Applicability of Topaz Composites to Electron Dosimetry

K S Bomfim and D N Souza
Departamento de Física, Universidade Federal de Sergipe
São Cristóvão, SE, Brazil, 49100 000

E-mail: dnsouza@fisica.ufs.br

Abstract. Thermoluminescent dosimetric topaz properties have been investigated and the results have shown that this mineral presents characteristics of a good dosimeter mainly in doses evaluation in radiotherapy with photons beams in radiotherapy. Typical applications of thermoluminescent dosimeters in radiotherapy are: *in vivo* dosimetry on patients (either as a routine quality assurance procedure or for dose monitoring in special cases); verification of treatment techniques; dosimetry audits; and comparisons among hospitals. The mean aim of this work was to evaluate the efficiency of topaz-Teflon pellets as thermoluminescent dosimeters in high-energy electron beams used to radiotherapy. Topaz-Teflon pellets were used as TLD.

1. Introduction

Thermoluminescent dosimetric topaz properties have been investigated for some years and the results have shown that this mineral presents characteristics of a good dosimeter mainly in doses evaluation in radiotherapy with photons beams in radiotherapy [1-4]. In a comparative analysis between the TL response presented by topaz pellets and the conventional dosimetric procedures in radiotherapy of a 6 MV x-ray beams performed with a ionizing chamber Magalhães et al. observed that the topaz-Teflon pellets show a similar behavior to the results obtained by the conventional dosimetry, because the dose profiles obtained in equivalent tissue material had a good agreement [4].

Nowadays, typical applications of thermoluminescent dosimeters (TLD) in radiotherapy are: *in vivo* dosimetry on patients (either as a routine quality assurance procedure or for dose monitoring in special cases); verification of treatment techniques; dosimetry audits; and comparisons among hospitals [5, 6].

Megavoltage electron beams represent an important treatment modality in modern radiotherapy, often providing a unique option in the treatment of superficial tumors [5]. As the TLD are already widely employed in dosimetry to photons beams is expect the interest in these dosimeters electron beams monitoring. However, unlike in MV photon beams over regions of electron equilibrium, the response of a TL detector placed in a phantom exposed to a beam of electrons in the megavoltage energy range may depend on several factors, such as the mean electron energy at the phantom and detector surfaces, detector size, density of the detector and of the phantom medium or depth in the phantom at which the detector is irradiated [6].

The mean aim of this work was to evaluate the efficiency of topaz-Teflon pellets as thermoluminescent dosimeters in high-energy electron beams.

2. Materials and Methods

Topaz-Teflon pellets of size 6 mm diameter × 1 mm thickness were used as thermoluminescent dosimeters. The preparation of topaz-Teflon was as described by Souza et al. in a previous paper [3].

The simulations in electron beams were performed on a linear accelerator from Radiotherapy Service of the Hospital de Urgência de Sergipe, using megavoltage electron beams (8, 10, 12 and 14 MeV) at the source surface distance of 100 cm for 10×10 cm^2 for the 5x5 cm^2 radiation fields.

The electron beam central axis depth dose curves were obtained by irradiation of topaz-Teflon on diverse depths under acrylic plates. To each irradiation a group of 5 detectors were irradiated with absorbed doses in the range from 10 to 200cGy.

The TL measurements were performed in Harshaw 3500 equipment using a linear heating program with a rate of 10^{o}C/s between 25^{o}C up to 300^{o}C.

3. Results

A good thermoluminescent dosimeter (TLD) must show a thermoluminescent peak at high enough temperature so as not to be affected by room temperature and still low enough so as not to interfere with black body emission from the heating planchet of the thermoluminescent equipment that occurs near at 400^{o}C.

Figure 1 shows the typical thermoluminescent glow curve of the topaz-Teflon after irradiation with dose of 2 Gy from a 10 MeV electron beam at the depth of maximum dose (22 mm) under acrylic plates. We can observe that the maximum TL peak intensity occurs on 200^{o}C. The glow curves exhibited by other pellets irradiated using 10, 12 and 14 MeV they were similar to this curve.

