

PERFORMANCE OF EPI DIODES AS DOSIMETERS FOR PHOTON BEAM RADIOTHERAPY

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ABSTRACT

In this work we present the preliminary results about the performance of an epitaxial (EPI) diode as on-line dosimeter for photon beam radiotherapy. The diode used was processed at University of Hamburg on n-type 75 μm thick epitaxial silicon layer grown on a highly doped n-type 300 μm thick Czochralski (Cz) silicon substrate. The measurements were performed with a diode which not received any type of pre-dose. In order to use this device as a dosimeter, it was enclosed in a black polymethylmethacrylate (PMMA) probe. The diode was connected to an electrometer Keithley 6517B in the photovoltaic mode. During all measurements, the diode was held between PMMA plates, placed at 10.0 cm depth and centered in a radiation field of 10 x 10 cm^2 , with the source-to-surface distance (SSD) kept at 100 cm. The short-term repeatability was measured with photon beams of 6 and 18 MV energy by registering five consecutive current signals for the same radiation dose. The current signals induced showed good instantaneous repeatability of the diode, characterized by a smallest coefficient of variation (CV) of 0.21%. Furthermore, the dose-response curves of the diode were quite linear with the highest charge sensitivity achieved of 5.0 $\mu\text{C}/\text{Gy}$. It worth noting that still remains to be investigated the pre-dose influence on epitaxial silicon diode response in radiotherapy photon beam dosimetry, the long term stability and the radiation hardness of these diodes for absorbed doses higher than that investigated in this work. All these studies are under way.

1. INTRODUCTION

Recent advances in radiotherapy have demanded the development of both new devices and stringent dosimetric systems. The use of semiconductor detectors has increased in radiotherapy practice since the early 1980s due to their fast processing time, small sensitive volume and high relative sensitivity to ionizing radiation [1,2]. Other major advantages of Si devices are excellent repeatability, good mechanical stability and high spatial resolution [3]. However, in radiation therapy dosimetry, it is important to know the sensitivity decrease with the absorbed dose in order to foresee when re-calibration of the dosimeter becomes necessary. This is the most important constraint against the use of ordinary silicon devices in medical dosimetry [4-7]. Nevertheless, this drawback has been overcome with the development of radiation tolerant silicon detectors [8] in the framework of High Energy

Physics research projects. Previous results obtained in our laboratory using some of these radiation-hard Si diodes in both radiation processing and clinical electron beam dosimetry [9,10,11] motivated us to investigate the response of thin n-type epitaxial (EPI) layers with high radiation damage tolerance. In this work the preliminary results about the performance of an epitaxial (EPI) diode as on-line dosimeter for photon beam radiotherapy are presented.

2. MATERIALS AND METHODS

The diode used was processed at University of Hamburg [12] on n-type 75 μm thick epitaxial silicon layer (nominal resistivity of 50 $\Omega\cdot\text{cm}$) grown on a highly doped n-type 300 μm thick Czochralski (Cz) silicon substrate [11]. The measurements were performed with a diode with 25mm² active area which not received any type of pre-dose. In order to use the diode as a dosimeter, it was enclosed in a black polymethylmethacrylate (PMMA) probe to provide protection from mechanical stress, light and moisture. The device was connected to the input of an integrating electrometer Keithley 6517B in the photovoltaic mode. During all measurements, the diode was held between PMMA plates, placed at 10.0 cm depth and centered in a radiation field of 10 x 10 cm², with the source-to-surface distance (SSD) kept at 100 cm. The device dosimetric response was evaluated for 6 and 18 MV photon beams from a Siemens Primus Radiotherapy Linear Accelerator, located at Sírío-Libanês Hospital. The short-term repeatability was evaluated for all energies by registering five consecutive current signals for the same radiation dose, switching the beam on and off. The dose-response of the device, given by the curves of charge (obtained via integration of the photocurrent signals vs time) as a function of the absorbed dose, was investigated. Measurements were performed with an average dose-rate of 2,11cGy/s (200 MU/min) and 3,70 cGy/s (300 MU/min) for the energies of 6 and 18 MV, respectively.

3. RESULTS

The short-term repeatability of the EPI diode was measured with photon beams of 6 and 18 MV energy. The results obtained with the device are depicted in Fig. 1. After each step of irradiation, the dark currents of the diode ($\cong 0.55$ pA) were acquired when the beam was just switched off just to check whether some radiation damage was produced in the device. As can be seen, during these measurements the dark current intensities were kept constant and four orders of magnitude smaller than the photocurrents generated in the sensitive volume of the device. The current signals presented in Fig. 1 are very stable. Indeed, a comparison between the coefficients of variation (CV) of both energies evidenced that the stability is almost the same, with CV = 0.21% and 0.26% to 6 and 18 MV, respectively.

