Mobilities in high-quality CVD diamond crystals evaluated by time-offlight measurements: experimental and simulation results

Audrey Valentin, V Mille, A Tallaire, J Achard, A Gicquel

Mobilities in high-quality CVD diamond crystals evaluated by time-of-flight measurements: experimental and simulation results

A. Valentin, V. Mille, A. Tallaire, J. Achard, A. Gicquel

[1]LSPM-CNRS, Laboratoire des Sciences des Procédés et des Matériaux, Université Paris 13, Sorbonne Paris Cité, avenue Jean-Baptiste Clément, 93430 Villetaneuse, France

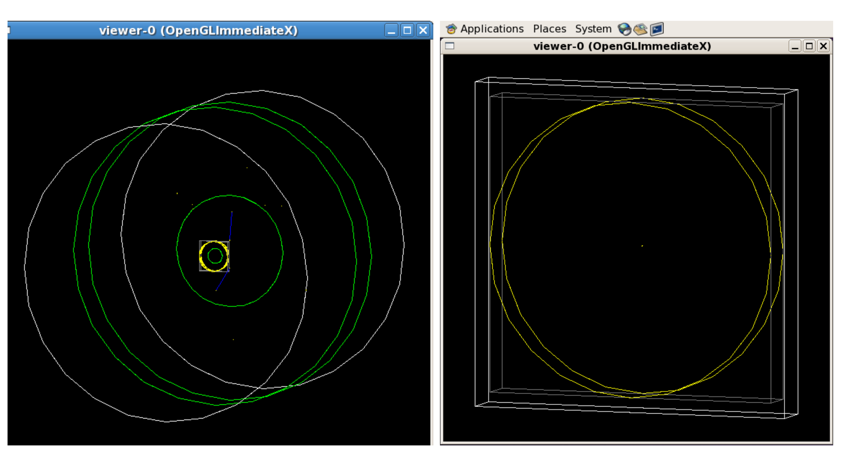
Abstract

Diamond is a promising candidate for power electronics as well as for radiation detection1. In both cases, device optimization requires an accurate knowledge of electron and hole mobilities.
In this study, time-of-flight (TOF) experiments were performed on intrinsic CVD diamond crystals to determine carrier mobilities. Electron-hole pairs were generated in a biased diamond layer by α rays. The resulting current peak was amplified and measured.

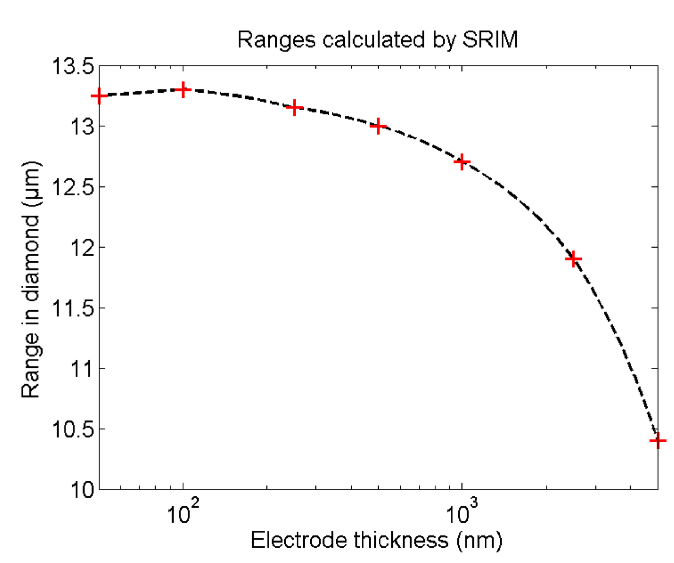
The distribution of electron-hole pairs in the sample has also been studied by means of simulation with SRIM and Geant4. This distribution has then been used to simulate the charge transport in the diamond. A drift-diffusion model, coupled with Poisson's equation, was implemented in COMSOL.
These simulation tools have been used to optimize the sample and experimental setup geometry.