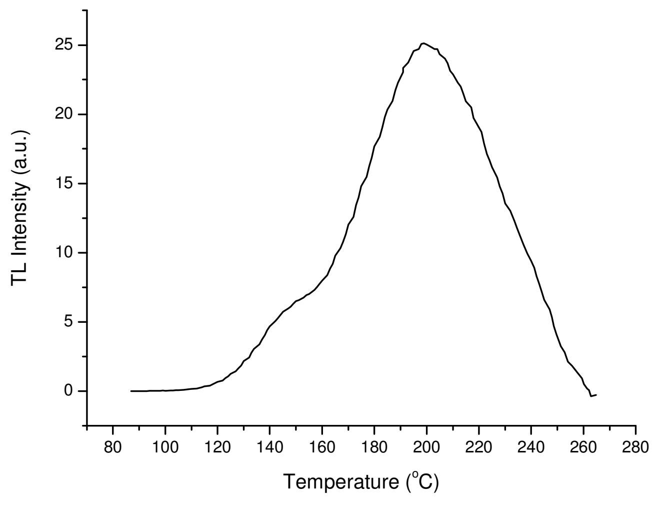

Figure 1. Thermoluminescent glow curve of Topaz-Teflon pellets irradiated with electron beams (8 MeV).

Figure 2 shows the TL response of the topaz-Teflon dosimeters as a function of absorbed dose from electron beams of 8 and 14MeV, respectively. The figure 3 shows 2 shows the TL response for the energies of 12 and 14 MeV. In both figures, the calibration curves presented responses proportional to absorbed dose between 10^{-1} Gy and 2 Gy. The curves are useful in the whole tested dose range and no dose saturation was observed. Meanwhile, a strong energy dependence can be also observed, the samples irradiated with 10 MeV showed a more intense TL response. Ideally, the energy response should be flat; the system calibration should be independent of energy over a certain range of radiation qualities, consequently for use of topaz-Teflon in monitoring doses from electron beams the energy correction must be included. The measurement uncertainties in those studies were always below 5%.

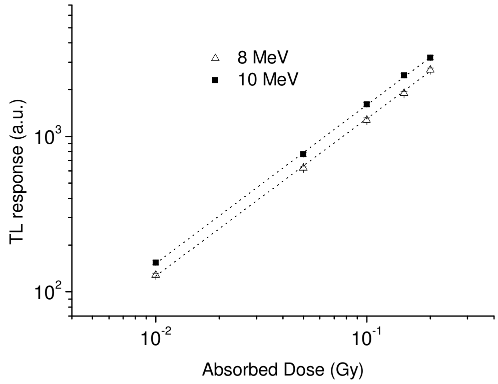

Figure 3. Dose response of Topaz-Teflon pellets irradiated by electron beams (8 and 10 MeV).

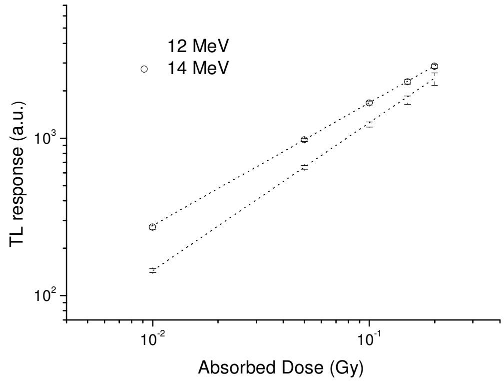

Figure 3. Dose response of Topaz-Teflon pellets irradiated by electron beams (12 and 14 MeV).

Figure 3 shows the result of energy dependence. The values were normalized to the TL response of the samples irradiated with 2 Gy in 8 MeV. The dependence of the TL and on the energy of X-rays between 8 and 14 MeV were less than 20% Samples exposed to the beam of 12 MeV showed the TL response of lesser intensity and when the pellets were exposed at 10 MeV beam they exhibit the highest intensity, 96% and 120% of the TL intensity when compared to dosimeters irradiated at the 8 MeV, respectively. The uncertainties associated with the measures were no more than 6.2%.

