Dosimetric Characterisation of Glass Bead TLDs in Proton Beams

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Motivation for use of glass bead TLDs for Proton Dosimetry

- Spherical physical shape with a hole in the middle
- Chemically inert nature
- Small size of 1.5 mm diameter and 1 mm thickness
- Inexpensive and readily available
- Reusable
- TL light transparency with negligible self-attenuation
Methods

- Sample preparation
  - Cleaning
  - Mass screening
  - Annealing
Characterization measurements

A thin window (0.1 mm thickness) phantom to position the glass beads in water.

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Readout systems?

TLD reader at Royal Surrey County Hospital
Dosimetric peak with TL system

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### Mass Attenuation Coefficient

**Table:**

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight %</th>
<th>Atomic %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>8.93</td>
<td>14.38</td>
</tr>
<tr>
<td>O</td>
<td>42.18</td>
<td>51.01</td>
</tr>
<tr>
<td>Na</td>
<td>10.55</td>
<td>8.88</td>
</tr>
<tr>
<td>Al</td>
<td>1.35</td>
<td>0.97</td>
</tr>
<tr>
<td>Si</td>
<td>33.62</td>
<td>23.16</td>
</tr>
<tr>
<td>K</td>
<td>1.09</td>
<td>0.54</td>
</tr>
<tr>
<td>Ca</td>
<td>1.92</td>
<td>0.93</td>
</tr>
<tr>
<td>Fe</td>
<td>0.37</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>100.00</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Density:** 2.09  
**CT Number:** 800-1300
Bead mass and radiation response

\[ y = 4059.6x + 5815.4 \]

\[ R^2 = 0.9978 \]

- No self absorption
- Important to use for high LET radiation beams such as proton and ion beam dosimetry
Radiation response to photon beams

\[ y = 43.023x - 86.899 \]
\[ R^2 = 0.9999 \]

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Radiation response to proton beams

\[ y = 33.065x - 9.4796 \]
\[ R^2 = 0.9998 \]

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Dose rate response (photon Beams)

Average TL Yield × 10^2

Dose Rate (cGy/min)

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Dose rate response (proton Beams)

![Bar graph showing dose rate response for proton beams. The y-axis represents TL Yield ranging from 200 to 450, and the x-axis represents Dose Rate (Gy/min) ranging from 5 to 100. Errors are shown using error bars.](image-url)
Proton beam profile

First experiment

Second experiment

Normalised dose vs. mm
Batch homogeneity & reproducibility

Batch homogeneity: $\pm 7.4\%$ (2 SD)

Uncertainty of the entire TLD process:
$1.7\%$ (1 SD)

Mean reproducibility for 138 dosimeter:
Within $0.23\%$ (2 SD)

TL Yield$ \times 10^3$

Dosimeter Number

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Directional response

45° 0° 90°

[Image of TL Yield vs Angle of incidence photons (deg.)]

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Energy response

![Bar chart showing energy response for different beam energies.](image)

- 80 kV: High TL Yield
- 140 kV: Lower TL Yield compared to 80 kV
- 250 kV: Moderate TL Yield
- 6 MeV: Moderately low TL Yield
- 9 MeV, 12 MeV, 16 MeV, 20 MeV: Similar low TL Yield
- 6 MV, 10 MV, 15 MV: Further decrease in TL Yield

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Thermal neutron response

- The neutron absorbed dose / Gy for 15 MV energy
  
  $0.28 \times 10^{-3}$ Gy,

  in agreement with $0.27 \times 10^{-3}$ Gy (McGinley and Landry, 1989) measured with Bonner sphere radiation detectors.
Storage & handling

Light sensitivity and Pre-dose effect

- after 24 hours storage in the dark
- immediately after annealing

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Fading Rate: 10%/30 days

- 2 days after radiation
- 30 days after radiation

(TL yield/unit dosimeter) × 10^3

Channel Number

EPR signal × 10^3

Channel Number

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Conclusion

- The dose linearity and dose rate independency shown suggest that glass beads have potential as TLDs for verification measurement in proton therapy.

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References

THANKS FOR YOUR ATTENTION

QUESTIONS

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Reproducibility of calibration factors at different energies

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