Diamonds from 2 K to 500 K

Benjamin Kraus, Nikolay V Aksenov, Rugard Dressler, Robert Eichler, Erich Griesmayer, Dominik Herrmann, Patrick Steinegger, Andreas Türler, Christina, Weiss … featuring H. Jansen et al.

PSI and CIVIDEC
Introduction

• 0 °C = 273.14 K
Measurements

• 2 K ... 300 K
• 300 K ... 500 K
Part 1

• 2 K ... 300 K (H. Jansen, CERN 2013)

• 300 K ... 500 K
Chemical Vapour Deposition Diamond

Charge Carrier Movement at Low Temperatures and Use in Time-Critical Applications

Dissertation zur Erlangung des Doktorgrades (Dr. rer. nat.) der Mathematisch-Naturwissenschaftlichen Fakultät der Rheinischen Friedrich-Wilhelms-Universität Bonn angefertigt bei der Europäischen Organisation für Kernforschung, CERN, Genf, Schweiz

von Dipl.-Phys. Hendrik Jansen aus Oberhausen
Figure 4.8.: The schematics of the α-TCT set-up.

Courtesy H. Jansen
TCT pulses

![Graph showing current vs. time for holes and electrons with different temperatures.]

- holes $V_{\text{bias}} = -500$ V
- electrons $V_{\text{bias}} = 500$ V

$T <$

Courtesy H. Jansen
Drift time

![Graph of drift time vs temperature for electrons and holes at 500 V, showing 10 ns delay.](image)

Courtesy H. Jansen
Drift velocity

![Graphs showing drift velocity vs. temperature for electrons and holes at different temperatures.](a) and (b)

Courtesy H. Jansen
Mobility

![Graph showing the mobility of electrons and holes at various temperatures with symbols and equations representing the data.](image)

**Equations:**
- $\mu_h \propto T^\alpha$
- $\mu_h = \left(1/\mu_{nis} + 1/\mu_{aps}\right)^{-1}$
- $\mu_e = \left(1/\mu_{nis} + 1/\mu_{aps}\right)^{-1}$

**Legend:**
- S52
- S57
- S79

*Courtesy H. Jansen*
Charge yield

(A) Charge vs. temperature for electrons with fits.

(B) Charge vs. temperature for holes with fits.

Courtesy H. Jansen
Part 2

- 2 K ... 300 K
- 300 K ... 500 K (PSI 2017, 2018)
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Corresponding Author: Dr. Patrick Steinegger, Ph.D.

Corresponding Author's Institution: Paul Scherrer Institute

First Author: Benjamin Kraus

Order of Authors: Benjamin Kraus; Nikolay V Aksenov, Dr.; Rugard Dressler, Dr.; Robert Eichler, Dr.; Erich Griesmayer, Prof. Dr.; Dominik Herrmann; Patrick Steinegger, Dr.; Andreas Türler, Prof. Dr.; Christina Weiss, Dr.
Setup
Measurement setup
Measurement setup
The crew
TCT pulses

A

Electron drift mode

B

Hole drift mode

\[ T > \]
Drift time

![Graph showing the relationship between temperature and drift time for electrons and holes. The graph plots drift time in nanoseconds (ns) on the y-axis and temperature in Kelvin (K) on the x-axis. Red dots represent electrons, and blue circles represent holes. The drift time increases with temperature for both electrons and holes.]
Drift velocity

Temperature, K

Drift velocity, cm/s

Electrons

Holes
Mobility

A. Charge carrier mobility $\mu$, cm$^2$/Vs

Electrons
- $T < 370$ K: $T^{-0.48}$
- $T > 370$ K: $T^{-1.10}$

B. Charge carrier mobility $\mu$, cm$^2$/Vs

Holes
- $T < 370$ K: $T^{-1.06}$
- $T > 370$ K: $T^{-1.88}$
Noise

![Graph showing Noise vs Temperature](image)

- Red dots represent Electrons
- Blue circles represent Holes

Noise, mV vs Temperature, K
Charge - TCT

![Graph showing area vs temperature for electrons and holes.](image)
Charge - spectroscopic

![Graph showing the relationship between temperature and pulse amplitude. The x-axis represents temperature (K), ranging from 300 to 480, and the y-axis represents pulse amplitude (mV), ranging from 800 to 1400. The data points are shown with error bars indicating variability. The graph suggests a nearly constant pulse amplitude across the temperature range.]
Energy resolution

Resolution, % \((E_\alpha = 5304\, \text{keV})\)

Temperature, K
Verification

• CERN 2016
2 Pulse area

Figure 1: Pulse area vs. temperature, measured at CERN.

Figure 2: Pulse area vs. temperature, measured at PSI.
3 Charge yield

Figure 3: Charge yield vs. temperature, measured at CERN.

Figure 4: Charge yield vs. temperature, measured at PSI.
4 Drift time

Figure 5: Drift time vs. temperature, measured at CERN.

Figure 6: Drift time vs. temperature, measured at PSI.
5 Drift velocity

Figure 7: Drift velocity vs. temperature, measured at CERN.

Figure 8: Drift velocity vs. temperature, measured at PSI.
6 Mobility

Figure 9: Mobility vs. temperature, measured at CERN.

Figure 10: Mobility vs. temperature, measured at PSI.
Conclusion

• CVD shows stable charge response from 2 K to 500 K.
Outlook

• In 2020 we go up to 500 °C.
Diffusion

Temperature, K

Diffusion coefficient $D$, cm$^2$/s

$D_e$ (this work)  
$D_e$ (Jansen et al.)  
$D_h$ (this work)  
$D_h$ (Jansen et al.)