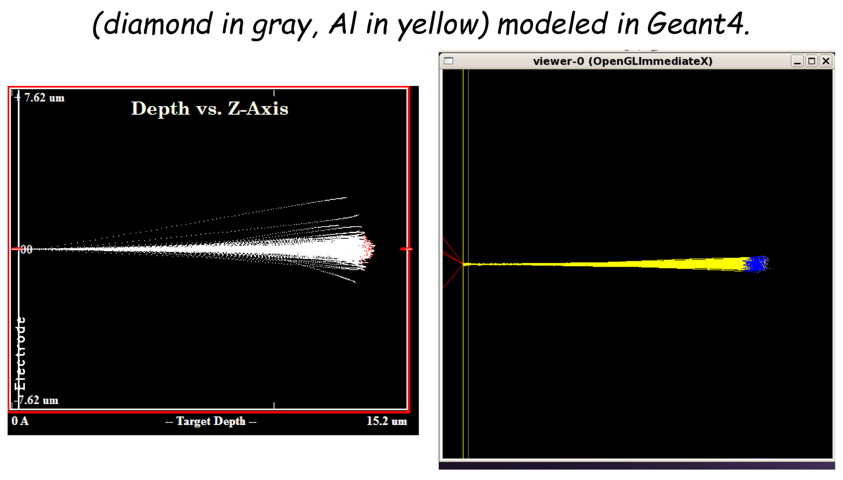
Radiation effect modelling

Particle ranges have been calculated with SRIM.
The full energy deposition profile have been calculated with Geant4 (with the Livermore energy model) which takes into account secondary electrons.

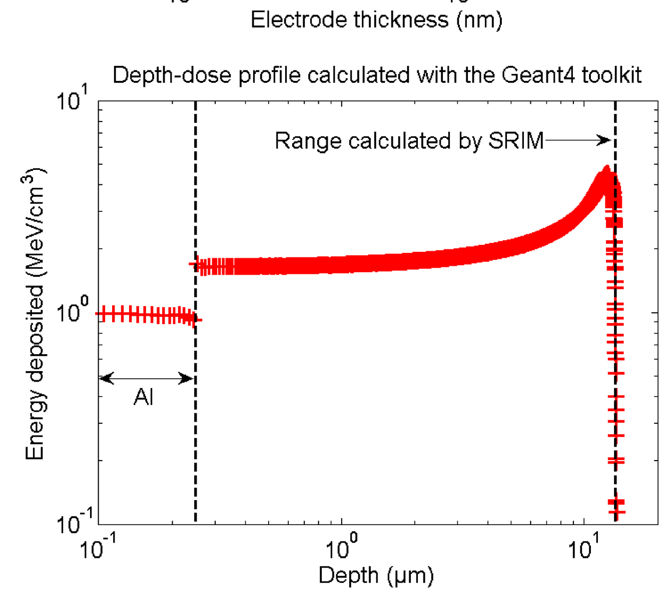


Full geometry of the sample holder (green), with the sample (diamond in gray, Al in yellow) modeled in Geant4.





Tracks of 100 α-rays calculated with SRIM (left) and Geant4 (right, with α particles in yellow and secondary electrons in blue).

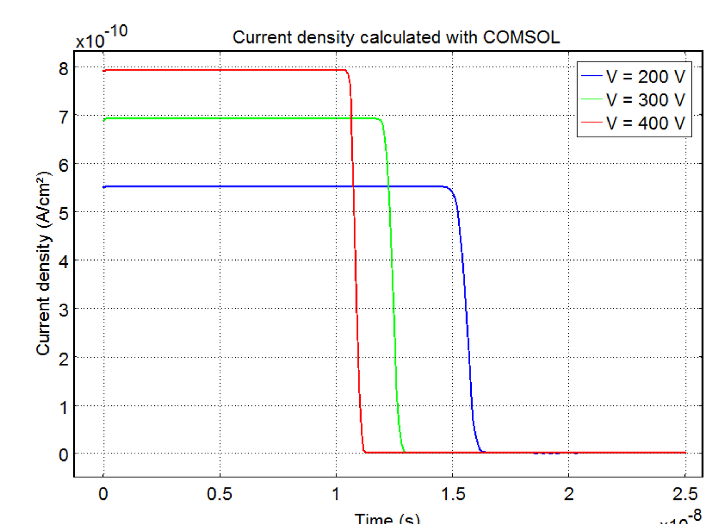


Results obtained with a 250 nm-thick Al electrode:

