High–Precision Alpha Spectroscopy Using sCVD Diamond Detectors

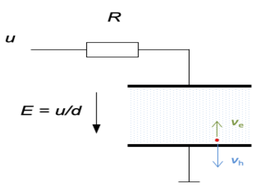
Divya[1,2], J.Melbinger[1,2], E. Griesmayer[1,2], C. Weiss[1,2] and D. Hainz[1,3]

[1]TU Wien, Wien, Austria | [2]CIVIDEC Instrumentation GmbH, Wien, Austria | [3]TRIGA Center Atominstitut, Wien, Austria

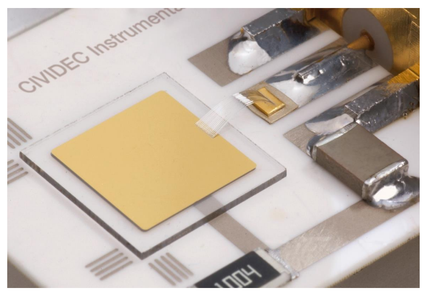
Abstract: Single-crystal chemical vapour deposition (sCVD) diamond detectors are known for their high radiation hardness and excellent performance at elevated temperatures. sCVD diamond sensors are promising candidates for particle spectroscopy in demanding environments. In this study, we present the achievable energy resolution of sCVD diamond detector. To do so, alpha spectroscopy is performed, a reliable technique for calibrating newly developed detectors. The measurements were conducted in a vacuum environment of 10^{-3} mbar using an unsealed ^{241}Am alpha-particle source and CIVIDEC's high-resolution data acquisition system, ROSY® AX106. The experimental results are compared to Geant4 simulations.

Introduction

Radiation-hard sCVD diamond sensors have low dark current, high electron-hole mobility, and excellent time and energy resolution.



Schematic for the current readout in sCVD sensor.

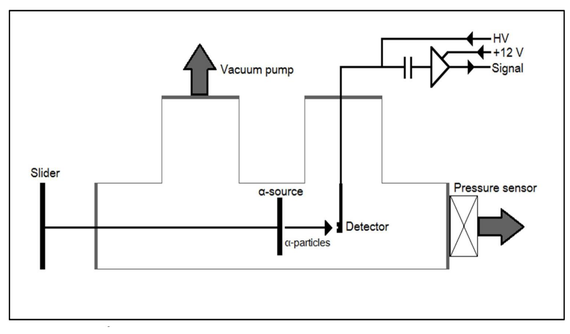


CIVIDEC Diamond sensor.

Methodology

Alpha spectroscopy is a standard and reliable method for detector analysis. The energy of the alpha particle in sCVD is measured to assess its energy resolution. A stable vacuum of 10^{-3} mbar is maintained to minimize energy losses.

- CIVIDEC ROSY® AX106: 14-bit resolution.
- CxL spectroscopic amplifier.
- 4.5 mm × 4.5 mm × 500 µm sCVD with 100 nm Ti electrode.
- Unsealed 241Am source used.



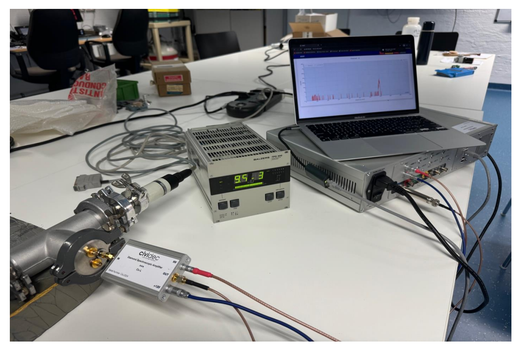
Schematics of experimental setup in vacuum.

Experiment Setup

The experiment set up at Atominstitute, Wien.

sCVD detector mounted on vaccume flange.

Unsealed ^{241}Am source.



Experimental setup.

Sensor Calibration

The sCVD sensor is calibrated at CIVIDEC. Optical quality control is used to assess the defect level before metallization, while the Transient Current Technique helps analyse the movement of electrons and holes, as well as the ionization energy. Current-time measurements provide the dark current profile of the sensors.

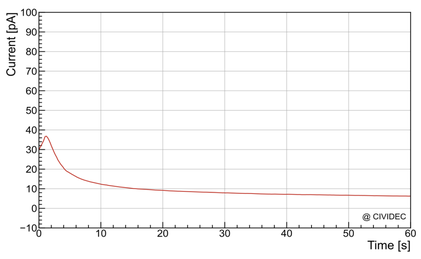


Fig. 1: The dark current of the sCVD sensor at +500V for 60s.

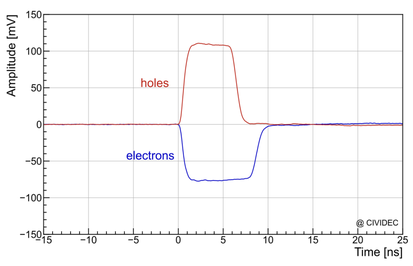


Fig.2: TCT measuremnet for holes and electrons for ^{241}Am α-particles.

