



Determination of Dose Distribution of Ruthenium-106 Ophthalmic Applicators

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Contents

ABSTRACT.....	vi
DECLARATION.....	viii
ACKNOWLEDGMENTS.....	ix
PREFACE.....	xii
1. RUTHENIUM-106 OPHTHALMIC APPLICATORS.....	1
1.1. Physical properties of ruthenium-106 ophthalmic applicators.....	1
1.2. Nuclear properties of ruthenium-106 applicators.....	4
1.3. Dosimetry of ruthenium-106 applicators.....	7
1.4. Outline of the current project.....	11
2. GENERAL PRINCIPLE OF THERMOLUMINESCENT DOSIMETER.....	13
2.1. Introduction.....	13
2.2. Basic phenomenon of thermoluminescence.....	14
2.2.1. Characteristics of TLD phosphors.....	15
2.2.2. Glow curves.....	15
2.2.3. Sensitivity.....	18
2.2.4. Dose response curves.....	19
2.2.5. Energy response.....	20
2.2.6. Thermal fading.....	20
2.2.7. Annealing conditions.....	21
2.3. Characteristics of commonly used TL phosphors.....	21
2.3.1. LiF:Mg,Ti.....	21
2.3.2. LiF:Mg,Cu,P.....	23

2.3.3. BeO.....	25
2.3.4. CaSO ₄ :Dy.....	26
2.4. Thermoluminescence readout instrumentation.....	28
2.4.1. Dosimeter heating system.....	29
2.4.2. Light collection unit.....	29
2.4.3. Light measuring systems.....	29
2.5. Beta radiation dosimeter.....	31
2.6. Conclusion.....	32
3. STUDY OF BASIC CHARACTERISTICS OF CaSO₄:Dy TLD.....	34
3.1. Introduction.....	34
3.2. General properties of CaSO ₄ :Dy TLDs.....	35
3.2.1. Reading reproducibility.....	35
3.2.2. Dose response linearity.....	35
3.2.3. Sensitivity.....	36
3.2.4. Irradiation-orientation dependence and reading-orientation dependence.....	36
3.3. Experimental instruments and procedures.....	36
3.3.1. Experimental instruments.....	36
3.3.1.1. CaSO ₄ :Dy TLDs.....	36
3.3.1.2. Radiation sources.....	37
3.3.1.3. TLD reader.....	37
3.3.1.4. Annealing oven.....	38
3.3.1.5. Effective point of measurement.....	38
3.3.2. Experimental procedures.....	39
3.3.2.1. Irradiation and reading of TLD samples.....	39
3.3.2.2. Measurement of dose response sensitivity and reproducibility of CaSO ₄ :Dy TLDs.....	40
3.3.2.3. Measurement of dose response linearity of CaSO ₄ :Dy TLDs.....	42

3.3.2.4. Observation of orientation and reading dependence of CaSO ₄ :Dy TLDs.....	43
3.4. Experimental results.....	44
3.4.1. CaSO ₄ :Dy TLD dose response sensitivity.....	44
3.4.2. CaSO ₄ :Dy TLD dose response reproducibility measurement results.....	45
3.4.3. CaSO ₄ :Dy TLD dose response linearity measurement results.....	46
3.4.4. Measurement results of irradiation-orientation and reading-orientation dependence of CaSO ₄ :Dy TLDs.....	48
3.4.4.1. Results of irradiation-orientation dependence experiment.....	48
3.4.4.2. Results of reading-orientation dependence experiment.....	50
3.5. Discussion of experimental results.....	51
3.5.1. Dose response sensitivity of CaSO ₄ :Dy TLDs.....	51
3.5.2. Measurement of reproducibility of CaSO ₄ :Dy TLDs.....	51
3.5.3. Measurement of CaSO ₄ :Dy TLD dose response linearity.....	52
3.5.4. Measurement of irradiation-orientation and reading-orientation dependence of CaSO ₄ :Dy TLDs.....	52
3.6. Conclusion.....	53
 4. MEASUREMENTS OF COB AND CCA TYPE RUTHENIUM-106 OPHTHALMIC APPLICATOR DOSE DISTRIBUTIONS.....	
4.1. Introduction.....	55
4.2. Preparation and calibration of small CaSO ₄ :Dy TLDs.....	56
4.3. Measurement of ruthenium-106 ophthalmic applicator dose distributions with small CaSO ₄ :Dy TLDs.....	57
4.3.1. Measurement instrumentation.....	57
4.3.2. Measurement procedures.....	59
4.3.3. Calculation of depth dose from reading results.....	64
4.4. Measurement results.....	65
4.4.1. Calibration results of small CaSO ₄ :Dy TLDs.....	65