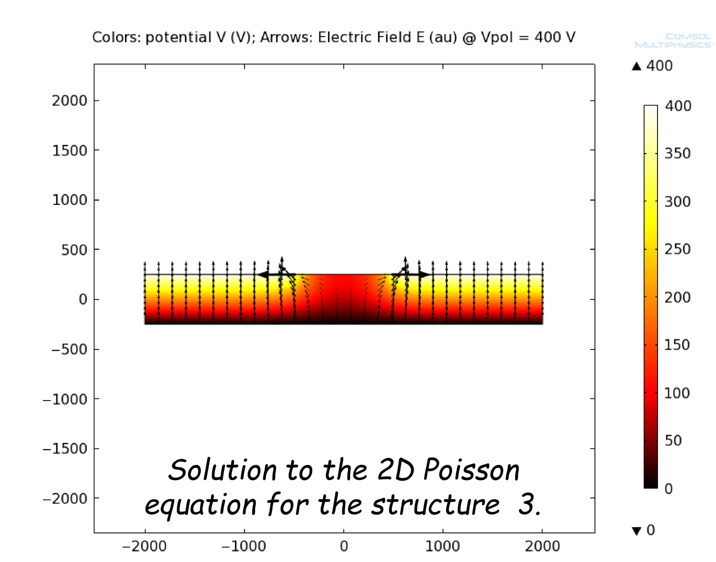
- Range = 13.4 µm
- 99.3 % of the energy is deposited in the diamond layer
- 0.4 % of α particles hit the diamond

Charge transport modelling

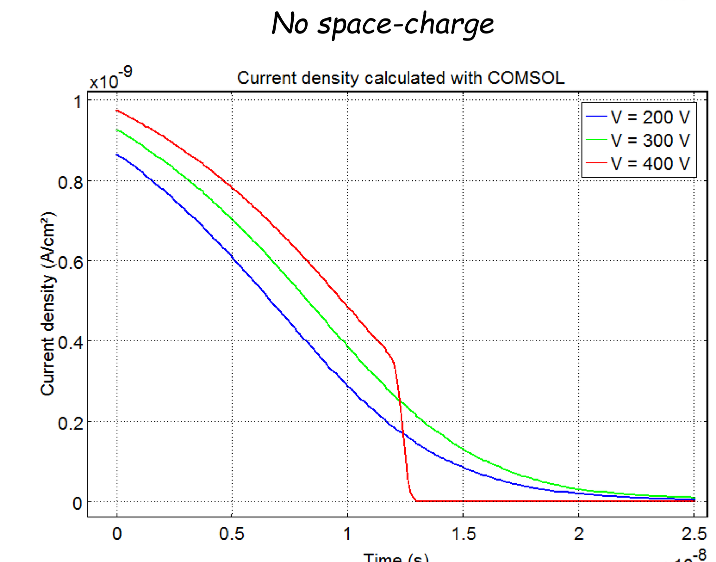
A drift-diffusion model has been used to study the charge transport in diamond.
The drift-diffusion equations coupled to Poisson's equation are solved with COMSOL.



