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THE USE OF COMPOSITES OF TOPAZ-GLASS AS TSEE AND TL DOSIMETERS

C. M. S. de Magalhães[1], M. E. G. Valerio[1], L. V. E. Caldas[2], D. N. Souza[1,3]

[1]Universidade Federal de Sergipe, Departamento de Física

49100-000, São Cristóvão, SE, Brazil

[2]Instituto de Pesquisas Energéticas Nucleares, CNEN

C. P. 11049, Pinheiros, 05542-970, São Paulo, SP, Brazil

[3]Universidade Federal de Sergipe, Depto. de Educação, CECH

49100-000, São Cristóvão, SE, Brazil

Corresponding author. Tel.: +55-79-212-6636. FAX: +55-79-212-6807. E-mail: dnsouza@fisica.ufs.br

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Abstract

The proprieties of the thermally stimulated exoelectron emission (TSEE) and thermoluminescent emission (TL) of composites of topaz-glass were studied with the aim of use as solid state dosimeters. The TSEE response was studied as a function of the radiation energy (photons and particles) and as a function of the absorbed dose. For electromagnetic radiation (^{60}Co and X-rays) topaz-glass composite presented a linear TL and TSEE response to dose within a range of 0.01-1 Gy. The topaz-glass composites presented higher TSEE peaks than topaz-Teflon pellets. In dosimetry of the irradiation fields normally used in radiotherapy the responses of the topaz-glass dosimeters are comparable to topaz-Teflon pellets. And the results confirmed that these samples can be useful in monitoring the quality of the radiation sources. This dose mapping techniques is particular useful to investigate the dose distribution throughout a planned target volume.

Key Words: topaz, composite, TL-TSEE

INTRODUCTION

The thermoluminescent (TL) properties of manufactured composites with a mix of topaz-Teflon have been studied by our group since 2000 with mean to develop a new solid state dosimeter [1-4]. In 2003 was presented the first results about TL response of topaz-glass composites prepared with a mixture of the powdered topaz crystal and powdered commercial glass [3].

Published results in previous work showed that the topaz composites are very promise candidate for differing TL applications, mainly in dosimetry of patients on radiotherapy [1-4]. The composites present a linear response for gamma rays from 10^{-2} Gy up to 1 Gy for of the topaz-glass and until 20 Gy for those of topaz-Teflon. Dose for TL saturation response to gamma dose are the about 2 kGy. Both composites and pellets present a dose response dependent of the radiation energy. This dependence can be reduced with the use of an appropriated filters combination in the dosemeters' badges; and that this dependence may be utilised to determine the effective energy of an unknown radiation source. Composites to display feasible for the successive irradiation-reading-annealing cycles without appreciable change in their sensitivity.

The main known advantage of the topaz-glass composite over the topaz-Teflon pellets as a TL dosimeter is which it can be annealed at 400°C. Topaz-Teflon composite can be thermally treated only up to 300°C, above this Teflon is volatilised. Thermal treatment at 400°C is more efficient to depopulated the traps, witch possibilities eliminate completely the TL signal before reusing [4].

Another technique used for studied dosimetric characteristics of the composites topaz-Teflon was the thermally stimulated exoelectorn emission (TSEE). TSEE is a technique that can be applied specially for detection of not much penetrating radiation, like low energy X rays, electrons, alpha radiation and beta.

In 2001 we presented the first results of TSEE analyses with topaz-Teflon pellets [2] These previous work presented the influence of the dose and the energy of alpha, beta, gamma and X rays on the TSEE response. Results about TL responses of these composites were also studied. These techniques were combined in order to check the possibility of building a solid state dosimeter that should be used in both techniques. Those one showed efficient for dosimetric applications by TSEE techniques too. Like TL results, TSEE response increased with the dose of radiation and is dependent of the energy of the beam.

The main of the present work is to investigate the potentiality of applicaton of the topaz-glass as a new TSEE dosimeter and continue to the investigation about topaz-Teflon pellets.

EXPERIMENTAL

Composites of natural colourless topaz samples from Santo Antonio do Jacinto, Minas Gerais, Brazil was employed in this work. The topaz-Teflon pellets were prepared with powdered topaz samples with grain sizes from 0.75 and 0.150 mm, mixed with Teflon in the 1:2 ratio (wt) and pressed producing pellets with sizes of 6 mm diameter × 1 mm thickness [1].

