Memory and Polarization Effects in Heteroepitaxial 'quasi' Single-Crystal Diamond Detectors*

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The trapping of drifting electrons and/or holes in the deep defect levels of defective diamond detector materials causes the build-up of an internal space charge. Subsequently created electron-hole pairs will experience an altered electric field inside the detector. A method, which is called priming or pumping, is used in order to stabilize diamonds before their usage as nuclear detectors. Priming is preferably carried out with penetrating radiation (^{90}Sr electrons) which ionizes homogenously the bulk material. The ionized charge carriers passivate the defects along their drift path. Depending on the spatial distribution and the nature of the traps, these processes lead either to polarization and/or to memory effects [1], which consequently enable detector signals at zero bias voltage. The 'memory signals' are defined as detector signals of the same polarity as of the previously biased detector (Fig. 2, left). In case of polarization, the detected signal is of opposite polarity (Fig. 2, right).

To investigate polarization and memory effects, the detector was first operated for 30 minutes in electron or hole drift configuration (Fig. 1). Due to the short range of ^{241}Am α-particles in diamond (~13µm), only one charge carrier species contributes to the detector signal. The pulses were amplified with a non-inverting diamond broadband amplifier (DBA) and monitored with a 6 GHz DSO of 20 GS/s resolution. After this time of biased operation, the high voltage was tuned as fast as possible to zero. The still appearing detector signals were continuously recorded for a long period of time (Fig. 3).

For single crystal CVD diamond (scCVDD) negligible polarization and no memory effects could be measured - in contrast to polycrystalline CVD diamond (pcCVDD) detectors, which are often influenced by both effects. Interestingly, the 'quasi single crystal' Diamond-on-Iridium (DoI) sensors showed only positive signals at zero bias, independent of the polarity of the previously applied bias (Fig. 2). That means, the memory effect in the tested DOI film exclusively appears after electron drift, whereas polarization after hole drift configuration, respectively.

Concluding, the remaining internal electric field at zero bias is comparable to the effective field generated during electron drift configuration. Therefore the polarization and memory effects in the tested DoI sample are supposed to be dominated by only one type of traps - in contrast to the pcCVDD in these measurements. Electron traps are suspected to be responsible, because the charge collection efficiency (CCE) of DoI is for electron drift significantly worse than for hole drift [2].

The count rates of detected signals were recorded in intervals of 5 min and the time constant (τ) of the rate decay of the polarization events was extracted by fitting an exponential to the experimental data (Fig. 3, right). Comparing initial count rate (f_0) and time constant, the strength of polarization in the DoI samples lies between that of pcCVDD and scCVDD, ($\tau_{PC} < \tau_{DOI} < \tau_{SC}$; $f_{0PC} > f_{0DOI} > f_{0SC}$). Eventually, it was noticed that pcCVDD polarizes immediately after biasing, whereas scCVDD very slowly.

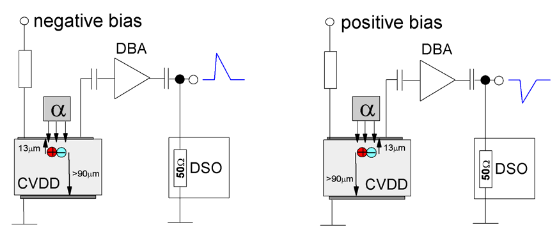

Figure 1: Measurement setup in electron drift configuration (left) and hole drift configuration (right).

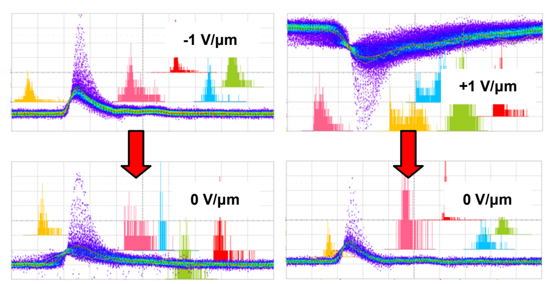

Figure 2: Illustration of memory (left) and polarization effect (right) in DoI 886-2. The DSO displays a 5 ns time window. The green traces are 'most probable' α- signals.

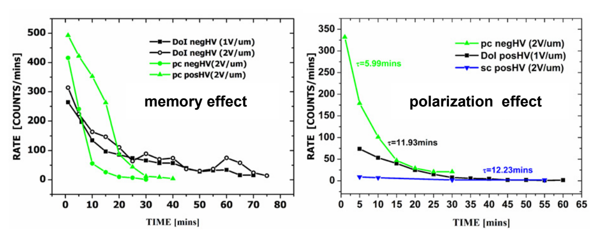

Figure 3: Count rate of memory and polarization signals versus time in different types of CVD diamond detectors.

References

[1] A. Lohstroh et al., J. Appl. Phys. 101(2007) 063711.
[2] E. Berdermann et al., this report.

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