Low-purity IIa scCVD diamond material for high-current heavy-ion experiments in HADES/CBM at FAIR *

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The physics program of the planned HADES and CBM experiments at the FAIR facility requires high current beams, especially the CBM experiment which plans to operate at up to 10^9 ions/s. Thus, a critical requirement of the beam and T0 detectors for these experiments is high rate capability and radiation hardness. The position of the detector in the beam line has to be optimized such that the count rate per channel stays below 10^7 ions/s (readout limitation) and the detector area (cost) remains affordable. The high purity scCVD diamond material, called Electronics Grade (EG) diamond, is perfectly suited for this application [1] but is very expensive with prices in the order of £1500.00 [2] for a single 4.5 mm x 4.5 mm x 0.3 mm plate. In this project we performed a feasibility study of using lower purity scCVD diamond material which is more than factor of 7 cheaper than the EG material. Both types of material belong to the same class of diamond, IIa [3]. The EG type is the highest purity commercially available with nitrogen contamination N_{contam} <5 ppb whereas the low purity IIa diamond, used in this experiment, has N_{contam} <1 ppm. The prototype detector with an active area of 4.5 mm x 4.5 mm and a thickness of 500 μm was metallized with 50 nm Cr layer, covered by a 150 nm gold layer and annealed at 500 °C prior to the experiment. The detector was mounted to PCB with 2 stages of amplification as shown in Fig.1.

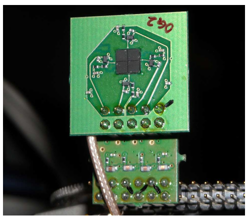

Figure 1: Low purity IIb scCVD diamond mounted on the test PCB.

The experimental setup, shown in Fig.2, was designed such that the 400 MeV/c carbon beam would first pass through the test detector and then though a EG detector. Charged particles crossing the diamond detector produce excess charge carriers which drift following the electrical field and generate signals in the readout electronics. In the lower purity diamond, with chemical impurities (mainly nitrogen), the charge carriers are trapped and can stay in the trap for several hours. This leads to incomplete charge collection [1]. It was expected that at very low rate, at the beginning of the experiment, the low purity material should show large signal amplitude fluctuations but it was thought that if subjected to a sufficiently high beam intensity such that all traps were filled, it could perform like an EG detector. Indeed, during the first 30 minutes of the test experiment the signal amplitudes from low purity diamond were on average about a factor of 10 lower than from the EG reference detector. After about 45 minutes of irradiation at 10^5 C ions/s the signal amplitude saturated at a value comparable to the EG diamond and the low purity plate performed like an EG diamond. Based on the reference detector we estimated the time resolution of both detectors. The time difference spectrum is shown in the Fig.3 and the measured time resolution is $27\,\mathrm{ps}/\sqrt{2} \approx 19\,\mathrm{ps}$.

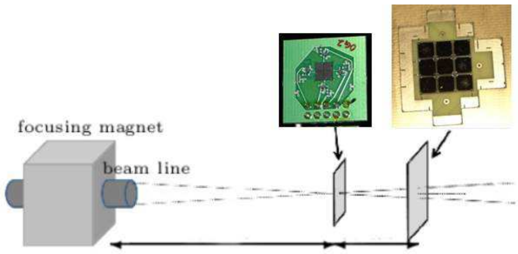

Figure 2: Sketch of the beamline setup.

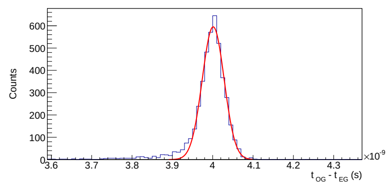

Figure 3: Time difference measured between EG diamond and the low purity diamond. The obtained resolution of the system, is 27ps σ.

References

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