To produce topaz-glass composites were used recycled window glass, classified as transparent for industrial usage. For the preparation of the composites, topaz crystals were powdered with in the size interval of 45 – 65 μm. The glass was crushed into pieces with diameter of ~ 0.5 mm. After the milling step, the glass powder was dried and mixed with the topaz crystals (50 % in mass) and formed via uniaxial pressing into the form of pellets with 6 mm in diameter and 2 mm in thickness [4].

Composites and pellets were always thermally treated for 1h before irradiation, Topaz-Teflon at 300°C and topaz-glass at 400°C.

Photon irradiations were performed at IPEN/CNEN/SP facilities. X-rays irradiation were performed using a Rigaku Denk generator, model Geirflex, with Philips tube (60kV), with effective energies of 14.3, 17.2 and 21.2 keV. Gamma irradiation was carried out using the Gamma-Cell 220 (^{60}Co) system. Radiotherapic simulations were performed in a Siemens accelerator of a radiotherapy institution. Irradiation with gamma and 6 MV X-rays was done with the composites kept under Lucite badges in the order to obtain the electronic equilibrium conditions. All the irradiations were done at room temperature.

For measurements in radiotherapy the dosemeters were installed in acrylic phantoms fulfilled with water. The phantom was used to simulate the pelvis region of a adult. The composites were placed in the geometric center, in the entrance, in the exit and in the depth (half thickness) of the radiotherapy fields.

Figure 1 shows the phantom that has been used for simulated radiotherapy treatments based on current clinical trials.

The TL readouts were done in Harshaw 3500 equipment using a linear heating program with a rate of 5°C/s in the temperature range from room temperature up to 350°C.

The TSEE signal was registered using a system with a 2π windowless gas-flow proportional counter, with hemispherical volume [5]. The heating was linear at a rate of 5°C/s from room temperature up to 350°C.

RESULTS AND DISCUSSION

Figure 2 presents the TSEE glow curves for topaz-glass composites and topaz-Teflon pellets irradiated with 5 Gy of X-rays (21.2 keV). Both the samples displayed only one main peak at about 190°C. This peak presents in the same temperature range of the most intense TL peak. However, a comparative TL glow curve analyses with both composites show another peak at 110°C [4]. TSEE response of the topaz-glass composites was more intensity that one of the topaz-Teflon composites by a 10 factor, approximately.

In the figure 3 is showed the response of the TSEE of the topaz-glass composites as a function of absorbed dose for gamma and X radiation with 21.2 keV in the interval between 0.5 Gy and 5.0 Gy and of 17.7 keV in the range from 1.0 at 5.0Gy. The integrated areas of the TSEE peaks were calculated. The TSEE responses increase with the dose and are more intense to the composites irradiated with X-rays of 21.2 keV than those irradiated with 17.7 keV.

In order to determine the dependence of the TSEE response to the radiation gamma (^{60}Co) the topaz-glass composites were irradiated in the range from 0.005 at 0.04 Gy. As the TSEE response of topaz-glass composites is more intensity than topaz-Teflon pellets was possible measure low doses than 0.5 Gy. The lower dose observed by topaz-Teflon is 0.5 Gy (2). As expected, the TSSE response of the composites increased with the dose. And as the response to 0.005 Gy was intense, will be possible to measure low doses.

A comparative analyse of the TL response presented by topaz-glass in dosimetric procedures in radiotherapy is showed in figures 5 and 6. In this figures we presented the theoretical value and experimental measurements of TL response versus the field of irradiation and the depth that the composites were positioned inside the phantoms. The topaz-Teflon and topaz-glass composites were irradiated with 0.45 Gy (X-rays of 6 MV). The TL signals were analysed to measure in the half thickness (12.0 cm) and in the exit surface. The dose profiles show a god agreement with the profile of the equivalent tissue material.

CONCLUSIONS

The topaz-glass composites presented higher TSEE peaks than topaz-Teflon pellets. Indicating that the TSEE response of the former can be suitable to analyse the entrance dose in radiotherapy. In dosimetry of the irradiation fields, normally used in radiotherapy, the TL responses of the topaz-glass dosimeters are comparable to topaz-Teflon pellets.

The dose response in the depth of topaz-glass composites was in accordance with the literature results.

The results confirmed that these samples can be useful in monitoring the quality of the radiation sources. This dose mapping techniques is particular useful to investigate the dose distribution throughout a planned target volume.

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REFERENCES

[1] Souza, D.N., Valerio, M.E.G., Lima, J.F., Caldas, L.V.E. *Dosimetric Properties of Natural Brazilian Topaz: A Thermally Stimulated Exoeletronic Emission and Thermoluminescence* Study. Nucl. Instr. and Meth. B, **166-167**, 209-214 (2000).

