

## Al<sub>2</sub>O<sub>3</sub> Sintered Pellets for Dosimetry at Radiotherapy Level

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### INTRODUCTION

As a part of a quality assurance program, in vivo dosimetry is a very effective method to determine errors that may occur during different steps involved in a radiation therapy treatment (1,2,3). The variation for the absorbed dose can not exceed 5.0% to the target volume (4). In order to limit the errors during the treatment course, in vivo dosimetry is one of the methods used to determine the absorbed dose actually delivered to the patient during a treatment session (5, 6). Thermoluminescent dosimeters (TLD) are commonly used to determine the absorbed doses. Among various materials, Al<sub>2</sub>O<sub>3</sub> is a suitable candidate for quality control of in vivo dosimetry.

Aluminium oxide as a TL dosimeter in different forms (pure and doped) has received the attention of several authors (7,8,9,10) in recent years. The aim of this work is to investigate the performance of calcined alumina powder (alpha phase), in the form of pure and doped sintered pellets in relation to their dosimetric properties, to study its feasibility and possible applications for in vivo dosimetry for photon and electron beams.

### MATERIALS AND METHODS

Calcined alumina powder (alpha phase) produced by Alcoa (Poços de Caldas, MG, Brazil) and chemically pure graphite powder were used to produce sintered pellets of either pure Al<sub>2</sub>O<sub>3</sub> or Al<sub>2</sub>O<sub>3</sub> with a 0.5, 1.0, 10 and 20.0% graphite content (5.5 mm diameter and 0.8 mm thickness). They were first uniaxially pressed in a steel die under 100 MPa and then sintered at 1650°C in air during one hour (batch 1) and three hours (batch 2) respectively. The sintering procedure during three hours was realized only for pure Al<sub>2</sub>O<sub>3</sub> samples, in order to obtain larger size grains. The dosimetric characteristics of the sintered pellets, i.e., TL glow curve, reproducibility, radiation dose response, fading, detection lower limit and energy dependence were determined using gamma radiation from a panoramic source of <sup>60</sup>Co (Yoshizawa Kiko Co. Ltd) with an exposure rate of 30.8 C.kg<sup>-1</sup>.h<sup>-1</sup>, at the distance of 5cm. The samples were always irradiated under electronic equilibrium conditions, that is, the samples were placed between Lucite (Polymethyl methacrylate) plates. The response behavior of alumina sintered pellets to a Varian Clinac 600 linear accelerator (6 MV therapeutic X-rays beams) and to a CGR Saturne II linear accelerator, model Therac with 6 to 20 MeV electrons beams used in radiotherapy was also studied. Measurements of the TL response of the samples were carried out using a Harshaw Nuclear Systems Model 2000A/B TL Analyser, with a heating rate of 5°C.s<sup>-1</sup>. The reading cycle was performed within 65 s, with a constant flux of N<sub>2</sub> of 6.0 L.min<sup>-1</sup>. The maximum temperature of 300°C was reached in each readout cycle. The output data were recorded in a X-Y register (ECB - Equipamentos Científicos do Brasil - Brazil), model RB102, with two channels. Prior to each irradiation, the samples were thermally treated at 400°C (1 hour), a condition that was considered adequate to eliminate previous exposure signals.

### RESULTS

- Reproducibility

The reproducibility of the TL response of the Al<sub>2</sub>O<sub>3</sub> sintered pellets (batches 1 and 2) was obtained measuring them ten times after repeated standard annealing and irradiation procedures. The standard deviation after ten readout cycles was 3.5% (batch 1) and 3.0% (batch 2). The reproducibility of the Al<sub>2</sub>O<sub>3</sub> doped with 0.5, 1.0, 10 and 20.0% of graphite content are not shown, because a TL increase in the response occurred, and the tests could not be finished.

- Glow Curve

The TL glow curves were obtained submitting either the pure Al<sub>2</sub>O<sub>3</sub> samples (batch 1 and 2) or Al<sub>2</sub>O<sub>3</sub> with a 0.5% graphite content, to gamma radiation with an absorbed dose in air of 50 mGy. The main glow peak

or dosimetric peak appears at about 200°C for all kinds of materials, and the experimental result is shown in Figure 1.

