Strip Detector for high spatial resolution dosimetry in microbeam radiation therapy

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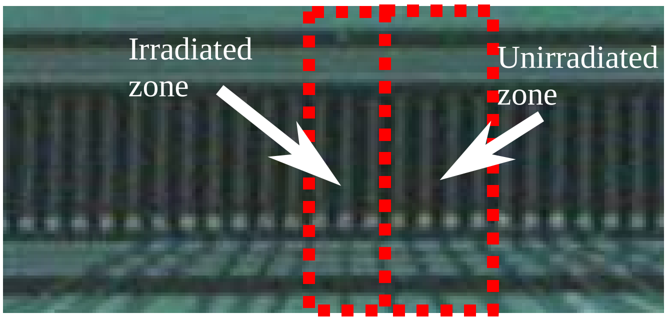
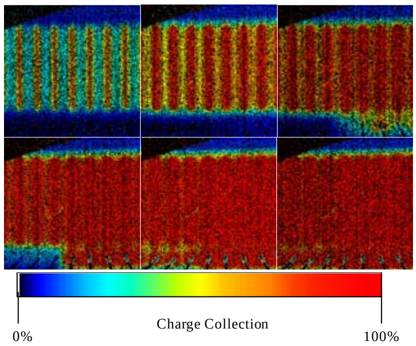
Radiation therapy is increasingly becoming more sophisticated in terms of the radiation oncology modalities, the type of radiation used and the method of delivery, leading to very conformal dose delivery. The ability to verify the delivered dose with high spatial resolution and in real time is important for quality assurance of dose planning software and radiation dose delivery during the treatment. Semiconductor detectors are proving to be the choice for such verification due to their small size, ability to provide real time information on the instantaneous dose rate or integral dose, which can be electronically read out.
Microbeam radiation therapy (MRT)[1] is a new form of radiation treatment being developed for children with inoperable and otherwise untreatable brain tumours. A new on-line dosimetry system is currently under development at the Centre for Medical Radiation Physics, University of Wollongong, Australia, which will be used to measure peak dose for each microbeam and the instantaneous MRT peak-to-valley dose ratio (PVDR). The peak dose and PVDR is an important physical parameter in MRT that indicates the quality of the MRT beam and must be measured with an accuracy of better than 5%. The detector will also be used to act as a fast beam-stop trigger to avoid an undesirable dose being delivered to the patient undergoing MRT treatment within milliseconds time treatment delivery. Therefore the radiation damage induced in these detectors is important for understanding the reliability of the deduced dose using these detectors and will determine the useable lifetime of the detectors. The work outlined in this article discuss radiation damage studies induced in the bulk silicon strip detector utilized in the dosimetry system. Such radiation damage studies have not been widely studied under the very intense pulsed , low energy (average energy 100 keV) synchrotron X-ray photons.
The detector is made up of 128 p+ p-n junction strips each with a width of 20 microns, length of 500 microns and with a strip-pitch of 200 microns produced on a 375 micron, n-silicon substrate of resistivity of 5 kOhm cm and 500 Ohm cm. We have carried out preliminary testing of the developed system by evaluating 2D dose distributions in small medical LINAC radiation fields. We have also investigated the radiation hardness of these detectors using ion beam induced charge collection (IBIC) studies, after exposure in a synchrotron X-ray microbeam radiation field to an equivalent tissue dose of 100 kGy. The radiation damage induced in these detectors is important for understanding the reliability of the deduced dose using these detectors and will determine their useable lifetime. Such radiation damage studies have not been widely studied under the very intense pulsed, low energy (average energy 100 keV) synchrotron X-ray photons.
Figure 1 (left) shows a photograph of part of the strip detector used in these studies and (right) a corresponding IBIC image with the detector biased from 0 volts (top left) through to 50 V (bottom right) at 10 V increments after irradiation. Radiation damage is evident when the detector is biased, predominantly in the region immediately below the contact

pads of the irradiated strips (one can clearly observe the wire bonds associated with each strip in the image). The mechanism for the radiation damage is related to the creation of the MOS structure formed by the aluminium contact above the field oxide, outside of the p-n junction area of the p+ strip. The build up of positive charge in the field oxide results in an electron enhancement channel on the silicon surface leading to lateral shrinkage of the depletion layer of p-n junction of p+ strip. Increasing of the negative bias above critical voltage (15 V) is leading to the disappearance of this induced electron channel and consequent abrupt lateral depletion.





The proposed model of radiation damage of the n-Si strip detector for MRT dosimetry on ESRF synchrotron beam based on build up charge in a field oxide only has been proved. This model was successfully applied for explanation of the IBIC results. No bulk defect was observed that make detector radiation hard in this application. The build up charge effect can be avoided by overbiasing of the strips or by regular annealing under 150 ^{0}C if detector will be used in passive mode [2].

References

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