Pulse height defect in the sc CVD diamond detector versus the applied electric field measured with fission fragments from ^{252}Cf

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The response of semiconductor detectors to the energy lost by heavy ions is complicated because the kinetic energy of the ion is not completely converted into an electric signal. The emerging pulse-height defect (PHD) depends on the energy, mass, and charge of the ion as well as on the applied electric field. The PHD is defined as the energy difference ΔE between the kinetic energy E_k of an ion incident in the detector and the apparent energy E_{DD} derived from the measured electric signal.

Most detailed studies of PHD were performed for Si detectors.[1–3] Another promising detector material that appears to extend the possible applications for heavily-ionizing particles compared to Si is chemical vapor deposition (CVD) diamond.[4,5] However, the use of diamond detectors (DDs) as detectors for low-energetic heavy ions is still at its beginning. There are only few publications about PHD in DD.[6–8]

The use of DD as fission fragment detectors was studied by Fregeau et al.[7] The authors concluded that all their DDs showed inadequate energy resolution and suffered from extensive PHDs. The detected pulse height never exceeded about 30 % of what they expected from a simulation of the stopping of ^{252}Cf fission fragments in DD.

In an earlier experiment at the FLNR, Dubna, we investigated the PHD for fission fragments of a ^{252}Cf source at different electric fields.[8] Values between 0.7−2.5 V/μm were used. The charge collection slowly increased towards saturation, but it was not yet saturated at 2.5 V/μm. At 0.7 V/μm, the PHD is about 70 % of the kinetic energy for heavy (HF) and light (LF) fragment groups of ^{252}Cf and about 59 % at 2.5 V/μm.

The aim of our new measurements at the HotLab, RIKEN, was to study the dependencies of the PHD caused by fission products of ^{252}Cf versus the applied electric field up to the highest possible bias and to compare these results with those of previous studies obtained with another single-crystal (sc) CVD DD.

The experiment was carried out at the HotLab, RIKEN. The dependence of the peak positions for the fission fragments of the ^{252}Cf source of 0.5 MBq activity on the electric field were measured with a sc DD manufactured at the GSI detector laboratory. The charge sensitive preamplifier CSTA2, the ORTEC spectroscopic amplifier, and the multichannel analyzer Kromek K102 were used. Detector dimensions were 3 $\times$ 3 mm^2 with a thickness of 200 μm. The DD had CrAu electrodes with thicknesses of 40 nm. The ^{252}Cf source was placed at a distance of 10 cm from the DD. The energy calibration was performed with α particles from a mixed source that has energies of 4.780, 5.480, and 5.795 MeV. The calibration of the electronics was performed with a precision pulser. The mean energies of the heavy and light fragment groups of ^{252}Cf were measured. The difference between the measured energies and the values reported in the literature[1,9] was defined as the PHD.

The working electric field for DDs is about 1.0−2.0 V/μm[10] although its breakdown value for DDs is much higher. All the charge created by α particles with energy of about 5 MeV has already been collected at 0.5 V/μm, and the pulse height remains the same at all values of the electric field from 0.5 to 5.0 V/μm (applied in our experiment). In contrary, for fission fragments of the ^{252}Cf with an increasing electric field from 1.0 to 2.0 V/μm, the pulse height increased by 8 %, indicating that the created charge is not fully collected. Further, PHD dependency on the applied electric field, which has a quite steep slope in the region 1.0−2.0 V/μm goes almost to its saturation between 2.5 and 3.5 V/μm. Namely, the PHD decreases in this region only by about 1 % for LF and about 2 % for HF. It was not possible to use an electric field higher than 3.5 V/μm for fission fragments of ^{252}Cf because occasional breakdowns started to occur.

We conclude that the application of an electric field higher than 2 V/μm slightly improves the charge collection efficiency of DDs for fission fragments of ^{252}Cf.

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