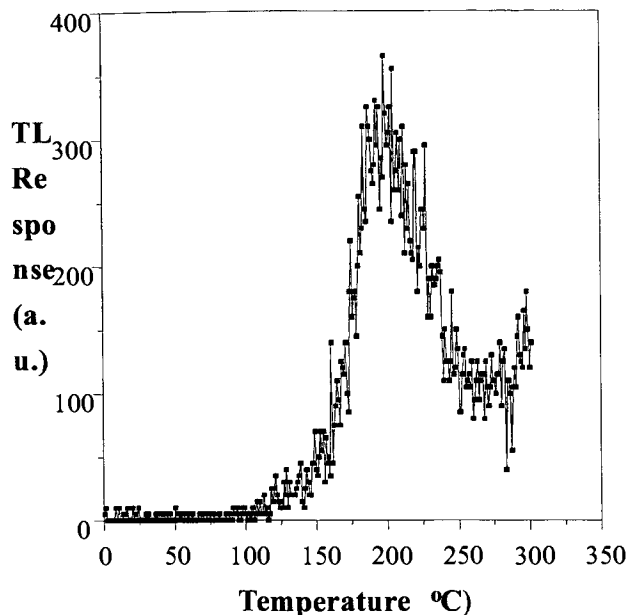


Figure 1. TL glow curve of a sintered pellet of  $Al_2O_3$  irradiated with 50 mGy of  $^{60}Co$ .

- Lower Limit of Detection

The lowest detectable value was determined studying the variability of the signal obtained by the reading of non-irradiated pellets. It was taken as being equal to three standard deviations from the mean zero dose reading of the pellets. The lowest detectable value was 1.0 mGy for batches 1 and 2.

- Calibration Curves

The TL response as a function of the absorbed dose of  $^{60}Co$  gamma radiation for alumina samples (batch 1 and 2) was obtained in the interval between 0.01 and 100 Gy. The results are shown in Figure 2.

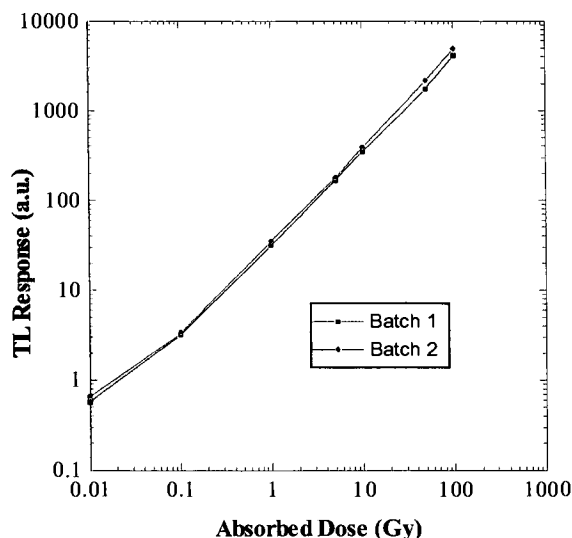


Figure 2. TL response of  $Al_2O_3$  sintered pellets as a function of absorbed dose for gamma radiation of  $^{60}Co$ .

A supralinear behavior for the alumina samples as a function of the absorbed dose can be observed. The standard deviation values were not greater than 11.0% for dose measurements with these materials.

The TL response was also obtained as a function of absorbed dose, when the alumina samples were submitted to photons with energy of 6MV of the linear accelerator, model Clinac 600. The results obtained are

shown in Figure 3. The range of doses in this case varied from 0.25 to 1 Gy. The standard deviation values were not superior to 13.0%. It can be observed practically the same behavior as obtained before.

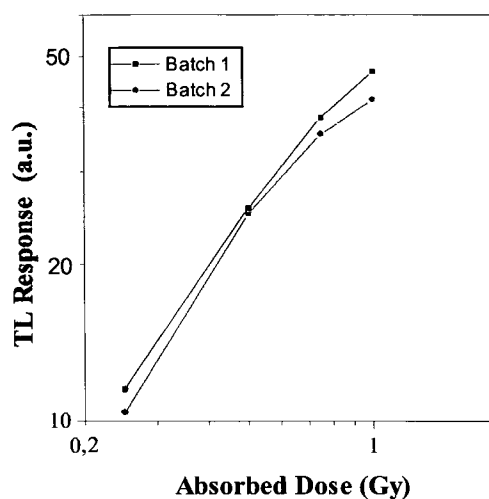


Figure 3. TL response as a function of absorbed dose for alumina samples irradiated with 6MV photons at a linear accelerator.

