Characterization and Optimization of Microionization Chamber

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12/01/2013

An increase in the delivery of small and non-standard radiation fields has led to the development of small-volume ionization chambers (< 0.02 cm^3), called microchambers. Microchambers are used for dosimetry measurements in radiation therapy clinics around the world, and the University of Wisconsin Accredited Dosimetry Calibration Laboratory has experienced a significant increase in requests for the calibration of microchambers for low- and medium-energy x-ray beams as well as the ^{60}Co beam. This indicates that these chambers are being used for reference-dosimetry measurements in a wide range of therapy applications and beam energies.

Unfortunately, microchambers demonstrate a series of anomalous behaviors not seen in larger-volume chambers. In this work, a comprehensive characterization of five microchamber models was performed for a ^{60}Co beam, high-energy pulsed beams, and low- and medium-energy x-ray beams. In all cases a lower signal-to-noise ratio was measured for the microchambers compared to larger-volume chambers; however, for high-energy pulsed beams and often for the ^{60}Co beam, the leakage current comprised less than 0.1% of the chamber signal. For all beams investigated, the microchambers exhibited large voltage-independent and dependent polarity effects which caused an inverse proportionality between the chamber response and the applied voltage and anomalous ion recombination correction factors. Furthermore, the microchambers exhibited a strong energy dependence for kilovoltage x-ray beams relative to ^{60}Co. These anomalous behaviors varied from microchamber to microchamber, even among the same chamber model; however, the behavior of an individual chamber was consistent.

A series of investigations were performed to determine the cause of these behaviors. The energy dependence was attributed to high-Z materials inside the collecting volume of the microchambers. The source of the voltage-dependent polarity effects was isolated to a potential difference between the collecting and guard electrodes, distorting the electric field lines and altering the collecting volume of the chamber. It was determined that a difference in the conductance of materials of the electrodes was likely causing the potential difference.

An optimized microchamber design was created and manufactured. The microchamber was composed of a low-Z conductive plastic to eliminate the energy dependence. Furthermore, the electrodes were composed of the same batch of plastic which was manufactured to reduce inhomogeneities in the conductance of the material. With the optimized design, the chamber demonstrated negligible energy dependence and a significant reduction in the voltage-dependent polarity effects.