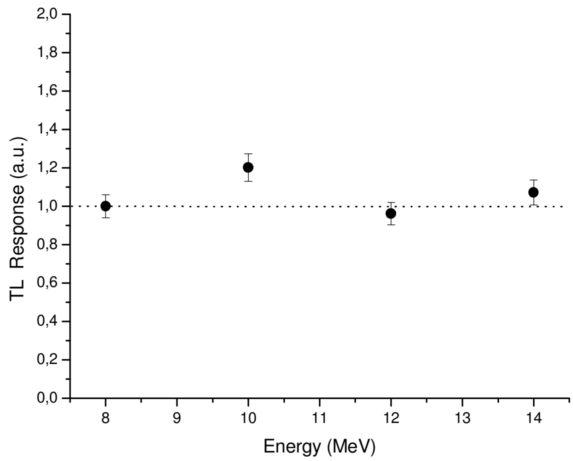

Figure 4. Dependence of the TL response topaz–Teflon pellets on the energy of electron beams. All the samples were irradiated to 2 Gy.

Typically, the electron beams central axis depth dose curve exhibits a high surface dose (compared with megavoltage photon beams), and the dose then build up to a maximum at a certain depth referred to as the electron beams depth of dose maximum [5]. In order to analyse the TL response the detectors were irradiated with doses between 0.1cGy and 200cGy under different thickness of acrylic plates.

The TL response of detectors irradiated with electron beams were similar to central axis percentage depth dose (PDD) curve obtained in conventional dosimetric procedures performed with ionizing chamber (calibration in routine procedures). TLD results showed that the absorbed doses presents around 80% in surface and increased up to 100% in depth of dose maximum (build-up region) for each evaluated energy and it was reduced in the high depths, as can be seen in figures 4 to 7.

To 8 MeV beams the maximum dose was obtained in the depth of 17 mm, in one of 26 mm the PPD result was of 77.1± 3.0% showing a 3% low then the value obtained by conventional procedures. When the depth increases more than 30 mm was observed divergences if compared with results obtained with ionizing chamber (figure 4).

Figure 4 shows the PDD to 10 MeV irradiation. In this figure it is possible observe that the maximum absorbed dose occurs at 22 mm. Moreover, we can say that the average values of PDP found with the TLD and the one obtained by calibration are in accordance up to the depth of 30 mm. In depth of 35 mm the PDP obtained with the pellets was equal to 57.6 ± 2.8%, 12.8% lower than the value found by the calibration, 64.7%. For depths higher than 35 mm the PDP values seemed quite distinct from obtained by the calibration, although by calibration PDD have not been obtained in depth of 40 mm.

The topaz-Teflon detectors when irradiated with 12 MeV, showed a accordance to the results of calibration, with an PDD of approximately 83% in surface witch increased by 100% to a depth of 28 mm and it being similar up to the depth of 35 mm in depth, the PDP obtained with TLD was 89%, only 3.4% lower than the obtained with calibration in water, which was equal to 92%. From the depth of 40 mm the differences between the responses to PDP were higher reaching up to 38% in depth of 45 mm (figure 5).

In the energy of 14 MeV the maximum dose depth was 29 mm according to calibration results obtained in routine procedures. The PPD results obtained with topaz-Teflon pellets has been showed lower than calibration in the interval of depth to range from 15 to 35mm, to depth of 15 mm this difference was 4.2%; to 45mm the result was similar to the one of calibration and to a depth of 60 mm the difference was 45% (figure 6).

The depth of the 90% dose level beyond the depth max is defined as the therapeutic range for electron beam therapy. To the energies studied the PDD obtained with topaz-Teflon pellets were almost similar to PDD obtained on calibration procedures.

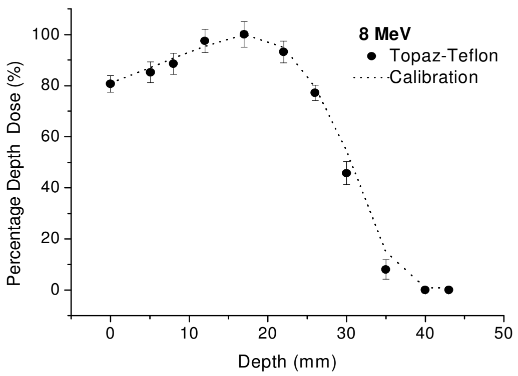

Figure 4. Percentage depth dose obtained by topaz-Teflon pellets irradiated for a 8 MeV electron beams.

