

Active heating of large gel dosimeters

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Abstract. Temperature uniformity of 3D dosimeters is key factor for accurate measurements. For gel dosimeters larger than 1 litre the time to change from storage to room temperature can be several hours. Local thermal histories within certain dosimeter materials can also cause measurable differences in ionizing radiation response. Passive heating by immersion in a water bath may not be optimum. Active uniform heating of 15 cm diameter, hydrogel, dosimeters using a near-infrared, incandescent light source reduced the time required to heat a hydrogel from 4 to 20°C uniformly from greater than five hours to less than 3 hours.

1. Introduction

Temperature is an important variable in chemical radiation dosimeters. Thermal gradients inside 3D dosimeters can cause artifacts in measured dose distributions [1]. Temperature dependent dose response has been observed in virtually all gel dosimeters. Babic *et al* [2] found a 4% per degree increase in dose response during irradiation of leuco crystal violet micelle gel at 20°C. Olding *et al* [3] reported a 3% per degree increase in attenuation coefficient for ferrous-xylenol orange gel (FX) during readout at 590 nm. Certain versions of the radiochromic plastic dosimeter PRESAGE® have the lowest temperature sensitivity: 2.5% per degree at 20°C [4]. Exothermic polymerization gel dosimeters are likely even more sensitive to thermal gradients during and after irradiation. Also, the local thermal history of gel dosimeters may have a spatially dependent effect on dose sensitivity. Babic *et al* [5] demonstrated how thermal history and auto-oxidation can lead to apparent variations in low dose response (<0.5 Gy) for FX gels. These effects suggest cooling and heating gels up uniformly is prudent. It is common practice to let gels acclimate to room temperature passively, in order to achieve a uniform temperature distribution prior to irradiation experiments. Experiments to validate dose response uniformity of 3D dosimeters are crucial for validating a specific measurement protocol. If thermal gradients are present during irradiation but not accounted for, deviations from the actual dose distribution will occur. As gel dosimeters become larger, the warm-up time increases, lengthening measurement sessions and reducing practicality. In this study we present, proof of concept results from an active heating system to accelerate uniform gel warming. Incident near-infrared light is absorbed by the water within the hydrogel as the gel is rotated in a water bath.

2. Methods

2.1 Gel Fabrication

A 15cm diameter, 2.2 litre, cylindrical PETE vessel was filled with a 4% gelatin (300 Bloom, porcine, Type A, Sigma) hydrogel (without radiochromic dye) and stored in a refrigerator at ~4°C. The gel was



cast with transparent plastic drinking straws (outer/inner diameter = 5.0/4.7 mm) held vertically, with the bottoms sealed, placed at the rotation axis and at 5cm radius, to form channels for insertion of a thermistor probe. The straws were filled with water to the height of the gel surface.

2.2 Passive Heating

The gel was removed from the refrigerator and placed in a water bath initially at a temperature of 20 °C. The water bath temperature and the gel temperatures at the 0 and 5cm radii were measured over approximately 5 hours. The water bath was continuously stirred.

2.3 Active Heating

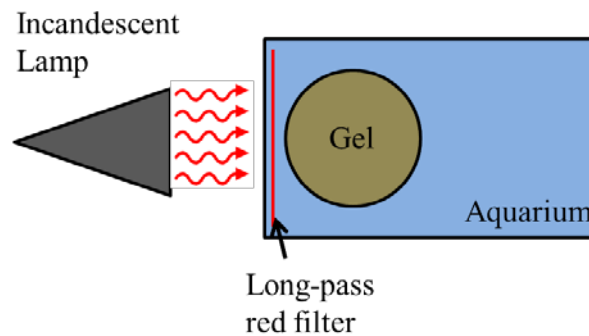


Figure 1. Top view schematic of active heating apparatus. Gel rotated manually.

Figure 1 shows the schematic for the active heating device. The gel cylinder was placed 1 cm inside the entrance window of a glass aquarium which was illuminated by a Sylvania 250 W infrared heat lamp from one side. The water bath provides additional sample surface heating and filtration of longer wavelengths by absorption. A piece of red transparent acetate film was placed in the water on the lamp side to absorb shorter visible wavelengths for warming of gels that will be already coloured. The aquarium was initially at a temperature of 21.4°C. The gel was manually rotated by 90° approximately every 15 minutes, and the water bath temperature was lowered back to 21.5°C roughly once per hour. The temperature at the center was measured over a 3 hour timespan. The temperature at 5 cm radius was measured periodically after approximately 1 hour 50 minutes of warming.

3. Results and Discussion

Figure 2 shows the water bath, 5cm radius, and central axis temperatures at mid height of gel as a function of time for the passive heating experiment. It required approximately 5 hours to reach equilibrium within ~1°C.

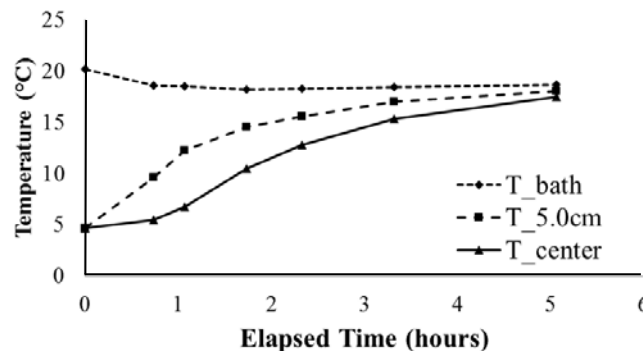


Figure 2. Hydrogel temperature versus time for passive heating.

Figure 3 shows the water bath, 5cm radius, and central gel temperatures as a function of time for the active heating experiment. The gel was brought up to equilibrium temperature within $\sim 1^\circ\text{C}$ after approximately 3 hours, demonstrating the improved speed achieved using active heating.

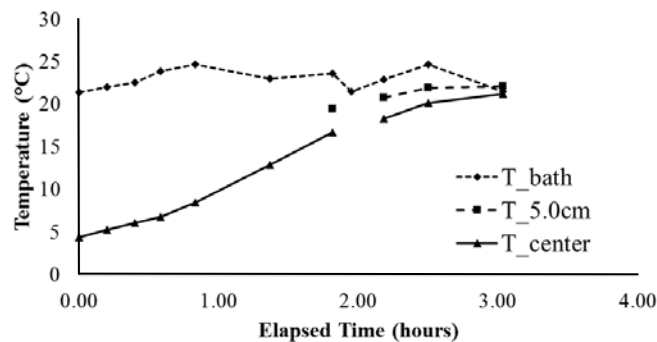


Figure 3. Hydrogel temperature versus time for active heating. Note that water in the aquarium was replaced periodically in order to maintain a bath temperature below approximately 25°C .

4. Conclusion

Active heating of hydrogels by NIR light absorption reduced the time to warm a 15 cm diameter gel dosimeter from 4°C to 20°C from more than five hours to three hours. Future work will involve increasing the number of illumination beams, increasing beam power, optimizing beam shapes and automating sample rotation to uniformly warm the gels to room temperature in one hour. Thermally uniform gel dosimeters are expected to provide more reproducible data and better agreement with independent measurements and calculations.

5. Acknowledgments

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6. References

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