[2] Souza, D.N., Valerio, M.E.G., Lima, J.F., Caldas, L.V.E. *The use of Pellets of Brazilian natural topaz as radiation dosimeters*. Rad. Eff. Def. Sol. **156**, 325-330 (2001).

[3] Souza, D.N., Valerio, M.E.G., Lima, J.F. and Caldas, L.V.E. *Perfomance of Pellets and Composites of Natural Colourless Topaz as Radiation* Dosemeters. Radiat. Prot. Dosim. **100**, 413-416 (2002).

[4] Souza, D.N., Meira, R. A., Valerio, M.E.G., Lima, J.F. and Caldas, L.V.E. *Evaluation of Doses in Radiotherapy Using Solid-State Composites Based on Natural Colourless Topaz.* App. Radiat. Isot. **58**, 489-494 (2003).

[5] Rocha, F. D. G. and Caldas L.V.E. *Calcium Sulphate Sintered Pellets for Area Monitoring of na Electron Accelerator using the TSEE Technique*. Radiat. Prot. Dosim. **84**, 403-405 (1999).

[6] CEI/IEC 1066, 1991. *Thermoluminescence Dosimetry Systems for Personnel and Environmental Monitoring, International Standard CEI/IEC 1066*, 1991.

Figure Captions

Figure 1. Phantom used for simulations in radiotherapy.

Figure 2. TSEE emission curves of the composites irradiated with 5 Gy of X-rays (21.2 keV)

Figure 3. TSEE response (area) of topaz-glass composites as a function of absorbed dose for X radiation (17.7 and 21.2 keV).Figure 4. TSEE response (area) of topaz-glass composites as a function of absorbed dose for gamma radiation (^{60}Co).

Figure 5. Percentage depth doses presented by the topaz-Teflon pellets as a function of radiotherapic fields.

Figure 6. Percentage depth doses presented by the topaz-glass composites as a function of radiotherapic fields.

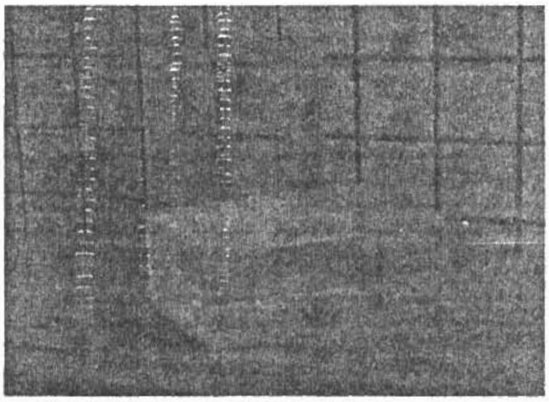
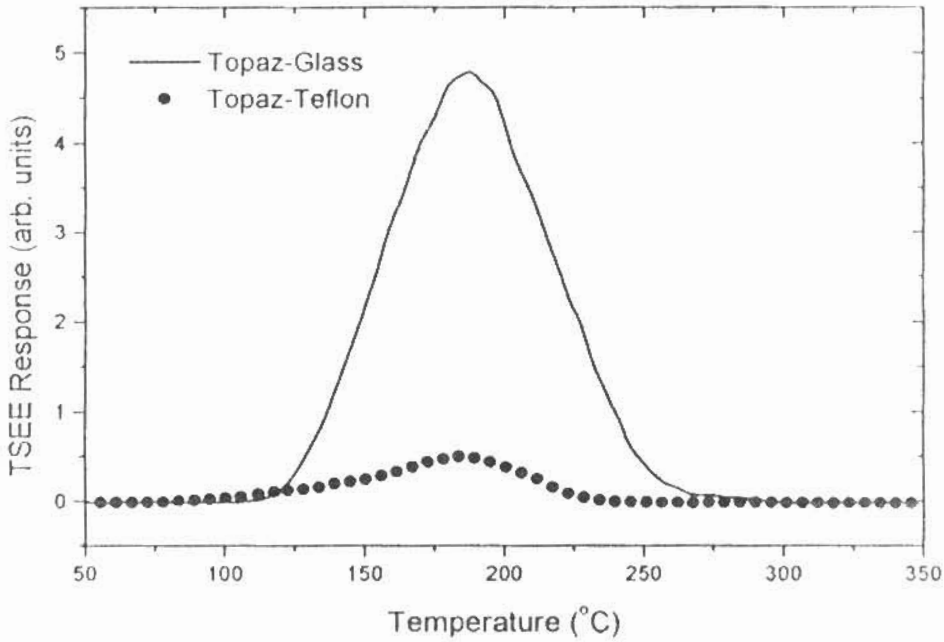


