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Synthetic single crystal diamond dosimeters for conformal radiation therapy application

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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

A synthetic single crystal diamond based dosimeter in a p-type/intrinsic/metal structure, operating in photovoltaic regime, is proposed for application in highly conformed radiotherapy dosimetry. The device was characterized by using 6 and 10 MV Bremsstrahlung X-ray beams and electron beams from 6 MeV up to 18 MeV, obtained by a CLINAC DHX Varian accelerator. All measurements were performed in a water phantom and commercial ionization chambers were used for calibration and comparison. Results showed a very good agreement of the diamond device response, as compared with the reference dosimeters, fast response times and high spatial resolution. One of such diamond dosimeters was then tested using a real Intensity Modulated Radiation Therapy (IMRT) prostate cancer treatment plan and its performance was compared with the ones from ionization chambers and a 2D diode array. The obtained results clearly assess the suitability of synthetic single crystal diamond for dose measurements in highly conformed radiotherapy and particularly in IMRT applications.

1. Introduction

Modern radiotherapy techniques employ very small and highly conformed irradiation fields for treating localized tumors. In particular, Intensity Modulated Radiation Therapy (IMRT) is obtained by linear accelerators equipped with multileaf collimators (MLCs). During IMRT treatments a conformal dose distribution is delivered by superposing several sub-fields (segments) either in sequential static mode (SMLC-IMRT) or in continuously dynamic mode (DMLC-IMRT) [1–3]. In this way the irradiation intensity within the beam is modulated so to create highly conformal dose distributions and reduce unwanted irradiation of surrounding healthy tissues. A careful control of the dose distribution in IMRT calls for stringent requirements on dosimetric systems. Besides human tissue equivalence, radiation hardness, stability, linearity, high sensitivity and independence from energy and dose rate, that is the usual properties of a conventional radiotherapy dosimeter, an ideal IMRT application dosimeter should also exhibit fast response time and high spatial resolution. This is because of the need to follow the spatial distribution and temporal evolution of the delivered dose.

Diamond physical properties make it a perfect candidate as an active material in radiotherapic dosimetry [4]. Type IIa natural diamond based dosimeters are commercially available since a relatively long time [5]. However their response often shows a dose rate dependence, making it necessary to correct the as measured data [6]. Moreover, natural diamonds possessing detector grade quality are extremely rare and a severe selection over large amounts of nominally pure diamonds must be performed. As a result, natural diamond dosimeters are very expensive and the delivery times are quite long. On the other hand, polycrystalline diamonds deposited by Chemical Vapor Deposition (CVD) [7–10] or synthetic single crystal diamonds grown by High Pressure High Temperature (HPHT) technique [11] do not have the same quality of carefully selected natural diamonds intended for such an application. The presence of structural and crystallographic defects spoils their electronic properties, strongly affecting the stability and the reproducibility of their response. The above limitations have fostered research efforts to grow synthetic high quality single crystal diamonds, possibly overcoming the limiting factors which have hindered so far a widespread diffusion of diamond based dosimeters [12,13].

In this paper we report on the characterization of a Synthetic Single Crystal Diamond dosimeter (SSCD) fabricated at University of Rome "Tor Vergata" and its test in a real IMRT treatment plan. The device characterization was performed at San Filippo Neri Hospital in Rome, by using Bremsstrahlung 6 and 10 MV X-ray beams.

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