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Radiological X-ray dosimetry with single crystal CVD diamond detectors

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Abstract

Pulsed X-ray measurements have been carried out by using new single crystal epitaxial CVD diamond samples about 100 μm thick grown by microwave CVD in Roma Tor Vergata Laboratories on a 300 μm thick, low cost, HPHT diamond substrate. Both sandwich arranged and surface interdigitated contacts were used for the detectors in order to compare their performances. A standard X-ray radiological apparatus was used with maximum X-ray energies from 50 to 120 keV. Delivered doses were in the range between 0 and 50 mGy, with pulse duration times between 0.01 and 0.5 s were obtained either by using different time-integrated mAs products or, at a fixed value of mAs, by using different values of the bias voltage of X-ray generator. The linearity of the dose signal Q given by the integrated current with respect to dose recorded by ionization chamber Δ was checked by evaluating dose linearity index, i.e. the exponent in the equation $Q=AD^{\Delta}$. The values of Δ were very close to 1 (between 1.02 and 1.07) in the case of a fixed mAs product, while it was around 0.8 at fixed voltage in the range 50–120 kV. The response time of the detector as deduced from the tail of the pulse was between 15 and 20 ms. The reproducibility was very good among different series of measurements, with no memory or priming effect. These results suggest a strong and actually real possibility for diamond detectors to be used as solid state ionization chambers in radiology and for diagnostic purposes.

Keywords: CVD diamond; Homoepitaxial; X-ray dosimetry

1. Introduction

X-ray dosimetry with new detecting materials is a very interesting field of research not only for radiotherapy, but also for radiology, since some recent ICRP recommendations are directed towards the doses delivered to the patients during radiological assays. There are several options in this respect, such as CdTe or HgI_2, but, apart from its worse sensitivity, diamond [1–7] seems to be the more suitable for X-ray active dosimetry particularly because of its inherent tissue equivalence.

However, until now, natural diamond must be selected and previously "primed", while CVD diamond has still some problems of linearity, stability, time response and reproducibility [6]. In other words, diamond has not reached the state-of-art needed for real field applications. The recent availability of CVD diamond single crystals [6] obtained by homoepitaxy on HPHT diamond, which can display electronic properties even superior to those of natural diamond, may open new real possibilities for X-ray dosimetry. In this work, some results are reported concerning the use of an homoepitaxial CVD diamond film for monitoring X-ray pulses delivered by a portable X-ray apparatus.

2. Experimental

Two diamond detectors were investigated in this work, both of them grown by MW-CVD [8] on a 315 μm low cost HPHT diamond substrate. In both cases, CVD films were carefully characterized by X-ray diffraction and scanning electron microscopy, confirming the single crystal homoepitaxial deposition and the good crystal quality of the grown samples.

The former one was about 110 μm thick and equipped with circular Al electrodes, 2 mm in diameter, deposited on

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