Figure 1



Topaz-Glass
Topaz-Teflon
TSEE Response (arb. units)
Temperature (°C)
0
1
2
3
4
5
50
100
150
200
250
300
350

Figure 2

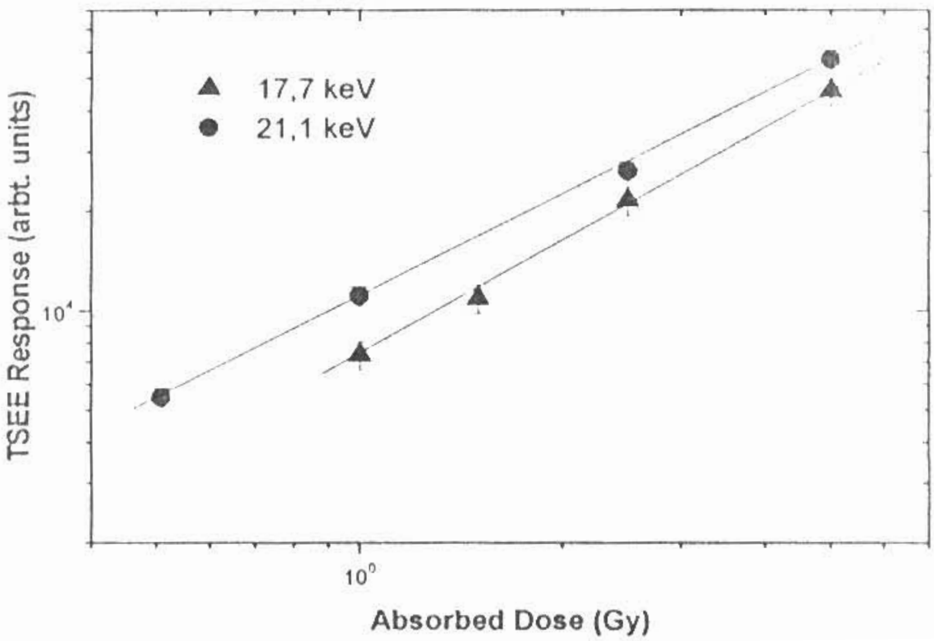

17,7 keV
21,1 keV
TSEE Response (arbt. units)
10⁴
10⁰
Absorbed Dose (Gy)

