Optical absorbance properties of PVA-GTA Fricke gel dosimeters irradiated with 6 MV and 15 MV X-rays

A. Marini, et al., Fricke gel dosimeters with low-diffusion and high-sensitivity based on a chemically cross-linked PVA matrix, Radiation Measurements (2017).
M. Marrale, et al., Analysis of spatial diffusion of ferric ions in PVA-GTA gel dosimeters through magnetic resonance imaging, NIMB (2017).

Purpose
Quality assurance procedures required in the modern radiotherapy would greatly benefit by the development of tissue equivalent dosimeters able of rendering 3D dose distributions with high spatial resolution. In this scenario, Fricke gel (FG), consisting in gel matrices infused with Fricke ferrous sulphate solution combined with xylenol orange, could be good candidates, but some limitations (such as diffusion of ferric ions) have restricted their interest in clinical practice. Recently, new FG formulations based on gel matrices of poly-vinyl alcohol (PVA) cross-linked with glutaraldehyde (GTA) have shown improvements as compared to FGs with natural matrices [1-4]. Purpose of this study is the characterization of the optical absorbance (OA) and dosimetric properties of PVA-GTA Fricke gel for dosimetry in photon beam radiotherapy.

Methods
✓ PVA-GTA Fricke gel dosimeters were prepared using 9.9% w/w of PVA and 26.4 mM of GTA. The dosimeters, placed in spectrophotometry cuvettes (50 mm optical path), were uniformly irradiated using 6 and 15 MV X-rays generated by a Varian Clinac-2100 linac, with the set-up shown in Figure 1. Optical absorbance spectra were measured by means of an Agilent Cary-100 spectrophotometer. For each dose value, 3 cuvettes were irradiated.
✓ Dosimetric properties of PVA-GTA-FG dosimeters, such as reproducibility, dose–response, sensitivity, dose-rate dependence and energy dependence, were studied.
✓ 3 sets of dosimeters have been used to study the effect of a crash or accidental fall. To study this effect, a set was subjected to an accidental fall from a table before the irradiation (SET 1) and a second set after the irradiation (SET 2), while a third set was used as reference (SET 3).

Results
The analysis of the optical absorbance spectra of the PVA-GTA-FG dosimeters in the wavelength interval of interest for dosimetry purposes (in the range 530-600 nm) revealed an intra-batch reproducibility of the order of ±5%. The OA proved to increase linearly with the dose, in the investigated interval 0–15 Gy; if the wavelength used for the analysis is properly chosen, as shown in Figure 2. The analysis at 555 nm provides a linear dose-response for the entire investigated dose range. The optical response of the PVA-GTA-FG dosimeters was independent of both energy and dose-rate (Figure 3 and Figure 4). The optical response of the PVA-GTA-FG dosimeters would seem not to be affected by pre and post irradiation trauma, as shown in Table 1.

Conclusions
This study confirmed the interesting properties of PVA-GTA FG dosimeters [2-3], in particular the independence from dose-rate and from radiation energy, and indicated the best parameters for their optical analysis, the use of 555 nm as wavelength to have a linear dose-response of PVA-GTA FG. Currently, studies are in progress in order to optimize Magnetic Resonance Imaging procedures for the assessment of 3D dose distributions in PVA-GTA FG phantoms.

References

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Figure 1 - Irradiations set-up, the cuvettes are in yellow

Figure 2 - Response to different wavelength used for analysis.

The lack of linearity characteristic for doses of a few Gy is similar to that found for FG with Xylenol produced with standard gelling agents [5].

Figure 3 - (a) Analyses of dose-rate dependence; (b) average and standard deviation at 585 nm.

Figure 4 – (a) OA at 585 nm versus dose for two different energies, the 6 MV and 15 MV curves overlap; (b) OA ratio of data show in (a).

Table 1 - Trauma effect

<table>
<thead>
<tr>
<th></th>
<th>Optical Absorbance at 555 nm</th>
<th>Reconstructed Dose (Gy)</th>
</tr>
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<tbody>
<tr>
<td>SET 1</td>
<td>0.473±0.002</td>
<td>6.58±0.07</td>
</tr>
<tr>
<td>SET 2</td>
<td>0.475±0.001</td>
<td>6.62±0.06</td>
</tr>
<tr>
<td>SET 3</td>
<td>0.474±0.002</td>
<td>6.61±0.07</td>
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