Homogeneity evaluation of phosphorus-32 epoxy plaques to be used in the treatment of spinal and intracranial cancer by brachytherapy

José T. Silva[1], Carla D. Souza[1], Beatriz R. Nogueira[1], Lucas V. Angelocci[1], Carlos A. Zeituni[1], Maria Elisa CM Rostelato[1]

1- Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP), Av. Professor Lineu Prestes 2242, 05508-000 - São Paulo, SP - Brasil

e-mail: tiagofisicausp@gmail.com

Abstract

In Brachytherapy, radioactive source is positioned close to the tumor. The most important advantage is that the target region receives most of the dose, protecting the healthy tissues adjacent to the tumor region. In order to use these sources, a high dosimetric uniformity must be achieved, so a homogeneous dose delivery need to be given to the target. In the present work, the consistency of the epoxy resin plate was evaluated using a methodology developed in the *Laboratory for Radiotherapy Sources Production* located at IPEN / CNEN - SP. Several tests were carried out to determine the best mold for the source manufacture. It was concluded that polytetrafluoroethylene (PTFE), commercially known as Teflon, obtained the best result, due to the ease unmold after the resin curing process. The epoxy plaques were produced with resin 2220 and catalyst 3154 (Avipol), at a 2:1 mass ratio. To simulate the radioactive material, hydrochloric acid (HCl) equivalent to 5% of the total mass (resin + catalyst) was added. The epoxy resin cured for 24 h at room temperature. The thickness of the plaques was measured reaching an average value of 0.300 mm ± 0.070. The measurements were made with a micrometer, measuring 10 points of each plaque. In order for the distribution of phosphorus-32 activity to be stipulated, a Monte Carlo Simulation using the MCNP code was performed. The maximum dose variation along the plaque, considering a totally uniform thickness of 0.300 mm, resulted in <0.5% up to 0.5 cm before the edge. The result of the simulation shows that with a uniformly thick plaque, the dose distribution trend is homogeneous. Based on the results, the epoxy polymer plaques are shown to be viable for use in brachytherapy, and the next step of the work will be the tests with radioactive material.

Keywords: phosphorus-32, epoxy resin, brachytherapy

1. Introduction

With the growing cancer numbers around the world, new and efficient forms of treatment are in high demand. Is also important that these new treatments are locally produced resulting in lower cost and ultimately becoming available for more patients. Among the possible treatment, brachytherapy is a strong contender. By placing radioactive seeds directly inside the cancer, it is possible to almost achieve the major goal of radiation therapy: focusing the effects of radiation in the target saving the healthy surrounding tissues [1,2].

Fabricating a new radioactive source in a semi-industrial scale is not easy task. Several steps must be fulfilled before even handling radioactive material. Usually, the initial prototype is fabricated without radioactive material to ensure high yields in the chemical and/or mechanical assembly. After a route is determined, optimization of each step is still performed with no radioactive material. This assures a good start point condition for radioactive tests. These initial tests are important because important steps such as concentrations, selection of the best tools, set ups, and others can all be determined without the presence of radiation assuring operator safety and avoiding unnecessary wastes. The constraints for manufacture in large scale are many, but the final product might be the only and/or the best treatment available [1,2].

The central nervous system (CNS) is formed by the brain and spinal cord. CNS cancer can be developed on the brain, cranial nerves, meninges, or on the spinal cord itself. Tumor resection in the spinal or cerebral region is a risk due to the proximity of the tumor to the dura, in addition to putting the patient at risk for possible neurological diseases. Low dose radiotherapy due to the complexity of the site has been used post-operatively in local recurrences. Patients with this tumor type experience a high degree of suffering due to a possible compression of the spinal cord and the numerous sequels that may occur, mainly because the disease affects regions that control the motor activity. [2]

1.1 Brachytherapy with phosphorus-32

The use of phosphorus-32 in brachytherapy has been used in various segments of medicine, including ophthalmology. Some patients who experienced relapse or residual disease after primary treatment were treated with a flexible film impregnated with phosphorus-32 to combat eye cancer. Although it approached a small number of patients, the study proved to be an innovative alternative for treatment. [3]

The treatment of CNS (central nervous system) cancer began around 1930 with the use of iridium-192 and gold-198 in neoplasms involving brain

tumors and pituitary lesions. Over time, other isotopes began to be used: iodine-125, cesium-131, and phosphorus-32. [4]

There are several types of treatment combinations for CNS cancer, the size of the tumor and the complexity of the site for tumor resection being decisive for this purpose. phosphorus-32 flexible plaques are used in brachytherapy as a post-operative support in the treatment of this type of cancer. The plaques are safe and viable, offer immediate treatment, direct application to the tumor, minimize spinal cord and brain damage. [4]

2. Objectives

In Brachytherapy, radioactive source is positioned close to the tumor. The most important advantage is that the target region receives most of the dose, protecting the healthy tissues adjacent to the tumor region. In order to use these sources, a high dosimetric uniformity must be achieved, so a homogeneous dose delivery can be delivered to the target. In the present work, the consistency of the epoxy resin plate was evaluated using a methodology developed in the laboratory for the production of radiotherapy sources at IPEN / CNEN - SP.