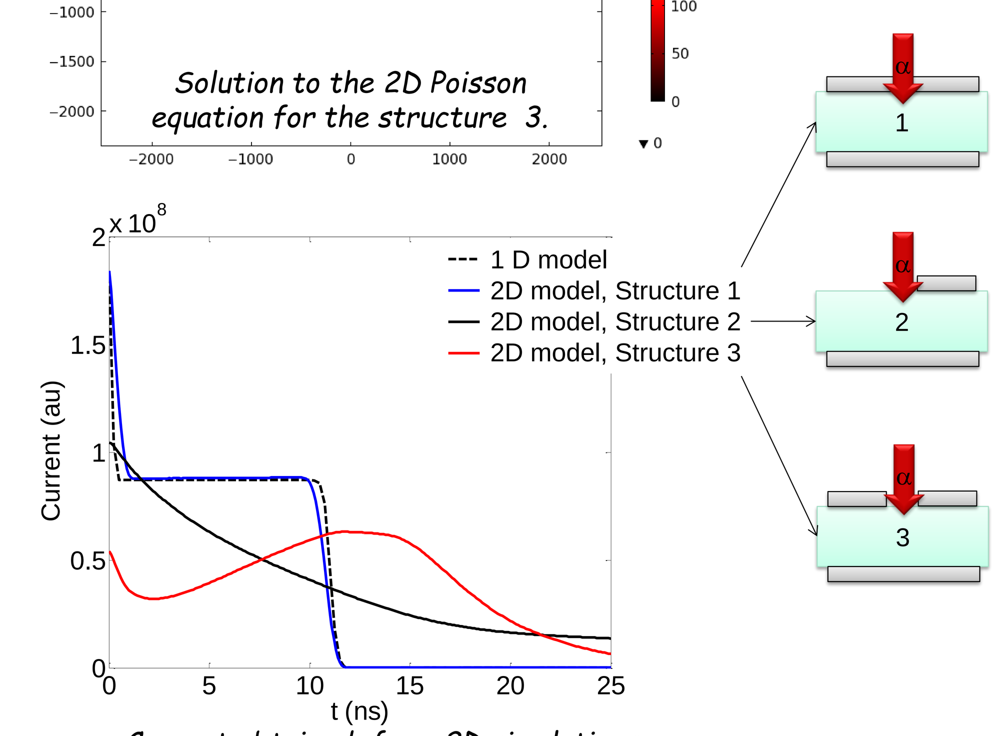
No space-charge



Solution to the 2D Poisson equation for the structure 3.



5.10^{11} cm^{-3} effective charge-space



Current obtained from 2D simulations with several electrode shapes

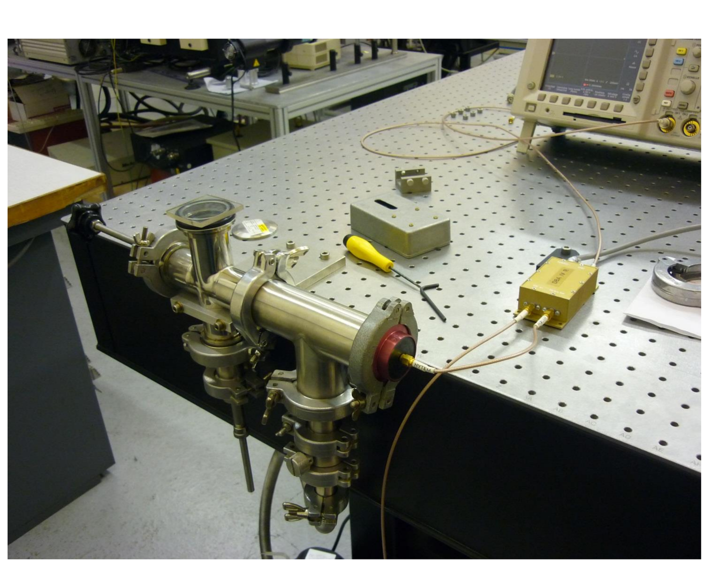
Results:

- the presence of a space-charge bends the current peak
- a hole in the electrode degrades the electric potential repartition..

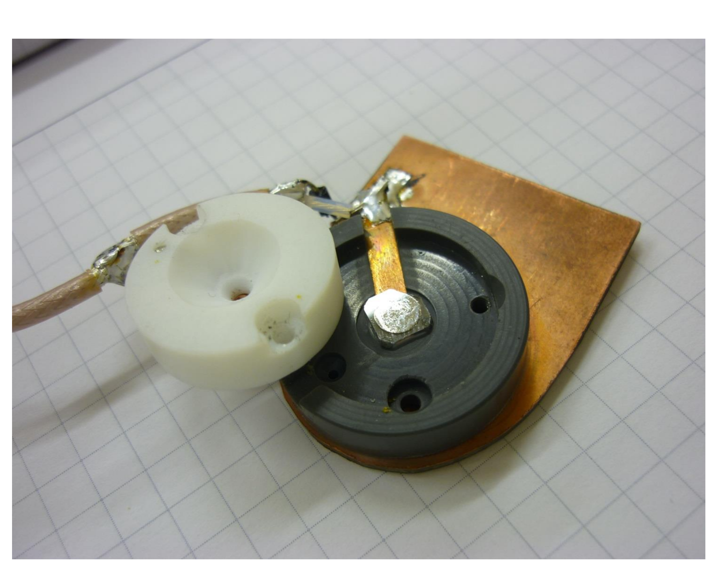
Time-of-Flight measurements

Electron-hole pairs are generated on one side of the sample with alpha rays from an ^{241}Am source.
The sample is biased with a Keithley 6487 used as a DC voltage generator to collect electrons and holes and the obtained current is amplified by a DBA-IV/R device.
The amplified current is finally measured with a Tektronix TDS300 oscilloscope.

The sample is a 620µm-thick intrinsic freestanding CVD diamond film onto which 250 nm-thick Al contacts were evaporated.