This calibration curve was obtained using a cylindrical ionization chamber calibrated in the reference conditions for photons beams used in radiotherapy, in a field of  $10 \times 10 \text{ cm}^2$ , with a build-up depth of 1.3 cm of Lucite and a skin-surface distance of 100 cm.

- **Fading**

The  $\text{Al}_2\text{O}_3$  sintered pellets were subjected to the annealing process and then were irradiated with an absorbed dose of 50 mGy ( $^{60}\text{Co}$  source). The fading at ambient temperature was studied up to 60 days. The TL response showed a decrease (6.0%) after 3 hours of irradiation and then 15.0% after 24 hours, reaching a relatively stability (1.5%) two days after irradiation.

- **Energy Dependence**

The energy response of the  $\text{Al}_2\text{O}_3$  sintered pellets was also verified varying the energy of an electron beam between 6 to 20 MeV, of the linear accelerator Saturne II, model Therac. The samples were irradiated under electronic equilibrium conditions, that is, the samples were placed between Lucite plates of 10.6 to 29.0 mm thickness. The results obtained are shown in Table 1.

Table 1. Energy dependence of sintered pellets of pure  $\text{Al}_2\text{O}_3$  for electron radiation.

Energy (MeV)	TL response (arbitrary units)	
	Batch 1	Batch 2
9	$32.68 \pm 0.14$	$36.31 \pm 0.07$
6	$45.40 \pm 0.07$	$43.23 \pm 0.06$
13	$46.73 \pm 0.19$	$44.48 \pm 0.09$
17	$46.10 \pm 0.19$	$47.23 \pm 0.09$
20	$48.40 \pm 0.14$	$47.72 \pm 0.07$

The TL response of the alumina sintered pellets was also measured for photons of 6 and 18 MV. The experimental results are shown in Table 2.

Table 2. Energy dependence of sintered pellets for photons of 6 and 18 MV.

Energy	TL response (arbitrary units)
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(MV)	Batch 1	Batch 2
6	47.35 ± 0.35	41.45 ± 0.21
8	39.56 ± 0.05	39.79 ± 0.13

It can be observed that there is an increase of the TL response as a function of electron energy in all the considered range. The energy dependence in this case was 48%. For photons in the 6-8 MV interval, the energy dependence was 19% for samples of the Batch 1 samples, the Batch 2 samples presented a almost energy independent response (4.2%).

## CONCLUSIONS

The dosimetric characteristics of alumina sintered pellets, such as TL glow curve, response reproducibility, calibration curves and energy dependence were studied. The results obtained show the feasibility of using these materials for field dosimetry at radiotherapy dose levels, after adequate corrections for fading. Although two batches of alumina samples have been used, there was no significantly change in the TL response, they practically present the same behavior.

The tests performed with the  $Al_2O_3$  samples with 0.5% of graphite content showed that these materials do not possess the necessary reproducibility for radiation dosimetry. New samples are being investigated to improve their properties, for use as TL dosimeters.

