Heavy Ion CVD-Diamond Detectors for R3B*

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CVD-diamond is a detector material with fast signals, high charge carrier mobility, smallest lattice constant, and large band-gap [1] resulting in radiation hardness, very good timing and high count rate capability. These properties make it an ideal material for heavy ion tracking and TOF detectors. Polycrystalline diamond is successfully used as detector material at GSI for some years at several experiments (HADES, FOPI,...). Especially for the R3B experiment where a minimum material budget around the target is essential, we carry on this development towards highly segmented, thin, large area ($50 \times 50\,\mathrm{mm}^2$) devices.

First investigations were made with a new material from the IAF Fraunhofer Institute Freiburg. We have produced small test detectors of $10 \times 10\,\mathrm{mm}^2$ area with different thicknesses ranging from 20 μm up to 100 μm and a segmentation of four strips in x and y direction on the front and the back side respectively. Leakage currents of typically 5 nA/cm^2 are constant up to fields of 5 V/μm and increases by a factor of 10 between 5 - 7 V/μm. We applied a field of 3 V/μm.

Basic tests were performed at the Munich Tandem accelerator using ^{16}O and ^{7}Li beams of 117 MeV and 48 MeV. The detectors were set up as a stack consisting of a diamond detector and a Si diode. After passing through the diamond detector the beam was stopped in the diode which provided a trigger and the residual energy signal.

The detector efficiency was measured for a 50 μm thick diamond substrate. Using the Li beam and an energy cut of 20 % of the average signal, 98 % of all particles passing the diamond are recognized. This value is consistent with the segmentation gaps of 50 μm at a pitch of 2 mm.

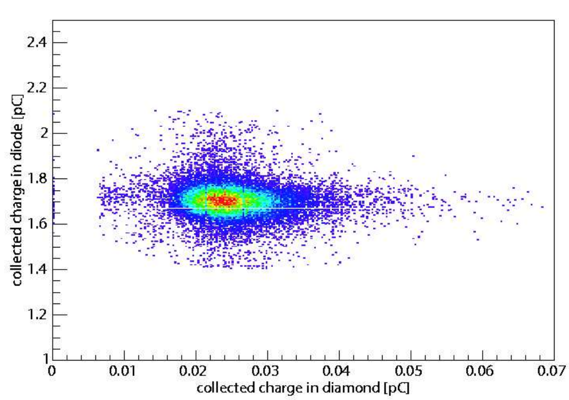

Figure 1: The collected charge in the diamond detector versus the collected charge in the diode.

In polycrystalline CVD-diamond material the electrons and holes only drift a fraction of the thickness in the electric field and recombine preferred at the grain boundaries. This charge collection capability typically widens the energy distribution (see fig. 1). An average collected charge of 25 fC corresponds to a charge collection depth of 12 μm which is already sufficient for heavy ions and has to be verified for different material thickness.

Another main task of the measurement was to test the radiation hardness of this material. Up to a dose of 10^{11} ^{16}O ions per mm^2 the average signal amplitude linearly dropped to about 70 %.

After these tests this type of detector was already used as start detector in the HADES experiment in 2005. It is only half the thickness of the old start detector and mounted closer to the target. Therefore particle background is reduced. The four fold segmented detector in this case was mounted on a new developed circuit board based on a fast, low-noise, low power 2 GHz broad band preamplifier in a SC70 package. It was tested in an 1 AGeV ^{27}Al beam from SIS/GSI and used in a beam time in September using ^{40}Ca of 1.9 AGeV.

The efficiency of the new start detector was measured in relation to the old one. 1.5 % of all particles were seen in the old start detector but not in the new one. This result is very similar to the Munich measurement reported before.

Investigating the time of flight between the old and the new start detector a time resolution of $\sigma\tau \approx 60\,\mathrm{ps}$ for each individual detector was measured. This did not depend on the signal amplitudes and is about a factor of two worse than expected from the signal rise time and the noise figure. Reasons for this have to be investigated in further tests.

A special feature of the detector material are particle induced persistent currents which have decay times of several seconds after switching off the beam. This effect also seen in laser excitation of CVD-diamond results from material impurities and the grain boundaries [1].

At beam intensities of $2 \cdot 10^6\,\mathrm{s}^{-1}$ a maximum current of 2 μA was observed in the first days of operation. This value dropped to 500 nA after 10 days.

Next steps in the development will be a higher segmentation with 30 μm gap and 110 μm pitch utilizing lithographic methods. The handling of large area diamonds has to be practiced. New readout schemes have to be implemented for these detectors and a first large area prototypes is expected end of 2006.

References

[1] C. Nebel, Semicond. Sci. Technol. 18 No 3 (March 2003) S1-S11, PII: S0268-1242(03)58317-1

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