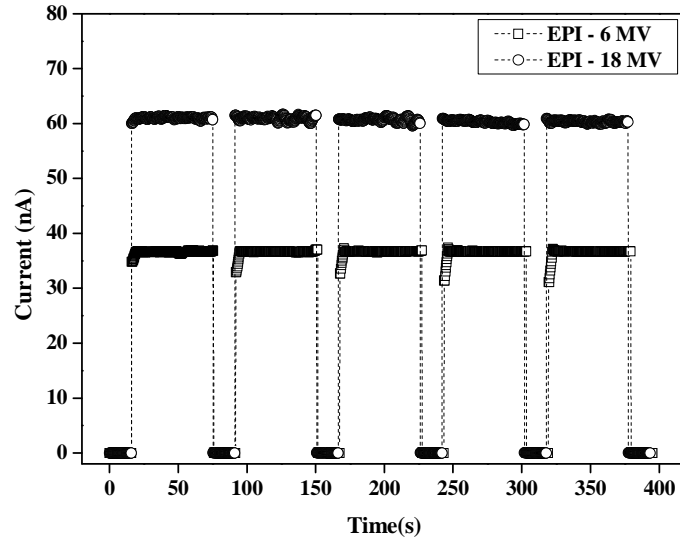


Figure 1. Current response of the EPI diode under irradiation with (a) 6 and (b) 18 MV photon beam energy.

The dose-response of the diode, given by the curves of the charge as a function of the accumulated doses from 63 cGy up to 370 cGy, is presented in Fig. 2. The results obtained with photon beam energies of 6 and 18 MV confirm that the dose-response curves of the diode are quite linear with correlation coefficients (R^2) of the 0.99994 and 0.99993 to 6 and 18 MV respectively.

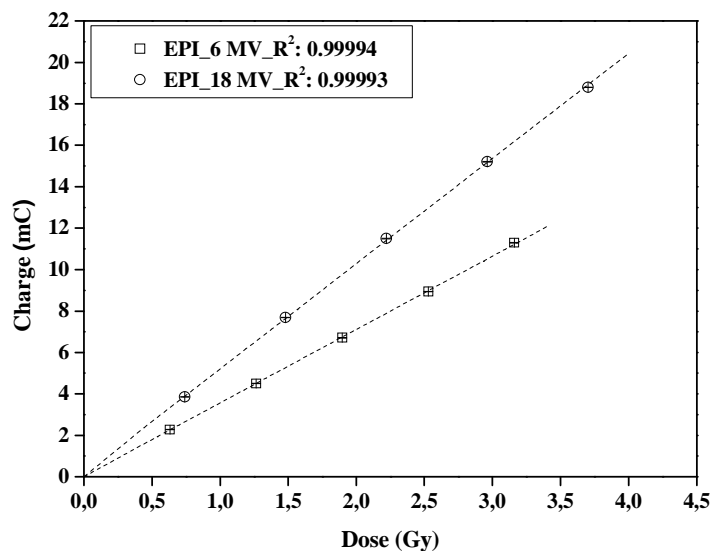


Figure 2. Dose-Response curves of the EPI diode for 6 and 18 MV photon beam energies. Experimental uncertainties are smaller than the symbols size.

The values of charge sensitivities, presented in Table 1, evidence that to 18 MV, the EPI diode is more sensitive than to 6 MV photon beam energy. However, that energy dependence might be attributed to the structure and small dimensions of the device. Some studies are under way to clarify the origin of this effect.

Table 1. Charge sensitivities of EPI diode for 6 and 18 MV photon beam energies.

Energy (MeV)	Sensitivity ($\mu\text{C}/\text{Gy}$)
6	3.54
18	5.08

3. CONCLUSIONS

In this work we present the preliminary results about the performance of an epitaxial (EPI) diode envisaging its application in on-line clinical photon beam dosimetry. The studies were evaluated for 6 MV and 18 MV. The results obtained evidenced excellent instantaneous repeatabilities of this unbiased device, with CV = 0.21% and 0.26% to 6 and 18 MV, respectively. The values of charge sensitivities evidence that to 18 MV, the EPI diode is more sensitive than to 6 MV photon beam energy. The dose-response curves of the diode are quite linear for both photon beams energies. However, the responses of the EPI diode were dependent on the photon beam energy. Further studies are demanded to clarify the origin of this effect.

Based on these results, one can conclude that the EPI diode can be used without any pre-irradiation procedure as a reliable alternative choice to relative radiotherapy photon dosimetry.

It worth noting that still remains to be investigated the pre-dose influence on epitaxial silicon diode response in radiotherapy photon beam dosimetry, the long term stability and the radiation hardness of these diodes for absorbed doses higher than that investigated in this work. All these studies are under way.

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