Figure 3

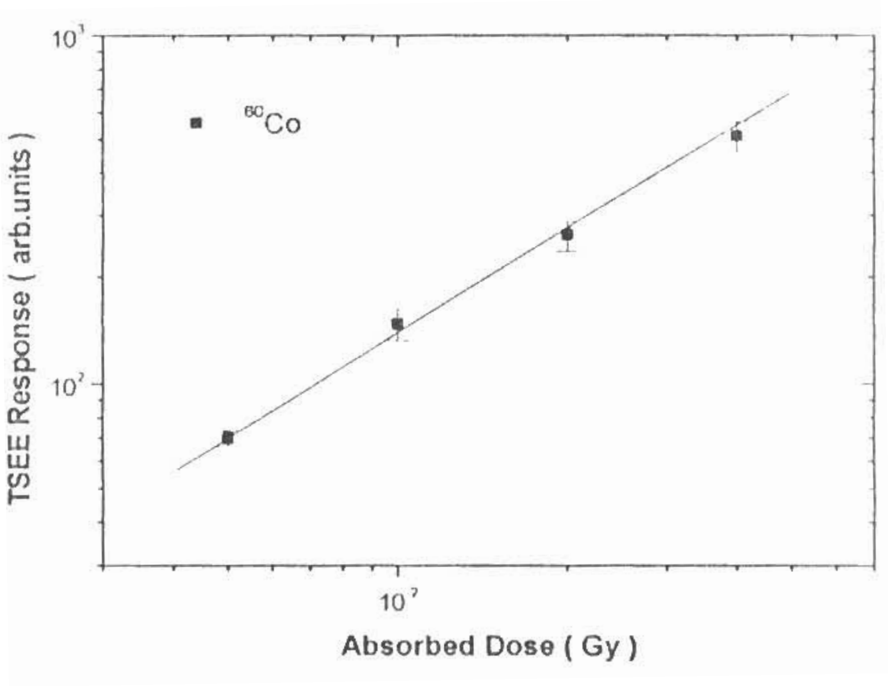
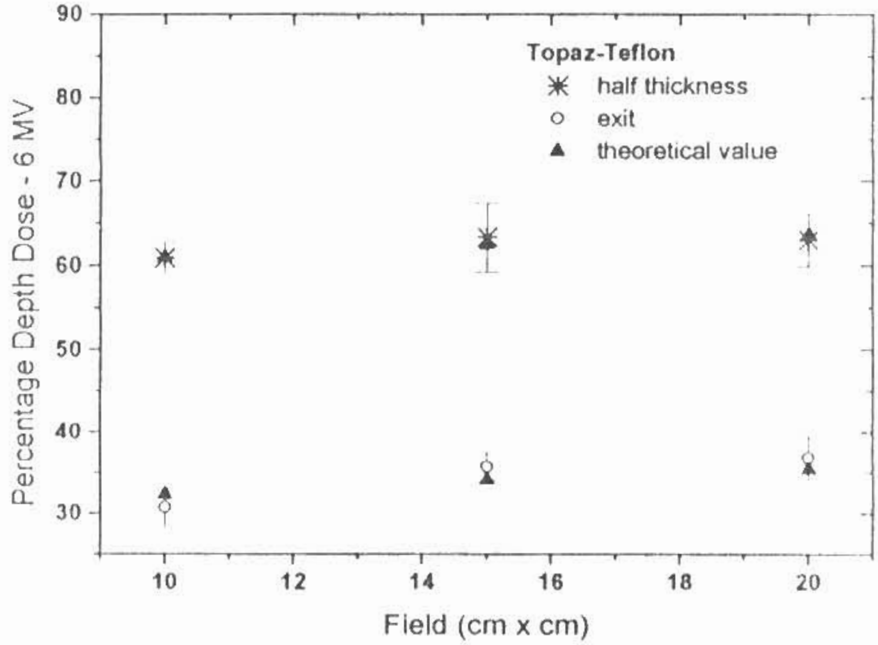
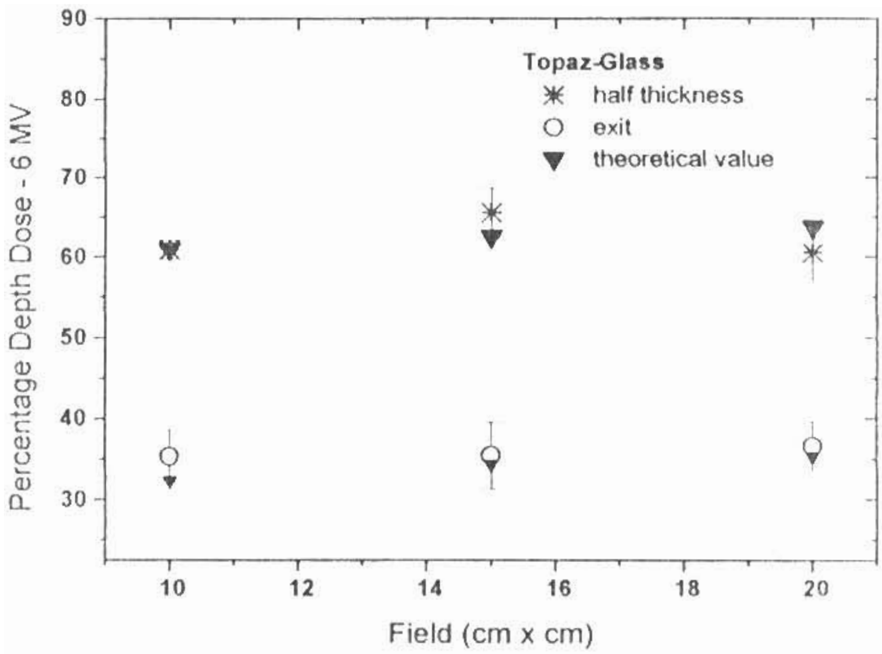


Figure 4



Topaz-Teflon
half thickness
exit
theoretical value
Percentage Depth Dose - 6 MV
Field (cm x cm)
90
80
70
60
50
40
30
10
12
14
16
18
20

Figure 5



Topaz-Glass
half thickness
exit
theoretical value
Percentage Depth Dose - 6 MV
Field (cm x cm)
90
80
70
60
50
40
30
10
12
14
16
18
20

Figure 6