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Characterization of CVD diamond detector with FLASH electron beam from modified LINAC accelerator

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A R T I C L E I N F O

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A B S T R A C T

FLASH Radiotherapy (RT) delivers an average dose-rate >40 Gy/s in less than 200 ms with extremely high instantaneous dose-rates, and preclinical studies demonstrated a tumoricidal effect comparable to conventional RT with an increased sparing effect on healthy tissues (FLASH effect). Within the INFN-FRIDA project, we are exploring thin silicon sensors and polycrystalline CVD diamond (pCVD) sensors as real-time beam monitors for electron and proton FLASH beams. Planar silicon sensors were first tested on conventional electron beams and subsequently on high-dose electron beams (ElectronFLASH machine, funded by the Pisa Foundation). Diamond, due to some of its properties including radiation resistance, could also be a viable alternative for monitoring FLASH beams. The first tests were carried out in Turin, and the sensor response was studied in terms of polarization voltage, integrated charge, charge collection efficiency and sensitivity.

1. Introduction

Ionization chambers (ICs) represent the state-of-the-art technology for beam monitoring in conventional radiotherapy, due to their robustness, transparency to the beam, large sensitive area, and good radiation resistance. However, a noticeable decrease in their ion collection efficiency has been observed when the dose per pulse (DPP) value exceeds 0.1 Gy/pulse [1]. The advent of so-called FLASH Radiotherapy (RT) [2], in which DPP is higher than 1 Gy and dose-rate is greater than 40 Gy/s, triggered the need to design new sensors to online monitor particle beams (mainly electrons and protons) at high dose-rates. Within the FRIDA INFN project the solid-state technology is being investigated to this aim, because of the fast signal (∼ns) and good temporal resolution (<100 ps) [3,4]. Silicon devices benefit of a well-developed manufacturing technology, high sensitivity (tens of thousand times higher than ICs with same active volume) and fast response, while the diamond atomic number ($Z = 6$, close to the human tissue one, i.e. $Z = 7.5$) and its strong binding energy makes it an ideal dosimeter, chemically inert and radiation hard material. Through a first characterization on FLASH electron beams delivered by dedicated machines, it has been verified that silicon responds linearly with the DPP up to ∼10 Gy/pulse (corresponding to an instantaneous dose-rate of ∼2.5 x 10^6 Gy/s for a pulse duration of 4 μs). Due to the typical average energy for the generation of an electron-hole pair (3.62 eV for silicon and 13 eV for diamond), for equivalent geometries, diamond is expected to be less sensitive than silicon, which represents an advantage in ultrahigh dose-rate applications and reduces the total charge produced in the sensor channel.

2. Materials and methods

The first detector we tested is a polycrystalline CVD diamond, characterized by an active area of 1.3×1.3 mm^2 and a thickness of 100 μm for a total active volume of 0.17 mm^3. Dual side contacts were made

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