On the use of high-sensitivity thermoluminescent dosimeters (TLDs) for dosimetric characterization of low-energy brachytherapy sources

Introduction: AAPMTG-43 dosimetry protocol recommends that all sources must undergo a comprehensive dosimetric characterization before they can be used clinically. Experimental characterizations are typically performed using small (1 x 1 x 1mm³) thermoluminescent dosimeters (TLDs), e.g. TLD-100 with “normal” sensitivities. While such TLDs are sufficient for measuring dose close to a source, they are very inefficient in characterizing the dosimetry properties at larger distances from the source because of the rapid dose falloff around low-energy sources. For example, to measure the radial dose function at the radial distance of 7 cm for a 2.7 U ¹²⁵I source, it would require approximately 38 days of irradiation to accumulate about 8 cGy dose to a normal-sensitivity TLD. The prolonged irradiation is not only inefficient but also introduces additional uncertainties, e.g. the fading of thermoluminescence signal during protracted irradiation, into the source characterization. The purpose of this work was to investigate the utility and accuracy of high-sensitivity TLD for dosimetric characterization of low-energy brachytherapy sources.

Method and Materials: One hundred high-sensitivity LiF:Mg,Cu,P TLDs (TLD-100H) and 100 normal-sensitivity LiF:Mg,Ti (TLD-100) were used for this study. The radial dose function of a Model AgX100 I-125 source was measured using both types of TLDs in water-equivalent solid phantoms. The radial dose function measured by the TLD-100H was compared with that measured by TLD-100. The TLD-100 was annealed at 400°C for one hour and then kept at room temperature for 45 minutes followed by 80°C heating for 24 hours. Annealing protocol for TLD-100H calls for high temperature annealing at 240°C for 15 minutes and then cooling at room temperature for 45 minutes followed by 100°C heating for one hour. Unlike regular TLD, an accurate and consistent annealing of the high-sensitivity TLD at 240°C for 15 minutes is challenging using conventional annealing ovens because the temperature in the oven chamber varies drastically over the 15-minute period after the opening (to put the TLD tray in) and closing of oven door. The temperature in the oven drops dramatically after the door is opened and ramps up gradually after the door is closed, often accompanied with significant temperature overshot. An overshoot by more than 5°C can significantly reduce the sensitivity of the TLD and the ramp-up profile varies with the duration of door opening. For consistent and accurate annealing of high-sensitivity TLDs, a novel thermal reservoir was used. These TLDs were then irradiated uniformly in a large cavity Cs-137 irradiator for biomedical research (Shepherd, Mark III) to determine the relative sensitivities of the individual TLDs.

Results and Conclusion: Consistent annealing of high-sensitivity TLDs was achieved using the thermal reservoir system. TLD-100H was found to be about 18 times more sensitive than TLD-100, which significantly shortened the time needed to measure radial dose function. For a ¹²⁵I source with a source-strength of 2.7U, the irradiation time for radial dose function characterization up to 7 cm can be cut down from 38 days to 3 days. The radial dose function measured by TLD-100H agreed well (within ±6%) with that measured by TLD-100. Measurements of other dosimetry properties such as the anisotropy function are in progress.