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Memory effects in CVD diamond

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Abstract

CVD diamond, as other wide energy gap semiconductors or insulators, is known to present polarization effects when used as a nuclear particle detector, which are due to the building up of an internal space-charge electric field and are responsible for "memory" effects if the polarization is not erased. Polarization effects are larger when the thickness of the sample is longer than the drift length of carriers and give rise to a shortening of the electric field region inside the sample. In this work, IBIC (Ion Beam Induced Charge) measurements with 1 and 2 MeV proton beams have been carried out on a relatively thin CVD diamond sample with the conclusion that no memory or hysteresis effects were present even by switching from one polarity to the opposite one in subsequent measurements. However, it resulted that the values of the charge collection efficiency (cce) did depend on counting rate and the lowering at large counting rates was attributed to a local polarization due to trapping. Finally, in some cases cce turned out to be larger than 1, a result which could be either due to local detrapping or to non-blocking contacts.

Keywords: CVD diamond; Nuclear detectors; Memory effects; Polarization

1. Introduction

Polarization effects, due to trapping of carriers, are responsible for time variations of charge collection efficiency (cce) in CVD diamond. A strong trapping induced on both carriers, i. e. priming or pumping [1], is used in order to try to stabilize diamond before its use as a nuclear detector. This priming is carried out with penetrating radiation and trapping events are more or less uniformly distributed in the bulk of the detector. Doses of the order of 20 Gy are usually delivered to the sample. When a detector, even a thin one as in the present case, is used with focussed beams of strongly ionising particles, i. e. low energy protons or alphas, it is quite easy to reach doses quantitatively similar to those of X-ray priming, but which are delivered only in selected regions of the detector – few tens of micrometers below the surface, for instance [2,3] in frontal geometry of irradiation – and can give rise to polarization phenomena, instead of priming. In order to investigate effects of this kind together with effects produced at large counting rates and to look at memory effects produced by previous irradiations and by previous applied voltages, we carried out a series of systematic measurements with a not strongly focussed beams of low energy (1 – 2 MeV) protons on a sufficiently thin (50 μm) CVD diamond sample by using alternatively positive and negative polarities. We will show that in a thin detector polarization and "memory" effects are not present, if the charge collection efficiency (cce) is large enough. It turned out also to be possible to overcome the value of 100% of cce, a result never observed in diamond in our conditions, with the possible exception of UV detectors.

2. Experimental

The investigated detector was 50 μm thick, as measured by SEM, and it was equipped with standard evaporated Au/Cr contacts on both sides about 0.5 cm in diameter and 100 nm in thickness (70 nm Au+30 nm Cr). The $I-V$ characteristic displayed an ohmic behaviour up to 160 V with very low dark currents.

The detector was placed in a scattering chamber equipped with standard charge sensitive electronics and acquisition apparatus. The detector was exposed to a proton microbeams of 1 and 2 MeV at counting rates from 1800 to less than 100 cps. The penetration depth in diamond is 8 μm at 1 MeV and 25

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