scCVD diamond detector signal properties investigated with ion microbeams at elevated temperatures

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GSI, Darmstadt

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## Overview

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Diamond detector
Characteristics and basic properties

- ≈ 65 to 70 µm thick sc-CVD diamond from Element Six
- Front and back electrode: tungsten (wolfram)
- Active surface: 4×4 mm²

Transmission: back side irradiation possible
Silver paste connection wolfram to gold wire

Gold contact plates
Ceramic plate with SMA Signal/BIAS connector

Back side view
Experimental procedure: Ion microprobe, heating

- Ion microprobe, heating setup
- Thermocouple reading
- Bulk copper (heating source)
- Signal connector
- Diamond

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Experimental procedure
Signal processing, fast traces acquisition

Control software:
SPECTOR_v2

Beamline DAQ (integration and PHA)

Oscilloscope (up to 4 GHz bandwidth)

Detector

CSA

Detector

CIVIDEC C2HV

IBIC
On line analysis

TCT
Off line analysis
Irradiation
5 MeV proton beam

<table>
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<tr>
<th>ions/cm²</th>
<th>LOW DAMAGE</th>
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<td>32 deg C</td>
<td>3.82E+12</td>
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High ion current during irradiation – beam chopping + RBS spectra for flux calculation

Chopping: 1 sec in, 1 sec out

Low, MID and HIGH irradiation damage areas

Same fluences on the new area

Irradiation
5 MeV proton beam

How the IBIC map usually looks like

What we got

Problem – after irradiation, IBIC maps showed irregular shapes of the damaged areas – fluence estimated

High ion current during irradiation – beam chopping + RBS spectra for flux calculation

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250 °C
LOW, MID and HIGH irradiation damage areas

32 °C
Same fluences on the new area

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Ion beam properties

• 5 MeV p(+) beam used for damage regions creation (irradiation)

• 2 MeV p(+) beam used for IBIC imaging – before and after irradiation

• 10 MeV C(3+) beam used for IBIC imaging – only after irradiation
Degradation of the full energy peak starts below $2V$ (0.03 V/µm)

$\Delta E/E = 1.7\%$

More is better
Beam impinging on front or back electrode
IBIC imaging at elevated temperatures
Virgin area properties

1. CCE remains \(\cong 100\%\)
2. No leakage current
3. Noise level is stable

- Slight shift to the lower energy
- Small increase in the FWHM

\[ E = 0.77 \text{ V/µm} \]
IBIC imaging at room temperature
Irradiated area properties

Histogram color bars are in the same scale!

Areas damaged at 32 °C

Areas damaged at 250 °C

$E = 0.15 \text{ V/μm}$
IBIC imaging at room temperature
Irradiated area properties

32 °C
Energy spectra from central regions of the damaged zones

Shift to the lower energies

250 °C

E = 0.15 V/μm
IBIC imaging at room temperature
Irradiated area properties

CCE of RT damaged areas v BIAS - 2 MeV protons

Bias (V)

CCE

-10  0   10  20

-20  -10  0   10  20

Bias (V)
IBIC imaging at elevated temperatures
CCE evolution

Results only for areas irradiated at 250 °C

Results with 10 MeV C were obtained first

Noise level increase at 280 °C soldering contact problem?
IBIC imaging at elevated temperatures
CCE evolution

Explanation of the behavior:
• No annealing of the traps for these temperatures
• Trapping time increases with temperature, mainly because of a decrease in charge drift velocity

\[ \frac{1}{\tau_c} \sim v_{drift}(T) \]
A few TCT traces...

- Ongoing active research exploiting TCT traces

Different sample – 500 μm diamond

\[ RC = 4.7 \times 10^{-10} \text{ s} \]
\[ t_{\text{rise}}(10\% - 90\%) \approx 1 \text{ ns} \]
Conclusions and next steps

**CONCLUSIONS**

- Good properties at room temperature: 1.7% energy resolution @2MeV
- Noise and full energy peak properties stable until 280 °C – soldering contact to be replaced with a better solution
- IBIC analysis of irradiated areas at elevated temperatures: CCE decreases (proportionally with damage dose) → higher trapping probability and no observation of defect annealing
- TCT – capacitance masks important signal shape properties

**NEXT STEPS**

- Repeat experiment ⇒ make well defined irradiation areas!
- Going to 500 °C („and beyond”)
- New diamond sample for obtaining TCT at high temperatures
**Info: Transnational access to RBI facilities**

### 2015-2019: AIDA 2020
- 18 experiments funded!
- 9 using IBIC
- 8 done at diamond

### 2019-2023: RADIATE project !!
- Simple and **fast response** to experiment proposals
- 10 funded experiments per year (at RBI)
- **Project supports: travel, accommodation** and beam time!
- Detector characterization capabilities: IBIC imaging; ion induced TCT; in situ damaging; temperature dependences (LN2 to 750 °C); single event upset tests

[https://www.ionbeamcenters.eu/radiate/radiate-transnational-access/application-for-transnational-access/](https://www.ionbeamcenters.eu/radiate/radiate-transnational-access/application-for-transnational-access/)
Acknowledgements:

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Thank you for your attention!