Investigation of charge buildup in cabled detectors in the Small Animal Radiation Research Platform (SARRP)

Department of Medical Physics
UNIVERSITY OF WISCONSIN
SCHOOL OF MEDICINE AND PUBLIC HEALTH

Jocelyn Jackson, Jeff Radke, and Larry DeWerd
University of Wisconsin-Madison

Introduction

Preclinical radiation experiments using small animals are an integral part of understanding radiation effects in tissues. Reproducibility has proven difficult with radiation biology preclinical studies, and it is suggested that much of this is due to lack of viable dosimetry for small animal irradiators.[1–3] This work is part of a larger goal of improving dosimetry in the Small Animal Radiation Research Platform (SARRP), a low energy conformal irradiator with imaging and delivery capabilities similar to those of a clinical linear accelerator.

The purpose of this work was to investigate trends in ion chamber readings taken in the SARRP. Analysis of behavior of ion chambers with high dose has shown electret (quasi-permanent electric charge on a dielectric material) formation in the insulating materials of dosimeter cables. This effect can cause high leakage current post-irradiation.

Methods

- Several different triaxial cables, electrometers, and ion chambers were used to attempt to understand the cause of the persistent post-irradiation current.
- The effect of the cable in the field was investigated in several scenarios involving moving extra cable into or out of the field, shielding the cable, and collimating the field to be just larger than the sensitive volume of an ion chamber.
- The effect of bias on ionization chamber behavior was examined by measuring current post-irradiation with a chamber biased at +300 V, +150 V, and 0 V.
- Dose due to scatter was examined by taking film measurements along the length of the ion chamber cable outside the field in a normal open field irradiation setup.
- Leakage current was measured days after irradiation over a period of several hours and compared to the behavior of a chamber that had not been in the SARRP.

Results

- Thirty second charge readings were taken post-irradiation for an A10 parallel plate chamber and diode. Readings are displayed as current in the figure 1. The retained charge due to electret formation was slow to decay and after about 2 hours the associated current synchronized with changes to the room temperature, resulting in the four spikes seen in the figure.
- Readings taken with a range of collimator sizes showed that collimation significantly reduced the post-irradiation current but did not entirely eradicate it.
- Readings taken with varying amount of cable and stem in the field showed that reducing the amount of cable also reduced the post-irradiation current.
- Post-irradiation current magnitude and decay was independent of chamber bias, , which suggests a charge-trapping mechanism such as that found in solid-state-detectors, where electrons fill traps that will release over time, resulting in lingering current following irradiation.
- Out of field dose to the cable of an ion chamber is shown in figure 2. Dose rate about 1 cm outside the field is approximately 10% of the 3 Gy/min dose at isocenter.
- Figure 3 shows charge readings for two A12 chambers with no radiation present. One chamber has been irradiated for 1 hour in the SARRP and one has not. Leakage was the same for both prior to irradiation of one chamber in the SARRP. These spikes continue for many days and coincide with rapid temperature changes
- All of these behaviors align with previous studies on the formation of electrets in insulating materials as a result of low energy photons or electrons[4–9]

Figure 1: A10 and diode post-irradiation

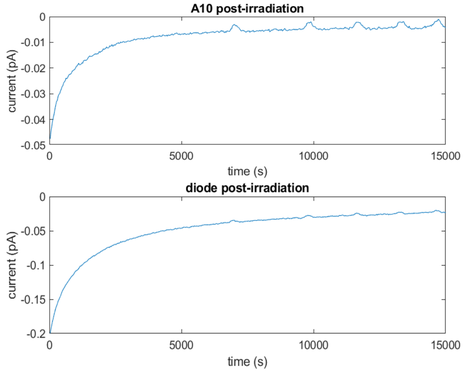


Figure 2: Out of field dose rate along ion chamber cable

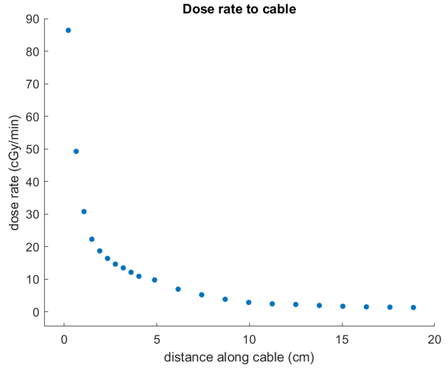
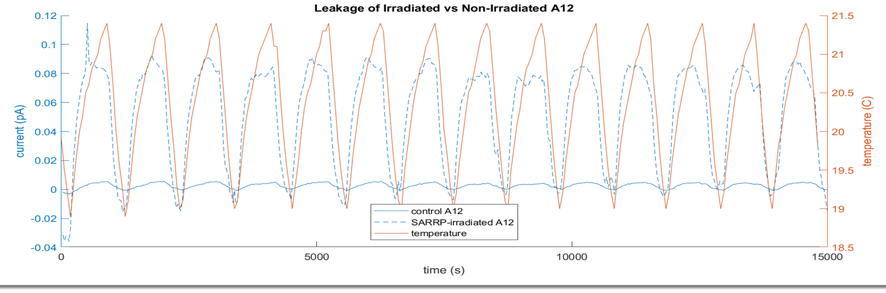


Table 2: Dark current of SARRP-irradiated A12 and control A12



Conclusions

- This study investigated the abnormal response of detectors in the Small Animal Radiation Research Platform (SARRP).
- It was found that charge builds up on the insulating materials during irradiation, forming electrets that cause trending measurements and post-irradiation current with a long half-life.
- These effects can be reduced by collimating the field to be just larger than the chamber.
- The presence of insulators in the stem and ion chamber also enables some charge buildup even with the cable entirely shielded.
- The effects are minimal in short irradiations, where the out of field dose to the cable will be minimal.
- This electret formation can be reduced if the cables are shielded as thoroughly as possible.
- The time in the beam should be minimized to reduce the amount of charge stored.

References

1. Draeger, E. *et al.* A Dose of Reality: How 20 Years of Incomplete Physics and Dosimetry Reporting in Radiobiology Studies May Have Contributed to the Reproducibility Crisis. *Int. J. Radiat. Oncol.* **106**, 243–252 (2020).

2. Dos Santos, M. *et al.* Importance of dosimetry protocol for cell irradiation on a low X-rays facility and consequences for the biological response. *Int. J. Radiat. Biol.* **94**, 597–606 (2018).

3. Desrosiers, M. *et al.* The Importance of Dosimetry Standardization in Radiobiology. *J. Res. Natl. Inst. Stand. Technol.* **118**, 403 (2013).

4.Gross, B. 4. Radiation-Induced Charge Storage and Polarization Effects.

5. Rawlinson, J. A., Bielajew, A. F., Munro, P. & Galbraith, D. M. Theoretical and experimental investigation of dose enhancement due to charge storage in electron-irradiated phantoms. *Med. Phys.* **11**, 814–821 (1984).

6. Thakur, R., Das, D. & Das, A. Study of charge decay in corona-charged fibrous electrets. *Fibers Polym.* **15**, 1436–1443 (2014).

7. Gross, B., Sessler, G. M. & West, J. E. TSC studies of carrier trapping in electron- and γ-irradiated Teflon. *J. Appl. Phys.* **47**, 968–975 (1976).

8. MacDonald, B. A. Charge transport and storage in the radiation-charged electret ionization chamber. *Med. Phys.* **23**, 1819–1819 (1996).

9. Murphy, P. V. & Gross, B. Polarization of Dielectrics by Nuclear Radiation. II. Gamma-Ray-Induced Polarization. *J. Appl. Phys.* **35**, 171–174 (1964).