## ACKNOWLEDGMENTS

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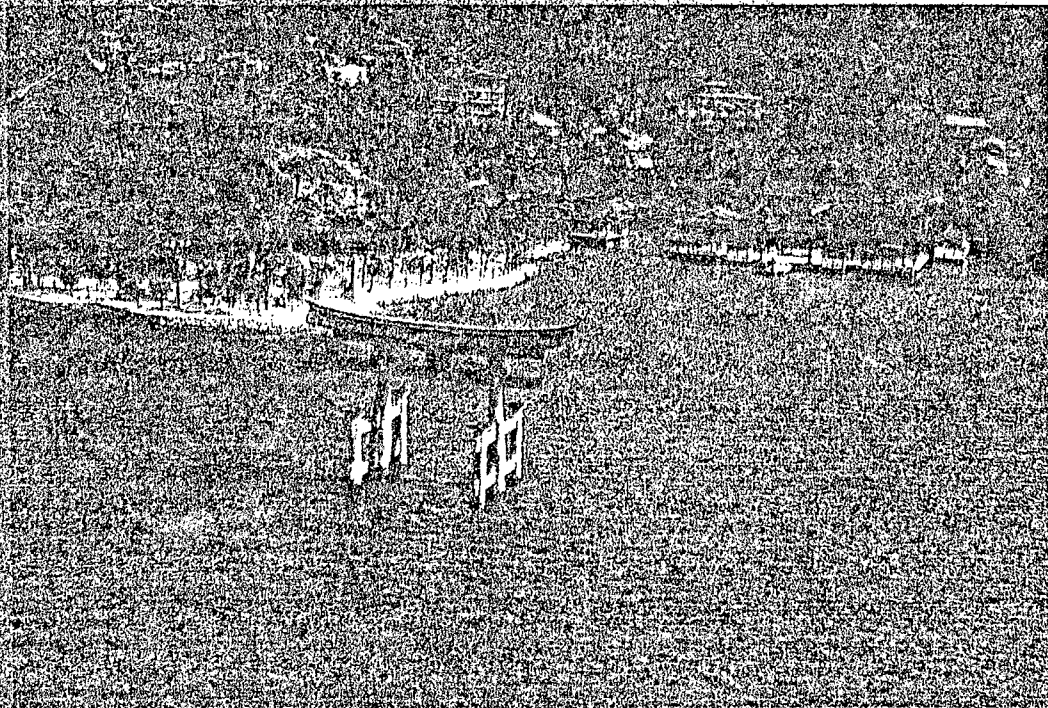
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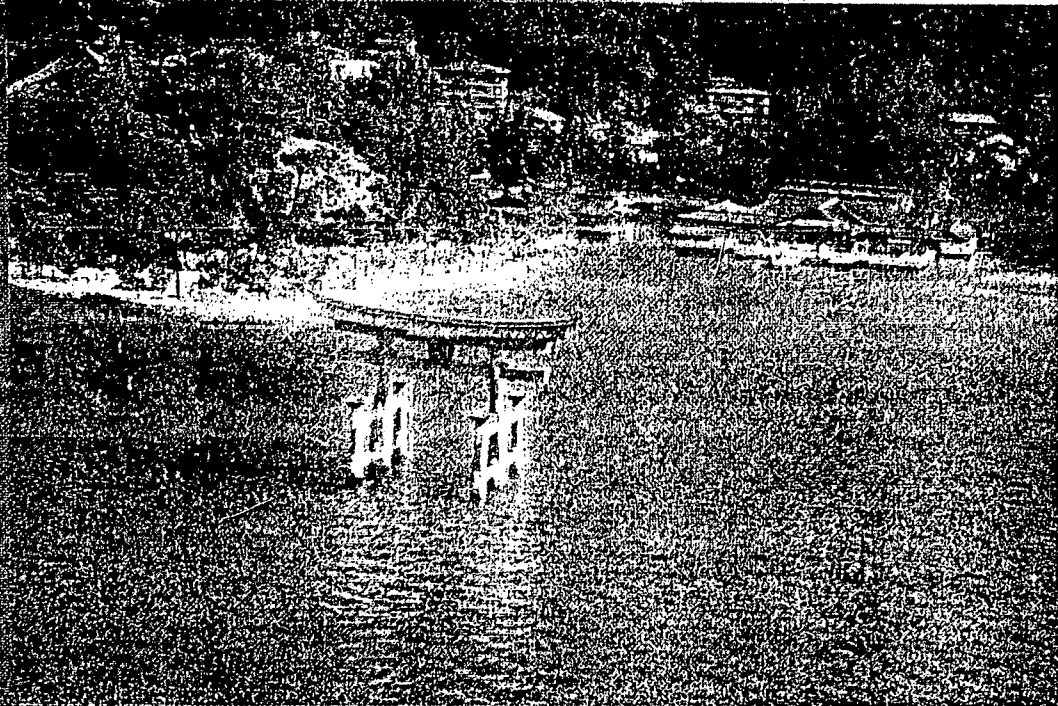


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