Spectroscopy

A Geant4 simulation was performed with a ^{241}Am source. The noise from the data acquisition system, the energy loss within the source itself, and the sCVD intrinsic noise were implemented in the simulation. The FWHM is calculated as follow:

$$FWHM_{Simulation} = \sqrt{(FWHM_{internsic})^2 + (FWHM_{Baseline})^2 + (FWHM_{Electrode})^2 + (FWHM_{Source\ thickness})^2}$$

where $FWHM = 2.355 * \sigma$

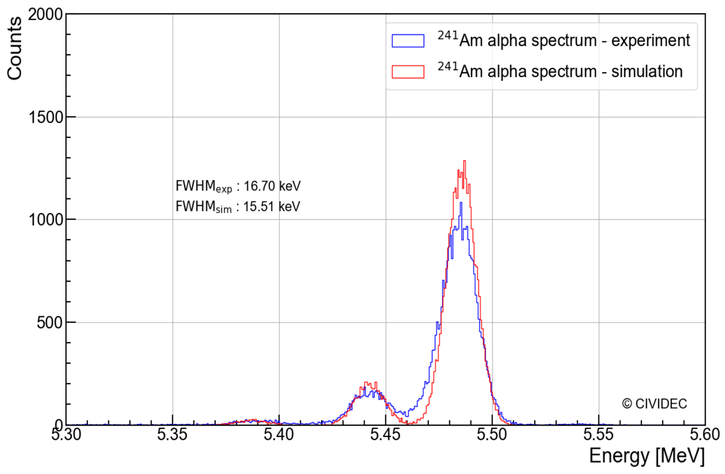


Fig.3: The comparison of measured ^{241}Am alpha spectrum with simulations.

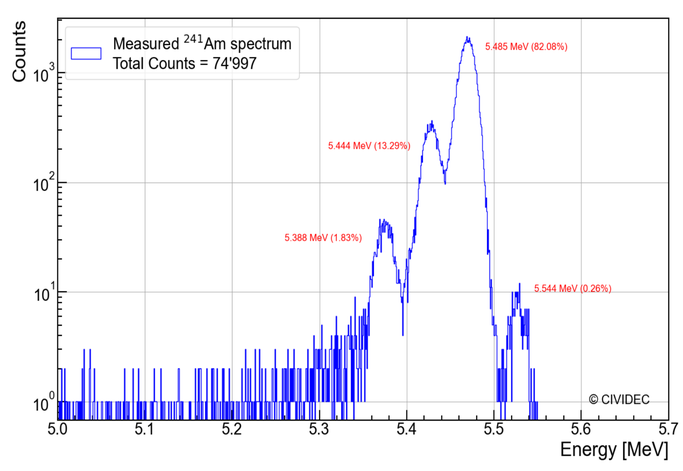


Fig.4: Measured ^{241}Am alpha spectrum on logarithmic scale.

Discussion

- FWHM values were calculated from histogram binning in experimental data.
- The energy resolution, measured as FWHM, is 15.51 keV for simulation and 16.70 keV for measurement.
- Four distinct peaks from ^{241}Am are visible in the experimental spectra: 5.388 MeV, 5.442 MeV, 5.485 MeV and 5.544 MeV and peaks contribution are 1.83%, 13.29%, 82.08% and 0.26%, respectively.
- The experimental data and simulation results are presented for direct comparison, highlighting both the accuracy and differences.

References

C. Weiss et al., "High-temperature performance of solid-state sensors up to 500 °C," *Nuclear Instruments and Methods in Physics Research A*, vol. 1040, p. 167182, 2022. DOI: 10.1016/j.nima.2022.167182.

B. Kraus et al., "Charge carrier properties of single-crystal CVD diamond up to 473 K," *Nuclear Instruments and Methods in Physics Research A*, vol. 989, p. 164947, 2021. DOI: 10.1016/j.nima.2020.164947.

T. Shimaoka et al., "Fano factor evaluation of diamond detectors for alpha particles," *Physica Status Solidi A*, vol. 213, no. 10, pp. 2777-2782, 2016. DOI: 10.1002/pssa.201600195.

M. Pomorski, "Electronic properties of single crystal CVD diamond and its suitability for particle detection in hadron physics experiments," *Ph.D. dissertation*, Wolfgang von Goethe University, Frankfurt am Main, Germany, 2008.

Acknowledgment

- This project is part of EuPRAXIA doctoral Network which has received funding from the European Union´s Horizon Europe research and innovation programme and the UKRI guarantee funds.
- This work is sponsored by CIVIDEC Instrumentation and was carried at TRIGA Center Atominstitut, TU Wien.

Contact: divya@cividec.at