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CVD diamond detectors for nuclear and dosimetric applications

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Abstract

The recent availability of single crystal (sc) CVD diamond samples of very good quality and suitable thickness and surface area has opened new application fields in nuclear detection and dosimetry such as hadron radiotherapy and neutron spectrometry in fusion reactors. At the same time, dot, strip, and pixel detectors with unprecedented performances have been successfully realized and exploited in the framework of high energy physics (HEP). While the goal of a charge collection distance (ccd) of 200 μm was reached with polycrystalline (pc) samples in the year 2000, values of ccd up to 0.42 mm at 0.2 V/μm are now reported for the new sc samples. From the point of view of "detector quality," the mobility–lifetime product for carriers is now approaching that of one of the best nonsilicon detector materials like CdTe, but it seems still far from that of Si. The most important point seems to be related to the homogeneity of new sc samples, which now in some cases displays an energy resolution down to 0.4% for Am-241 alpha particles and of 2.9% for 14.1 MeV neutrons. CVD single crystal beam monitors are now currently running in HEP experiments and their performances are compared with more recent radiation hard Si detectors. CVD diamond detectors are quoted to be capable to withstand particle fluxes over 10^{15} cm^{-2} (which corresponds to a 10-year experiment run) with no counting losses and only a small reduction in S/N ratio. A more intriguing question is concerning priming, which is very important for detector performances: while no priming seems necessary for sc samples, in the case of pc samples, a simple priming with blue light instead of X-rays or beta-rays is possible, with the issue of different or better detector performances. The paper will review the more recent history of CVD diamond nuclear detectors with respect to material quality and priming. Some detectors and dosimeter performances in different top level fields will be quoted and possible future scenarios will be described.

Keywords: Polycrystalline and single crystal CVD diamond; Nuclear detectors; Dosimeters; Priming

1. Introduction

The realization of nuclear detectors is probably the best way to improve the material quality of semiconductors: in fact the attribution of "detector grade" to a material should in general be given only in cases of noticeable improvements with respect to "electronic grade," a quality that should be given only to materials by which standard electronic devices are designed and built.

Nevertheless, the "detector grade" has been attributed in the past by taking into account the type of the material and the particular application: in fact the realization of gamma spectrometers with a good energy resolution is strongly different from particle counting or tracking. In the 1980s, even hydrogenated amorphous silicon of "solar grade" was used for some time as a nuclear detector and dosimeter. After a long research for building "big" high purity Ge spectrometers, we have seen in the 1970s strong efforts for materials like CdTe, which only now is really commercial; afterwards epitaxial GaAs and more recently SiC came into play for other kinds of application, since their atomic numbers were too low. From the start, diamond was planned for tracking applications in HEP experiments (because of radiation hardness, quite important for 10-year experiments in a harsh radiation environment) and for medical applications in X-ray radiotherapy (because of

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