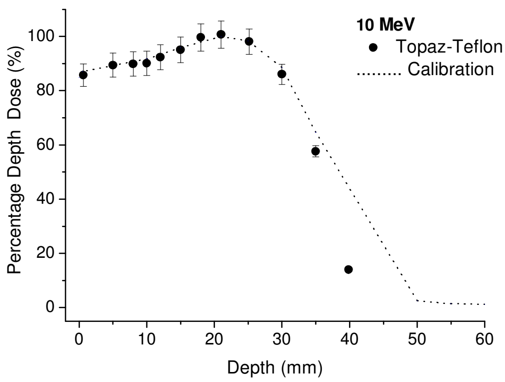

Figure 5. Percentage depth dose obtained by topaz-Teflon pellets irradiated for a 10 MeV electron beams.

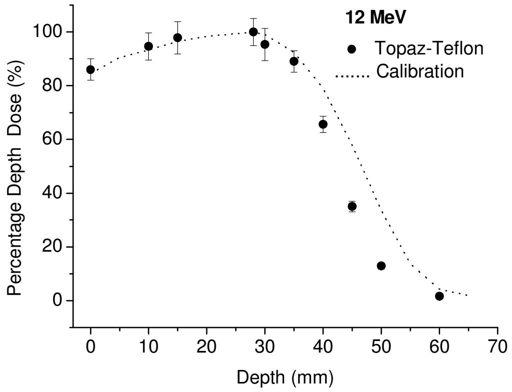

Figure 6. Percentage depth dose obtained by topaz-Teflon pellets irradiated for a 12 MeV electron beams.

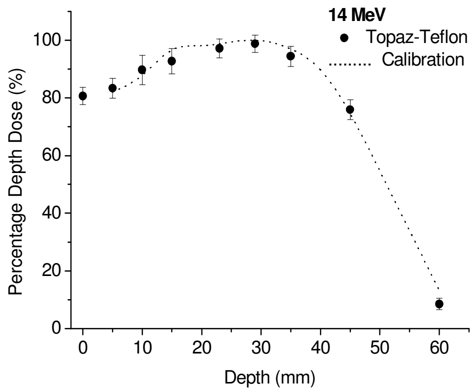

Figure 7. Percentage depth dose obtained by topaz-Teflon pellets irradiated for a 14 MeV electron beams.

4. Conclusions

The topaz-Teflon detectors showed TL response dependent to absorbed dose when irradiated in megavoltage electron beams, indicating that those TLD can be used for dosimetric monitoring in electron radiotherapy procedures mainly in the therapeutic range.

Ideally, the energy response should be flat; the system calibration should be independent of energy over a certain range of radiation qualities, consequently for use of topaz-Teflon in calibration procedures of electron beams the energy correction has to be included in the determination of absorbed doses.

5. Acknowledgments

The authors wish to thank Coordenação de Aperfeiçoamento de Pessoal Superior (CAPES) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazilian agencies, for parcial financial support.

References

[1] Souza D N, Valerio, M E G , Lima, J F, Caldas, L V E 2001 *Rad. Eff. Def .Sol* .**156** 325
[2] Souza D N, Valerio, MEG, Lima, JF and Caldas, LVE 2002 *Radiat. Prot. Dosim.* **100** 413
[3] Souza D N, Meira, R A, Valerio, MEG, Lima, JF and Caldas, LVE 2003 *App Radiat Isot* **58** 489
[4] Magalhães C M S, Macedo, Z S, Valério, M E G, Hernandes, A C and Caldas, L V E 2004 *Nucl Instr and Meth B* **218** 277
[5] Podgorsac E B Radiation Oncology Physics: A Handbook for teachers and students Viena: IAEA, 2005
[6] Nahajowski D, Góra E, Rozwadowska-Bogusz B, Lesiak J, Polak B, Kabat D, Zawadzki P and Waligórski M P R 2008 *Radiat.. and Measur.* 879