4.4.2. Results from measurements for dose distributions for a 20-mm ruthenium-106 ophthalmic applicator.....	65
4.4.3. Results from the measurements for dose distribution of a 15-mm ruthenium-106 ophthalmic applicator.....	69
4.5. Discussion of the experimental results.....	75
4.5.1. Calibration of small CaSO ₄ :Dy TLDs.....	75
4.5.2. Measurements of dose rate distribution of a 20-mm ruthenium-106 ophthalmic applicator.....	75
4.6. Conclusion.....	78
5. DETERMINATION OF THE DOSE RATE DISTRIBUTION USING A MOSFET DETECTOR.....	79
5.1. Introduction.....	79
5.2. Basic structure and principle of operation of MOSFET.....	81
5.3. Experimental instrumentation.....	84
5.3.1. MOSFET semiconductor dosimeter.....	84
5.3.2. Eye phantom modification.....	87
5.3.3. Ruthenium-106 ophthalmic applicator.....	88
5.4. Experimental procedures.....	88
5.5. Measurement results.....	90
5.5.1. Measurement of dose response linearity.....	90
5.5.2. Measurement of depth dose rate of ruthenium-106 applicator with MOSFET detector.....	90
5.6. Discussion.....	94
5.7. Conclusion.....	95
6. SUMMARY AND CONCLUSION.....	97
APPENDIX.....	105
REFERENCES.....	108

Abstract

Dose distributions of COB and CCA type ruthenium-106 ophthalmic applicators, of diameters 15 mm and 20 mm, respectively, were investigated using small $\text{CaSO}_4:\text{Dy}$ thermoluminescent dosimeters. The $\text{CaSO}_4:\text{Dy}$ TLD discs were irradiated with a 4MV linear accelerator (Varian Clinac 4/100) at the Royal Adelaide Hospital. A range of absorbed doses from 0.1 to 10 Gy was used to observe their reproducibility and linearity. This machine was selected because it provides an electron beam with an energy of approximately 1.3 MV that is close to the mean energy of beta particles produced by the decay of ruthenium-106. A TOLEDO Model 645D TLD Reader was used to readout the irradiated TLDs. It was found that these TLDs respond linearly to radiation doses up to 6 Gy above which supralinearity begins. A sensitivity factor for each TLD disc was measured and applied to subsequent readouts. Selected TLD discs were cut into small rectangular wafers with dimension of approximately $2 \times 3 \times 0.4 \text{ mm}^3$. The same method as described above was employed to obtain the sensitivity factor for each small TLD. Their relative dose response sensitivities ranged around the mean from approximately -20% to +17%.

Dose distributions of ruthenium plaques were observed by placing the small TLDs in different positions on an eye phantom. Eye phantoms were made of layers with different thicknesses and can be built up from 1 mm to 10 mm. The results showed that the radioactive layer was non-uniform on each plaque. Hot spots and cold spots were found in various positions throughout the plaques. In comparison to the depth dose values provided by the plaque manufacturer, the depth dose values measured by these small TLDs were

lower, and the percentage uncertainties were considerably improved. The highest uncertainty obtained was approximately $\pm 10\%$ compared with $\pm 30\%$ specified by the manufacturer. Determination of on-axis depth dose distributions of ruthenium-106 applicators was also conducted with the MOSFET semiconductor dosimeter. Its high sensitivity to radiation doses, instant readout and a simple measurement setup are some advantages of the MOSFET dosimeter. On-axis depth dose distributions measured with the MOSFET dosimeter were comparable with those measured with the small TLDs and those provided by the manufacturer ($\sigma = 8\%$).

