Homogeneous Large Area CVD-Diamond Detectors for Tracking and ToF*

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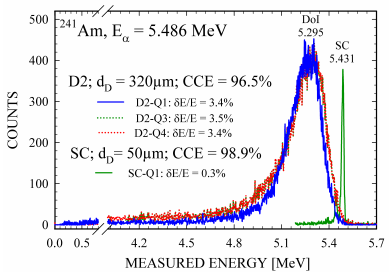
In the last year, we continued with the development of large-area diamond sensors grown at the University of Augsburg by chemical vapour deposition (CVD) on wafer scale Ir/YSZ/Si(001) substrates. Early results of diamond-on-iridium (DoI) sensors [1] were indicating significant defect densities within the detector bulk, which led to reduced charge collection efficiencies CCE = Q_{Coll}/Q_{Gen}= 40% (with Q_{Gen} the particle induced charge and Q_{Coll} the charge measured by the sensor) and broad spectra of energy resolution $\delta E/E \approx 30\%$. These values were obtained with traversing ^{241}Am-α-particles for the favourable case of a sensor of thickness d = 12µm = α-range in diamond.

A remarkable improvement of the crystal-quality has been achieved in 2010 by using ultra-pure H_2/CH_4 gas mixtures and optimized growth techniques [2]. Two DoI samples D1 and D2 of thicknesses d_{D1} = 293 µm and d_{D2} = 320 µm, respectively, were investigated. Ti/Pt/Au quadrant electrodes with common mass potential were applied in order to prove the spatial homogeneity of the detector performance. Almost symmetrical IE_D characteristics with respect to the bias polarity were obtained for each sector, while the dark current at electric fields $E_D \geq \pm$ 2 V/µm were of the order of 10^{-13} A, well comparable to homoepitaxial single-crystal (SC) diamond sensors.

Charge Collection Properties

The most sensitive parameters revealing both the crystal quality and the sensor performance are the CCE and the energy resolution δE/E measured with line sources using spectroscopy electronics [3]. Charge losses are a measure for defects (dislocations, traps, recombination centres), whereas the measured line widths for the homogeneity of crystal structure and detector response. Figure 1 shows ^{241}Am-α-spectra obtained from sectors Q1, Q3, and Q4 of D2 compared to the spectrum measured with sector Q1 of a SC diamond sensor of identical area but smaller thickness d_{SC} = 50 µm.



. **Figure 1:** ^{241}Am-α-spectra of sensor D2 (d_{D2} = 320µm) compared to the α-distribution obtained with a homoepitaxial sensor of same area but smaller thickness d =50µm.

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The similarity of the spectra obtained from all DoI sectors demonstrate the good spatial homogeneity of the detector response, and thus of the crystal structure. The peak values correspond to an excellent CCE_{D2} = 96.5%, which is slightly lower than the CCE_{SC} = 98.9% measured for the SC sample. The right hand parts of the DoI lines are Gaussians of a relative energy resolution $\delta E/E_{D2} \approx 3.5\%$ (compare $\delta E/E_{SC} \approx 3‰$), whereas the low-energy tail is a convolution of the unresolved ^{241}Am-α satellite lines and of α-signals affected by trapping.

Timing Properties

The intrinsic time resolution of D1 and D2 was measured with ^{40}Ar ions of E = 200 AMeV using DBA amplifiers. An excellent σ_{intr} = 18ps was obtained - as frequently confirmed also for polycrystalline and SC diamond sensors.

However, the broadband (BB) signal shapes (representing the internal electric field profile) cannot be understood. Triangular signals of ultra-fast rise time << 200 ps and FWHM ≈ 1.5 ns were recorded for sensor D1 at E_D = ± 2 V/µm (Fig. 2, blue signals), which indicate inhomogeneous internal fields and non-negligible charge trapping. This is in contradiction to the high CCE ≈ 93% measured with spectroscopy electronics also for this sample. We tested the effect of the measurement system's bandwidth (BW) to the signal shape with a thin (d = 12 µm) 'early' DoI sensor (Fig. 2, red/green signals). An improvement of the pulse area A ∝ Q_{Coll} by a factor 2 was obtained by modifying the DBA from BW = 2.3 to 3.4 GHz and by using, in addition, a 6 GHz DSO.

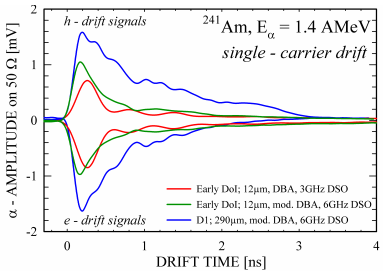

Figure 2: α-induced transient current signals in D1 (blue) and in an 'early' sample of d_D = 12µm. The red-green set of signals show the influence of the BW and the green-blue one the superior CCE of DoI sensors grown in 2010.

References

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[2] C. Stehl et al., "Growth of Heteropeitaxial CVD-Diamond Films on Ir/YSZ/Si(001) for Detector Applications", this Annual Report (2010).
[3] E. Berdermann et al., Diam Rel. Mat. 17 (2008) 1159