

CHARACTERIZATION OF THE ELECTRON BEAM RADIATION FIELD BY CHEMICAL DOSIMETRY*

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The aim of the work was to evaluate the distribution of the absorbed dose and the configuration of the isodose curves in parallel plans, perpendicular on the direction of the electron beam. There are distinct zones of uniformity in each plan so that a surface having uniformity over 70% is about three times higher than a surface with the uniformity over 90%.

Key words: Fricke, isodose, dose distribution.

1. INTRODUCTION

The last decades consecrated the electron accelerators in the development of nonconventional techniques used in various domains: industry, medicine, ecological applications to produce new materials, environmental depollution, processing of foodstuffs, sterilization of medical products and so on [1].

The determinant parameter of the development of the irradiation technology is the absorbed dose and its distribution in material in the radiation field. Consequently, it is important to know the spatial configuration of the radiation field so that the material positioning in the beam to be appropriate.

The absorbed dose by a dosimetric material situated in the radiation field characterizes very well the field and allows the fast valuation of the dose absorbed by any material that has close density to the chosen dosimeter. The absorbed dose is the amount of energy absorbed per unit mass of irradiated material and produces one of more effects: heating, atom and molecule excitation, ionization, free radicals, molecule splitting, etc., depending on dose value. The distribution of the dose absorbed from radiation field allows the determination of zones of minimum (D_{min}) and maximum (D_{max}) absorbed dose of the studied field as well as the dose uniformity ratio, $U = D_{max}/D_{min}$ [2, 3].

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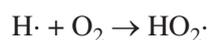
The characterization of radiation processing is performed using dosimetric methods that determine the dose absorbed by irradiated material, the dose distribution on surface or in volume of the material, or control the routine radiation process [4].

The literature reports few studies regarding the determination of the radiation field configuration. However, these works are dedicated mainly to the radiation installations with isotopic sources [2, 3], which have rather spherical symmetry. In contrast to them, the electron beam fields are strongly collimated and have axial symmetry.

The aim of this work was to evaluate the distribution of the absorbed dose as well as the configuration of isodose curves in parallel plans, which are perpendicular on the direction of the accelerated electron beam at three heights in the irradiation field, using Fricke chemical dosimeter.

GENERAL CONSIDERATIONS

Ferrous-ferric dosimeter system known generally as Fricke dosimeter is one of the most used chemical dosimeter being considered a standard one [4, 5]. Its advantage is the considerable chemical stability and the error below 2%. The dosimeter is based on the radiolytic oxidation of the ferrous ion (Fe^{2+}) to the ferric one (Fe^{3+}) in aerated acidic solution, the absorbed dose being calculated by spectrophotometric measuring of ferric ion concentration after irradiation. Briefly, the oxidation of the ferrous ions to ferric ones can be illustrated by the following scheme [5, 6]:



The Fricke dosimeter gives an appropriate response for the absorbed dose range from 20 to 400 Gy [7].

2. EXPERIMENTAL

The Fricke solution ($\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2$ 0,001 M, NaCl 0,001 M and H_2SO_4 0,4 M) was prepared with double distilled water according the standard in force [7].

Glass cells having outer diameter of 20 mm, glass thick of 1 mm and height of 26 mm were used in the experimental measurements. The height of the liquid

in cell is determined by the electron mean energy and represents about two thirds from electron path, assuring the maximum variation of 30% of the dose in the dosimetric solution depth. The cells with dosimetric solution were placed in a proper stand with a plan uniform distribution and subjected to irradiation for a while in order to achieve the required dose level.

The irradiations were carried out in a linear accelerator facility of 6 MeV mean energy, at room temperature and ambient pressure, in vertical beam obtained by magnetic deflection. The tests were performed successively in three parallel plans situated in the same vertical direction, at distances of 30, 40 and 50 cm from exit window of the accelerator, on surface of 32 cm × 16 cm.

After irradiation, the wavelength of the irradiated solution peak (302–305 nm) was determined spectrophotometrically followed by the measurement of the irradiated sample absorbance in comparison to the unirradiated sample.

The calculation of the absorbed dose [7] in the dosimeter solution was performed using the equation (1) as follows:

$$D = \frac{\Delta A}{\varepsilon \cdot G \cdot \rho \cdot d} \text{ [Gy]} \quad (1)$$

where: ΔA – net absorbance at the optimum wavelength (302 to 305 nm),

ρ – density of the dosimetric solution ($1.024 \times 10^3 \text{ kg}\cdot\text{m}^{-3}$),

ε – molar linear absorption coefficient of the ferric ions (Fe^{3+}) ($219 \text{ m}^2\cdot\text{mol}^{-1}$ at 25°C),

G – radiation chemical yield of ferric ions (Fe^{3+}) ($1.61 \times 10^{-6} \text{ mol}\cdot\text{J}^{-1}$),

d – optical pathlength of the dosimetric solution in the cuvette (m).

The reported data are the mean of five different measurements with standard deviation below 5%.

3. RESULTS AND DISCUSSION

Fig. 1 shows the dose distribution in the plan from 50 cm, perpendicular to the beam direction. It was observed the ellipsoidal shape of the irradiation field that appears due to the both spreading system built mainly from thin foils, and deflection magnetic field.

It was noticed the fast variation of the dose with the transversal distance, with low values of the dose at irradiation field periphery. This representation shows Gaussian distribution of the dose and confirms the energetic spectrum of the electron beam contains a reduced percent of low energy electrons that could affect the distribution dose.

