PUB_2009-8

Nuclear Instruments and Methods in Physics Research A 608 (2009) 191–194

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Synthetic single crystal diamond dosimeters for Intensity Modulated Radiation Therapy applications

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ARTICLE INFO

Article history:
Received 5 June 2009
Received in revised form
1 July 2009
Accepted 3 July 2009
Available online 10 July 2009

Keywords:
Single crystal diamond
Radiotherapy dosimeter

ABSTRACT

A synthetic single crystal diamond Schottky diode, in a p-type/intrinsic/metal structure, deposited by Chemical Vapour Deposition (CVD) and operating in photovoltaic regime, with no external bias voltage applied, was tested as a dosimeter for Intensity Modulated Radiation Therapy (IMRT) applications. The device response was compared with dose measurements from two commercial ionization chambers and a 2D diode array in an IMRT prostate cancer treatment plan. The obtained results indicate that CVD synthetic single crystal diamond-based dosimeters can successfully be used for highly conformed radiotherapy and IMRT dosimetry, due to their small size and high sensitivity per unit volume.

1. Introduction

Multiple small photon beams are increasingly used in advanced radiotherapy techniques, such as Stereotactic Radiosurgery (SRS) and Intensity Modulated Radiation Therapy (IMRT). In particular, IMRT is a special technique which allows changing the irradiation intensity within the beam, to create highly conformal dose distributions and reduce unwanted irradiation of surrounding normal tissue. These non-uniform beam intensities are generated by linear accelerators, equipped with multileaf collimators (MLCs), by superposing several sub-fields (segments) through a complex motion of the leaves either in sequential static delivery mode (SMLC-IMRT) or in continuous dynamic delivery mode (DMLC-IMRT) [1–3]. The number, shape and intensity of such irradiation segments are determined by the treatment planning system (TPS), using a mathematical optimization process, according to dose profiles and constraints set by the user. An "optimal" fluence map is usually achieved dividing each IMRT field into multiple small beams, whose dimensions are often smaller than the lateral range of secondary electrons produced. As a consequence, a detector characterized by a relatively large sensitive volume may cause fluence perturbations and dose averaging effects in peaked dose distributions, resulting in an incorrect dose determination. A decrease in size of the sensitive volume yields a reduction of dose averaging effects, and therefore, leads to more accurate measurements in high-dose gradient regions. The decrease in detection volume, however, is in a trade-off with sensitivity, so that high-sensitivity per-unit-volume materials are needed in order to keep statistical noise, reproducibility and accuracy acceptable. Ideally, IMRT detectors should exhibit other remarkable characteristics like stability, fast response time, linearity, independence of the measured dose on the radiation quality and dose rate, tissue equivalence, radiation hardness, high sensitivity and low bias voltage operating conditions.

Diamond dosimeters meet most of such stringent requirements. Natural diamond-based dosimeters have been extensively tested [4,5] and have shown to be suitable for IMRT applications [6,7]. This is not the case for synthetic polycrystalline diamonds mainly due to their slow dynamic response that makes them unable to reveal the sharp transients of IMRT fields [8].

Recently, a new Synthetic Single Crystal Diamond (SSCD) Schottky diode dosimeter, fabricated at Rome "Tor Vergata" University in a p-type/intrinsic/metal layered structure, has been successfully tested with radiotherapy beams [9]. Good results have been obtained in terms of linearity with respect to dose and dose rate, independence from radiation quality and tissue equivalence. Moreover, due to the existence of a built-in potential, the dosimeters can operate at 0 V bias, which is of great importance, when *in vivo* dosimetry applications are considered for such devices.

In this work, the performance of a SSCD dosimeter in the step-and-shoot IMRT treatment technique is described and compared with the ones obtained from two commercial ionization chambers and a 2D diode array.

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2009.07.004