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

SIGNED: _____

_____ **DATE:** 1-8-2003

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Preface

Background

Ruthenium-106 ophthalmic applicators have been widely used for treatment of eye tumours and its clinical use has been developed for more than a decade (Taccini *et al.* 1997). It has been indicated in several reports that the treatment of those eye disorders with the ruthenium plaques (in selected cases), is an effective and reasonable method (Lim & Petrovich, 2000, and Gunduz *et al.*, 2000). Similar to other types of brachytherapy, the most important requirement for the use of ruthenium eye applicators is that the prescribed dose must be delivered to the target tissue with accuracy so an effective treatment is provided and the irradiation of healthy tissue is kept as low as possible. This important objective cannot be achieved without an understanding of the radiological characteristics of the ruthenium applicators such as dose distribution patterns in the eye ball and uniformity of the active layer (ruthenium-106) coated on the plaques. Hence, the determination of the dose distributions and uniformity of the active layer of the eye applicators should be carefully investigated. Although the radiological characteristics of the ruthenium applicators, such as absorbed dose rate and depth dose rate distribution, were provided with the purchase of the applicators, they have an uncertainty of $\pm 30\%$ that is not acceptable for clinical use. Thus, an observation of the radiological characteristics of the applicators with an appropriate method providing an acceptable level of uncertainty is necessary.

Aims of the current research

Although improvements in the determination of the dose distributions of the ruthenium-106 ophthalmic applicators were achieved in previously published studies, evaluation of dose distribution characteristics of the ruthenium applicators needs be further investigated with the aim to obtain more accurate dose distribution patterns. Also, a simple and fast technique is needed to enable the routine measurement of radiation output of sources, for example to confirm the doses reported by the manufacturer (acceptance testing) or to check the integrity of the source after handling during treatments (quality assurance procedure). Some of the parameters to be investigated regularly may include the depth dose distribution (relative or absolute) along the central axis of the applicators, the horizontal dose distribution, and the homogeneity of the radioactive material distribution (ruthenium-106) in the applicators. Correspondingly, the specific aims of the presented research project include:

1. Determination of dose distribution characteristics of COB-494 and CCA-610 type ruthenium-106 applicators used for eye radiation treatments at the Royal Adelaide Hospital. Dose distribution patterns of these particular applicators in great details have not been reported previously.

2. Determination of dose distribution values (central depth dose and off-axis dose) for both mentioned ruthenium-106 applicators with an uncertainty acceptable (below 10%) for clinical use.

3. Development of a standard dosimetry method that can be used for evaluation of the dose distributions of ruthenium-106 applicators for routine quality assurance purposes.

In order to achieve this, two dosimetry methods were employed in the current work: small $\text{CaSO}_4:\text{Dy}$ thermoluminescence dosimeters and a semiconductor MOSFET dosimeter (the use of which has not been so far reported in literature). Correspondingly, the structure of this thesis is as follows: The general properties of ruthenium-106 applicators and previous studies about their dosimetry were provided in chapter 1, the general principles of thermoluminescent dosimetry will be summarised in chapter 2, followed by the study of properties of $\text{CaSO}_4:\text{Dy}$ TLD (sensitivity, dose linearity, reproducibility, etc) in chapter 3. Chapter 4 will deal with the experimental details and results of the application of small $\text{CaSO}_4:\text{Dy}$ TLDs to dose investigation of Ru-106 ophthalmic applicators and chapter 5 will discuss the application of MOSFET dosimeter for determination of applicator relative depth dose curve. Finally, the results of the current work will be summarised in chapter 6.

The publications and presentations with which the author has been participated during the course of this research are:

Conference Presentations

Takam, R., Bezak, E. & Byas, K. (2002). Determination of Dose Distributions of Ruthenium-106 Ophthalmic Applicators. **15th National Congress of the Australian Institute of Physics, AIP, July 8 – 11, 2002, Sydney.**