The ensemble of the dose measurements performed in three plans at different distances from the exit window of the accelerator, perpendicular to the

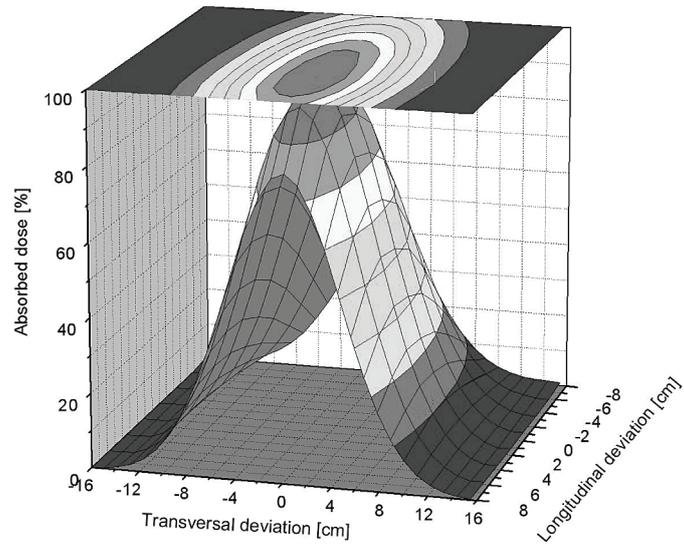


Fig. 1 – Absorbed dose representation for 50 cm plan.

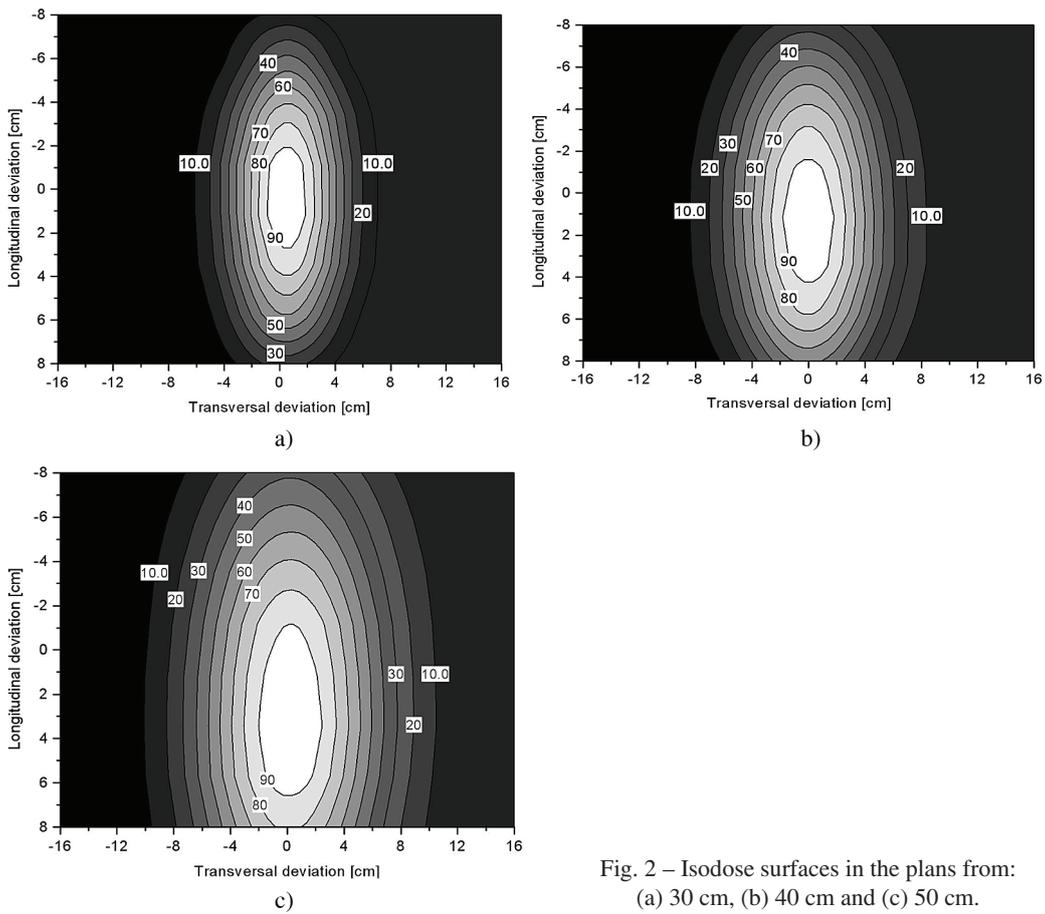


Fig. 2 – Isodose surfaces in the plans from: (a) 30 cm, (b) 40 cm and (c) 50 cm.

beam direction, is presented graphically in Fig. 2, which shows the isodose curves for the whole irradiated surface.

Analyzing these curves, the same configuration of the irradiation field was noticed for all representations. The dose-decreasing gradient in every plan reduced as the increase of the distance from the exit window. This evolution gives in variation law with square distance respecting a good approximation, the spreading of the field being a consequence of both the natural divergence and mainly beam scattering on the aluminum foils from the accelerator exit window.

Also, at the distance of 50 cm from accelerator exist window (Fig. 2c), it was observed a zone 5 cm in width on the transversal direction where the dose uniformity is 90%, while uniformity of 80% and 70% is available in a zone having width of 7 cm and 9 cm, respectively. Thus, it was obtained a surface of 40 cm² where the dose uniformity is over 90%, while a surface of 126 cm² assured uniformity over 70%.

4. CONCLUSIONS

It was proved the possibility of the determination of the isodose surface distribution at an electron accelerator facility using the chemical dosimetry. The cell sizes for dosimetry procedure have been proper and allowed the clear representation of the irradiation field configuration.

There are distinct zones of uniformity in each plan so that a surface having uniformity over 70% is about three times higher than a surface having uniformity over 90%.

The processing of the obtained experimental data would allow also the valuation of the sample sizes both for horizontal and vertical plan, so that the dose deviation at surface would be integrated to required limits.

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