Mapping single-crystal diamond with $^{12}$C micro beams

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Outline

- Introduction
- Experimental Setup
- Description of experiments done/ Calibration
- Principle of data treatment: example ⇒ PC-CVD
- SC-CVDD maps
- Energy resolution for stopped HIs
- SRIM Calculations
- Conclusions and Outlook
**Introduction**

- **Spectroscopy at Bragg-Peak**

- **XY scanning and Tuning of the beam energy**

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**Electrode 2:**
- @ + or - HV

**Electrode 1:**
- Scanned area @ ground potential

**Bragg peak 1**

**Bragg peak 2**

**XY scanning and Tuning of the beam energy**

**Measured Parameter:** Amplitude ~ $E_{\text{meas}}$, deposit ~ $Q_{\text{meas}}$

**Quality parameter:** Peak_E and $\Delta E(\text{FWHM})/E$

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Experimental Setup

Detector Contacts:
0.05 µm Cr + 0.1 µm Au

VACUUM 10^{-6} mbar

{1 0 0} direction

BEAM

SE detector: trigger and surface imaging

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Description of measurement I

- Ion Beam $\Rightarrow \, ^{12}\text{C} \, ^{2+}$ of two different energies
  
  - $E_{\text{low}} = 3.6 \, \text{A MeV} \, ; \, E_{\text{high}} = 9.515 \, \text{MeV/amu}$

- Irradiated areas $\Rightarrow 140 \times 93 \, \mu\text{m}^2; \, 93 \times 60 \, \mu\text{m}^2$

  Ranges in "Diamond": $^{12}\text{C}, \, \rho = 3.52 \, \text{g/cm}^3$

  for the reaction $\Rightarrow \, ^{12}\text{C} \, (^{12}\text{C}, \, ^{12}\text{C}) \, ^{12}\text{C}$

  - 27 $\mu$m
  - 126 $\mu$m

Mistake: $\Rightarrow$ we irradiated not exactly the same region!
Description of measurement II

- Beam contaminations with ions of same velocity and A/Q of primary beam (if any) can be used for precise energy calibration:

  $^{12}\text{C}^{2+}$ corresponds to $^{18}\text{O}^{3+}$

(Private communication accelerator people:
  $\sim 0.6\%$ of $^{18}\text{O}^{3+}$ ⇒ is known for this case!)

Big Advantage ⇒ reaction $^{12}\text{C} (^{18}\text{O}, ^{18}\text{O})^{12}\text{C}$
Principle of data treatment

PC-CVDD, irradiated with $^{12}\text{C}$, 5.9 AMeV $\perp$ to the growth direction

cleaved, "as grown" sample, $d = 120 \mu\text{m}$
Characteristics of the sample to test: E6-D3, d = 345 µm, sandwitch-dot Ø 2 mm

1. IV Behaviour

2. Energy Resolution

SC-D3, Cr-Au dots = 3.14 mm$^2$

$d_0$ = 345 µm

Volume = 1.1 mm$^3$

Mixed-nuclide α-source

$\Delta E$(FWHM)/E = 0.004

Energy [keV]

Counts

SC-D3, Cr-Au dots = 3.14 mm$^2$

Volume = 1.1 mm$^3$

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Collected-charge maps: $^{12}$C, 3.6 AMeV
Detector @ - 400 V (all data)

$E_1 = 3.6$ AMeV

Map at $27 \pm 10 \mu$m depth
(all $^{12}$C data)

Energy spectrum at $27 \pm 10 \mu$m depth
(all $^{12}$C data)

$(FWHM) \frac{\Delta E}{E} = 0.012$
Collected-charge maps: $^{12}\text{C}$, 9.515 AMeV
Detector @ - 400 V (all data)

$E_2 = 9.515$ AMeV

$E_2 = 9.515$ AMeV

Map
at 126 ± 7 µm depth
(all $^{12}\text{C}$ data)

Energy spectrum
at 126 ± 7 µm depth
(all $^{12}\text{C}$ data)

(calcul) $\Delta E/E = 0.027$
General position dependence of the E-spectra

$E_1 = 3.6 \text{ AMeV}$

$E_2 = 9.515 \text{ AMeV}$

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3.6 AMeV ($\Delta E_{\text{corr}}$)

9.515 AMeV-Zoom ($\Delta E_{\text{corr}}$)

Scanning the energy spectra step by step
Radiation damage/Micro Pumping?
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Scan 1

Scan all data

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Radiation Damage/ Micro Pumping?
A closer view to the spots of $E_2 = 9.515 \text{ A MeV}$
Energy Resolution: $^{12}\text{C}$, 3.6 AMeV

Energy deposit $E_1^* = 42.91$ MeV

ions: $\Delta E/E = 0.010$

$C_{\text{Gauss}} = 42.81$ MeV

ions: $\Delta E/E = 0.014$

$C_{\text{Gauss}} = 42.61$ MeV
Energy Resolution: $^{12}\text{C}$, 9.515 AMeV

Energy deposit $E^*_2 = 114.013\text{ MeV}$

ions: $\Delta E/E = 0.013$

$C_{\text{Gauss}} = 114.03\text{ MeV}$

$116.4\text{ MeV}$
SRIM2003 Calculations $^{12}\text{C}(^{12}\text{C} \; ^{12}\text{C}) \; ^{12}\text{C}$

3.6 AMeV

11.4 AMeV
Ion Range and Spread (SRIM2003):

$10^4$ events $\Rightarrow \ ^{12}\text{C}(^{12}\text{C} \ ^{12}\text{C}) \ ^{12}\text{C}; \ E = 3.6 \ \text{AMeV}$

after 0.1µm Au + 0.05 µm Cr + 300 µm $^{12}$C ($\rho = 3.52 \ \text{g/cm}^3$)
Projected Ion Range

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Conclusions and Outlook from this PRELIMINARY Analysis

- For a real HI beam ⇒ SC-CVDD is homogeneous
  - Spectroscopic Grade (SG) material.
- Limits of ΔE microbeam investigations:
  - Missing energy difficult to be localized along the particles track, except in case of high-resolution surface imaging (SE-D).
- The experiment (+ setup) must be improved
- A lot more analysis is needed to understand all peculiarities observed.
- However, Micro-Beams are a powerful tool for SC-DD characterisation