3. Methodology

3.1 Teflon mold

Polytetrafluoroethylene (PTFE), popularly known as Teflon, has excellent chemical resistance, a wide working temperature range (-260ºC to 260ºC) and a small friction coefficient, which allows it to be an inert material. [5]

From teflon plaque wtih 5 mm of thick was machined a mold with dimensions 5.00 x 5.00 cm ± 0.05 with 0.5000 mm ± 0.0005.

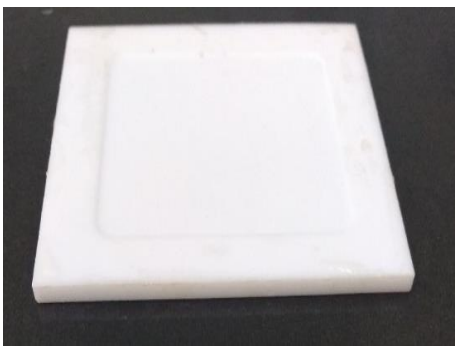

Figure 1 –Teflon mold

3.2 Epoxy plaque fabrication

The epoxy plaques are manufactured from a mixture of SQ2220 resin, with a density of 1.11 ± 0.02 g/cm^3 at 25ºC, and SQ3154 catalyst, with a density of 1.010 ± 0.005 g/cm^3, both from Silaex, the proportion being mixing is 2:1 (mass) respectively.

For the tests in this work, the proportion of 2:1 in mass of resin and catalyst was always used, respectively. To simulate the radioactive material, HCl was added with concentration of 2%, a concentration that was also fixed for this work. HCl is the phosphorus-32 vehicle solution that is provided by the Radiopharmacy Center (RF) of IPEN. The amount of HCl was 5% of the total mass value of the resin-catalyst mixture.

First, the mass of catalyst and HCl was measured in separate vials. Afterwards, these two products were manually mixed with a baguette for a time of 1 minute. Then the resin was added. 24 for performing resin curing. The surface on which the test took place was level with a level, and so it was throughout the work.

The mold received 4 g of the mixture: resin, catalyst and HCl. The amount of HCl was 10% on the total mass of resin and catalyst. Excess resin in the mold was removed by scraping it with the flat Teflon plaque.

3.3 Monte Carlo Method Simulation of Dose Distribution of Epoxy Plate phosphorus-32

In this simulation, only the electrons were transported, with a total of 10^8 particles followed, and the dose was calculated using tally F4, as this estimates the average trace of the particle in the medium, together with the information on stopping power of the electron in the water.

4. Results

4.1 Source manufacture

The table 1 show the results of thickness of epoxy plaque obtained from Teflon molds. Figure 1 show the manufactured molds.

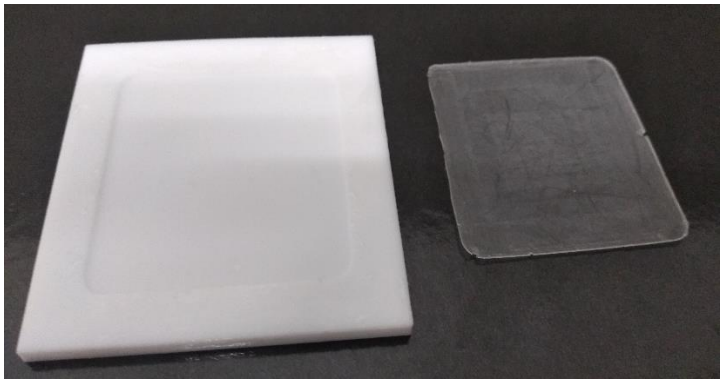

Figure 1: Manufactured molds for phosphorus-32 source fabrication.

Table 1: Teflon mold and epoxy plaque thickness results.

Samples	A	B	C	D	E
thickness (mm) ± 0.0005	0.296	0.371	0.504	0.400	0.367
	0.316	0.317	0.465	0.454	0.360
	0.324	0.285	0.405	0.373	0.363
	0.267	0.328	0.494	0.436	0.344
	0.310	0.373	0.454	0.484	0.348
	0.338	0.394	0.408	0.517	0.350
	0.359	0.355	0.475	0.517	0.351
	0.336	0.292	0.452	0.540	0.344
	0.321	0.292	0.397	0.557	0.325
	0.306	0.286	0.394	0.538	0.315
	0.270	0.345	0.433	0.585	0.299
	0.278	0.374	0.452	0.550	0.320
	0.280	0.410	0.458	0.451	0.366
	0.260	0.398	0.446	0.514	0.350
	0.260	0.362	0.461	0.537	0.353
Average	0.301	0.345	0.447	0.497	0.344
standard deviation	0.031	0.043	0.034	0.062	0.020

The thickness of the plaques was measured reaching an average value of 0.300 mm ± 0.070. The measurements were made with a micrometer, measuring 10 points of each plaque.