The experimental setup

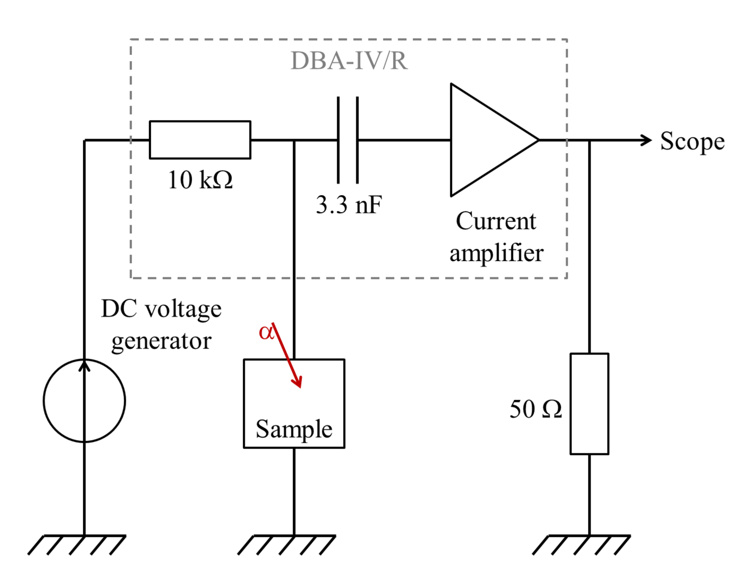


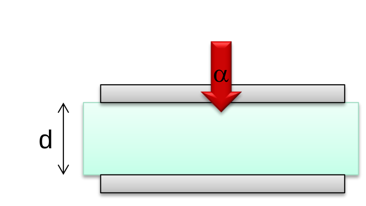
The sample in the sample holder

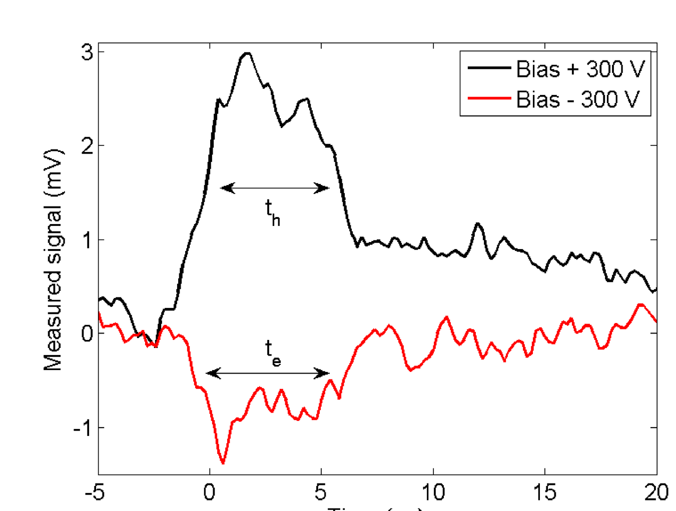
The measured signal is a peak which full width at half maximum is the time-of-flight.
The hole mobility μ_h and electron mobility μ_e are extracted from the measured time of flight t_h and t_e with

$$\mu_{e/h} = \frac{d}{E.t_{e/h}}$$

where E is the applied electric field and d the diamond thickness.







Measured signal and time-of-flight extraction

Results @ 300 V:

- Hole mobility of 2200 m²/Vs
- Electron mobility of 2200 m²/Vs

Conclusion

Time-of-Flight experiments have been performed. The experimental setup was studied by means of simulations.
The sample holder and the sample geometry have been studied. The effect of a particles in diamond and the charge transport have been modeled. Simulations show that the sample holder stops most of the particles while the electrode thickness is too low to have an influence on the energy deposition. The electrode geometry effect on the current measured have also been studied. This shows that a thin full plate electrode covering the sample is needed.
First measurements have shown a good electron and hole mobility in diamond. The experimental setup will be improved thanks to our simulation results to obtain more results.

Contact
+33(0)1 49 40 34 23 – valentin@lspm.cnrs.fr

SBDD XVIII – Hasselt 2013

LSPM-CNRS
Université Paris 13
Institut Galilée
99 avenue Jean-Baptiste Clément
93430 Villetaneuse France
Fax : +33 (0)1 49 40 34 14