J}{T^2} \right) = \ln \left( A^* \right) + C \sqrt{E} \quad \text{with} \quad C = \frac{\sqrt{\frac{q}{4\pi \varepsilon k_d}}}{k_b} \]

SCHOTTKY BARRIER \( \Phi_b \)

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Early Diamond-on-Iridium (DoI) samples
Detector setup for α-ToF measurements

- **Conductive rubber**
- **Main PCB back side**
- **Main PCB front side**

No α-collimator in this case

DoI 724b

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Early Diamond-on-Iridium (DoI) samples
The TC signals of DoI sensors show narrowest FWHM (< 500ps) and amplitudes (on 50Ω) comparable to homoepitaxial diamond.
Timing signal characteristics

HOLE DRIFT SIGNALS

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

16 µA ≈ 100 mV on 50Ω (at DBA gain 122.5)
Timing signal characteristics - DoI724b

- $\alpha$-source, DBAII, and - HV on growth side

ELECTRON DRIFT SIGNALS

30mV/div, -1V/µm

40mV/div, -2V/µm

50mV/div, -3V/µm

50mV/div, -4V/µm

16 µA \approx 100 \text{ mV} \text{ on } 50\Omega \text{ (at } DBA \text{ gain 122.5)}

$t$-axis: 500ps/div

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Early Diamond-on-Iridium (DoI) samples
Charge collection efficiency (CCE)

Stopped ions → STRONG POLARIZATION

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CARAT –Advanced Diamond Detectors
Homogeneity of the sensor response

Energy resolution (α’s): ‘Thin’ DoI \( \Rightarrow \delta E/E \leq 20\% \)
‘Thick’ DoI \( \Rightarrow \delta E/E \leq 40\% \)
Poly CVDD \( \Rightarrow \delta E/E >> \)

DoI \( \delta E/E \leq 20\% \)

CARAT – Advanced Diamond Detectors
Summary and conclusions

- Very low dark conductivity; order of $10^{-13}\text{A}$ at $4\text{V}/\mu\text{m}$
  - High activation energy $E_{ac} = 1.6\text{eV}$
  - Schottky conduction
- $CCE_\alpha \approx 40\%$
- Extremely fast timing signals; $\text{FWHM} \ll 500\text{ps}$; $\text{rt} < 200\text{ps}$
  - No really suitable electronics available for
- Timing $\alpha$-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 !!!