4.2 Monte Carlo Method Simulation

The maximum dose variation along the plaque, considering a totally uniform thickness of 0.300 mm, resulted in <0.5% up to 0.5 cm before the edge. The result of the simulation shows that with a uniformly thick plaque, the dose distribution trend is homogeneous.

The mean value of simulated dose distribution by mcnp was 4.8 x 10^{-2} MeV/g.decay ±0.3%. In the experimental part, the activity of phosphorus-32 on the plaque will have a value of approximately 300 mCi or 1.11 x 10^{10} Bq.

The dose rate was 8,5 ± 0,3% cGy s^{-1} estimated by mcnp.

Table 2: Values of dose obtained from Monte Carlo Method Simulation.

Dose (MeV/g.decay)					
1.20E-02	2.38E-02	2.39E-02	2.39E-02	2.39E-02	1.19E-02
2.39E-02	4.80E-02	4.80E-02	4.80E-02	4.80E-02	2.39E-02
2.39E-02	4.81E-02	4.80E-02	4.81E-02	4.80E-02	2.40E-02
2.40E-02	4.80E-02	4.81E-02	4.80E-02	4.80E-02	2.39E-02
2.39E-02	4.80E-02	4.78E-02	4.80E-02	4.80E-02	2.39E-02
1.19E-02	2.39E-02	2.39E-02	2.39E-02	2.39E-02	1.19E-02

Based on the results, the epoxy polymer plaques are shown to be viable for use in brachytherapy, and the next step of the work will be the tests with radioactive material.

5. Conclusions

Analyzing table 1, which deals with open teflon mold with epoxy plaqes cured with exposure to the environment and with removal of excess resin, we were able to notice good agreement between samples A, B and E, with respective values of average thickness (mm): 0.301, 0.345 and 0.344. There are also interesting values for samples C and D with respective mean thickness values (mm): 0.447 and 0.497.

The simulation by Monte Carlo Method to verify the dose distribution along the plaque was quite satisfactory. The simulation works with a plaque of totally uniform thickness and can be used for comparison with the practical part. The mean value up to 0.5 cm before the edge was 8.5 ± 0.3% cGy.s-1. The edges were left with a value below the average. The reason is that the phosphorus-32 epoxy plate was centered at the origin with a dimension of 5 x 5 cm. As the values

were processed every 1 cm, the edges were smaller, that is, 0.5 cm, thus returning a lower dose value. However, this can be better evaluated using more adequate parameters so that the dose values in the region of the edges of the plate have a clearer understanding.

The work is now ready to proceed to radioactive tests.

References

[1] PODGORSAK, E.B. ***Radiation Oncology Physics: A Handbook For Teachers And Students.*** International Atomic Energy Agency: Viena, 2005.

[2] SOUZA, C. D. ***Parâmetros para produção de fontes de iodo-125 utilizadas em Braquiterapia.*** 2016. 75 p. Tese (Doutorado) – Instituto de Pesquisas Energéticas e Nucleares, São Paulo.

[3] MARR, B. P.; ABRAMSON D. H.; COHEN, G. N.; WILLIAMSON, M. J.; McCORMICK, B.; BARKER, C. A. ***Intraoperative High-Dose Rate of Radioactive Phosphorus 32 Brachytherapy for Diffuse Recalcitrant Conjunctival Neoplasms.*** *Ophthalmic Oncology Service, Memorial Sloan Kettering Cancer Center, NewYork, 2014.*

[4] DALLE ORE, C. L.; AMES, C. P.; MAGILL, S. T.; DEVIREN, V.; AGHI, M. K.; LAU, D.; ***Initial experience with intraoperative phosphorous-32 brachytherapy during resection of malignant spinal tumors,*** *Department of Neurological Surgery, University of California, San Francisco, San Francisco, California, USA, 2018.*

[5] BENTO, R. E. ***Estudo do Comportamento da Resina Base na Formulação de Compósitos de Politetrafluoretileno com Bronze.*** Dissertação Mestrado em Engenharia Química. Universidade de Campinas, Campinas, 2011.

XIX Brazil MRS Meeting

August 30th to September 03rd IUMRS ICEM 2021

VIRTUAL

20 years SBPMat Brazil-MRS

Brazilian Materials Research Society

Excellence in Materials Science and Technology

Certificate

We hereby certify that the work

Homogeneity evaluation of phosphorus-32 epoxy plaques to be used in the treatment of spinal and intracranial cancer by brachytherapy,

submitted by

José Tiago da Silva, Carla Daruich de Souza, Beatriz Ribeiro Nogueira, Lucas Verdi Angelocci, Carlos Alberto Zeituni and Maria Elisa Chuery Martins Rostelato

was presented in **Poster** form by **José Tiago da Silva** at the XIX Brazilian MRS Meeting, held in online format, from August 30th to September 03rd, 2021.

Gustavo M. Dalpian
Conference Chair

Mônica Alonso Cotta
Brazil MRS President