CVD-Diamond Detectors - Status Report 2000

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The excellent results obtained from CVD-diamond detectors in heavy-ion timing measurements with intense beams initiate applications in new fields [1]. A large area (6 x 4 cm²) diamond strip detector of 200 µm thickness containing 32 strips of a 1.8 mm pitch has been successfully used in the atomic physics Cave A at GSI as the focal plane detector of a magnetic spectrometer. Beam loss monitors are under consideration, enabling controlled beam transport in hot regions along the high-current injector beamlines. Very first results from the time resolution in measurements with minimum ionizing particles are encouraging. Polished CVD-diamond material with a collection distance > 200 µm is being used for. Because of the much better Signal-to-Noise ratio required, new timing amplifiers are currently under development [2].

The investigations of CVD-diamond detectors are continued with studies of the influence of the electric field and the bias polarity to the detector response. A variety of papers [3] is available in the literature discussing the origin and the nature of numerous trap levels detected in the range from 20 meV to 3.6 eV in CVD diamond. Due to the appearance of fixed space charge in the diamond bulk, the electric field inside the detector is not homogeneous. The mobility of carriers in the crystalline grains is orders of magnitude higher than in disordered grain boundaries. Conductivity models are discussed, where the average collected charge is affected by electron capture in grain boundaries (assumed as amorphous carbon) and hole capture in grain defects. Because of the columnar growth structure of the polycrystalline CVD diamond the electrical behaviour of material neighbouring nucleation side is quite different compared to the growth side. The influence of the detector thickness to this picture is obvious.

Three detectors made of unpolished CVD diamond grown with identical process parameters but different thicknesses were used to study the detector behaviour under different electric field conditions. The detectors of an 1 cm² area were mounted in a stack with increasing thickness in beam direction (d_{D1} = 93 µm, d_{D2} = 158 µm, d_{D3} = 246 µm). The beam test has been performed with ^{84}Kr projectiles of 650 MeV/amu.

The data obtained are limited by the bandwidth and the sensitivity of the available electronics. In order to avoid saturation of the pulse heights as observed for D2 and D3 in some cases (see Fig. 2, Fig. 3) a new amplifier DBAIII (3 GHz) with variable gain 1:100 has been developed. Low sensitivity QDC's and TDC's of higher resolution than the currently used (25 ps/ch) are urgently required for future measurements.

Characterisation data of the D1 sample (d = 93 µm, C = 37 pF) are shown in Fig.1. The pulses (a) demonstrate the limitation of

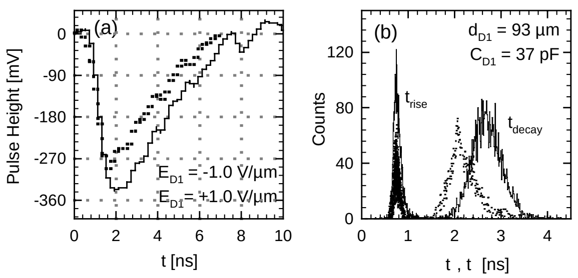

Fig 1: (a) Single-particle pulses at positive resp. negative bias. (b) The corresponding rise-time and decay-time distribution

the measurement system to determine the signal rise time. Commonly, a higher amount of charge is collected for positive bias on the growth side whereas a shorter carrier drifttime is observed for negative polarity (b).

Fig.2 shows the timing results obtained from each diamond detector versus a plastic scintillator used in coincidence. The σ–widths of the ToF spectra are plotted over the electric field applied in (a) and over the detector thickness in (b).

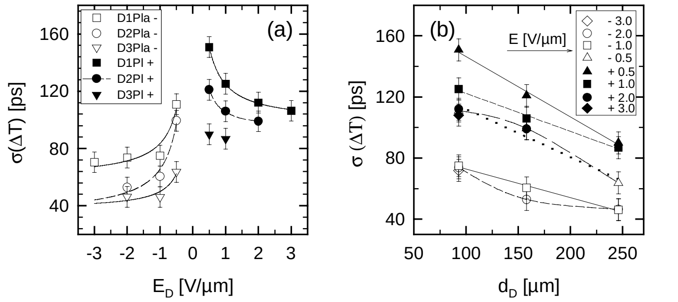

Fig. 2: ToF resolution measured with three diamond detectors of different thicknesses versus a scintillator detector. The σ-widths of the ToF spectra are plotted over the applied electric field E in (a) and over the detector thickness in (b).

The corresponding pulse-height results are shown in Fig. 3.

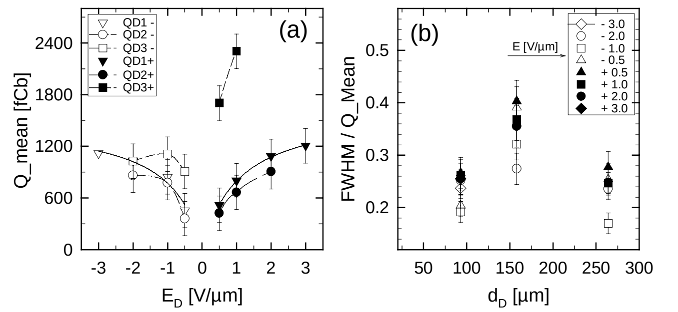

Fig. 3: The mean collected charge plotted over the applied electric field (a) and the pulse-height resolution under the same electric field conditions over the detector thickness (b).

Due to saturation effects of the D2 and D3 pulse heights no final conclusions concerning the thickness dependence of the collected charge signal can be extracted quantitatively. Nevertheless, the general trend is obvious. For both polarities the data indicate an erratic increase of the collected charge above a certain thickness. Although the charge collected with positive bias on the growth side is much higher, the best time resolution is obtained for thicker detectors at the highest negative electric field. These data have to be confirmed.

References

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