ON A POSSIBILITY OF NONDISTURBING MONITORING OF ELECTRON-RADIATION ABSORBED DOSE IN RADIATION-TECHNOLOGICAL PROCESSES

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Great deals of present-day radiation technologies that use electron accelerators involve the procedure of transporting the products under treatment across the irradiation zone normally to the beam scanning plane. The main controlled characteristic of the process is the electron radiation dose absorbed in the object under treatment. The present paper offers the method of nonperturbing real-time dose and electron energy monitoring. The method is based on the analysis of distribution of currents from the plates of a sectionalized beam charge absorber. The absorber is placed behind the conveyor and is periodically shut off from the beam by the object under irradiation. The method was preliminarily analyzed through computer simulation.

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1. INTRODUCTION

One of the methods for measuring the accelerated electron energy is based on determination of extrapolated electron range in a standard material, e.g., aluminum [1]. This method may, in principle, be used for continuous monitoring of electron energy in technological processes. In some cases (e.g., at radiation sterilization) this monitoring is also a requirement of regulatory documents [2]. The realization of the method may be exemplified by the use of a sectionalized beam absorber (SBA) at the accelerator LU-10-based technological installation [3] of the NSC KIPT R&D Prod. Est. "Accelerator", the SBA being placed behind the object under treatment. The SBA may be considered as a free-air Faraday cup for the beam part that has passed through the object. The measurement of absorbed-charge current distribution in the SBA provides a monitoring over the maintenance of assigned irradiation conditions for the products.

The present paper demonstrates a possibility to monitor not only the electron energy, but also the absorbed beam energy (dose) in the products under treatment through optimizing both the SBA structure and the procedure of measuring the current from the SBA plates. The analysis has been performed by the computer simulation method with the use of the PENELOPE/2001 program system.

2. RADIATION TREATMENT CONDITIONS

LU-10 is a one-section linear accelerator with a horizontal electron guide and a beam scanning system (see Fig. 1). The installation is provided with a conveyor for transfer of products from the loading hall via a labyrinth to the irradiation zone and back.

The products packed in carton boxes are placed into the irradiation container (suspension). The maximum size of the product loading pattern is determined by the suspension dimensions and measures 40 cm high by 38 cm deep by 108 cm long.

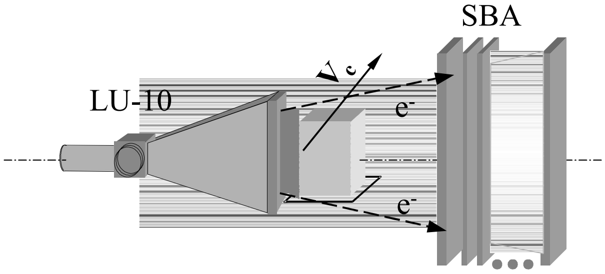

Fig. 1. Output devices of LU-10 installation

Downstream from the zone of products container transfer (symmetrically with respect to the radiation field) the SBA is located. It presents a set of 10 aluminum plates measuring 75 cm wide by 122 cm high, and having thicknesses of 5 mm (the 1st and 10th plates) and 2 mm (the remaining plates). The plates are fixed on insulators with a clearance space of 2 cm.

The PC-controlled beam scanning system provides a uniform distribution of beam density in the vertical within the near plane of the object under irradiation (in order to provide a uniform distribution of the absorbed dose). As a result, a part of accelerated electrons at the scanning zone boundaries comes directly to the SBA, by-passing the object.

The suspensions move across the irradiation zone at a velocity $\mathbf{V_c}$ 0.1…4.0 cm/s, depending on the absorbed dose value required. At an object surface density $\boldsymbol{\rho}_{\mathbf{surf}}<3$ g/cm^2, the treatment is generally carried out only on one side, and on two sides if $\boldsymbol{\rho}_{\mathbf{surf}} > 3$ g/cm^2.

3. SIMULATION RESULTS

3.1. Figure 2 shows the beam particle distribution on the surface of the SBA monitor as the object (40×38×100 cm, $\boldsymbol{\rho}_{\mathbf{surf}}=5.7$ g/cm^2) is passing through the irradiation zone (electron energy is 9.8 MeV, the beam scanning length at the exit window of the accelerator is ± 10 cm).

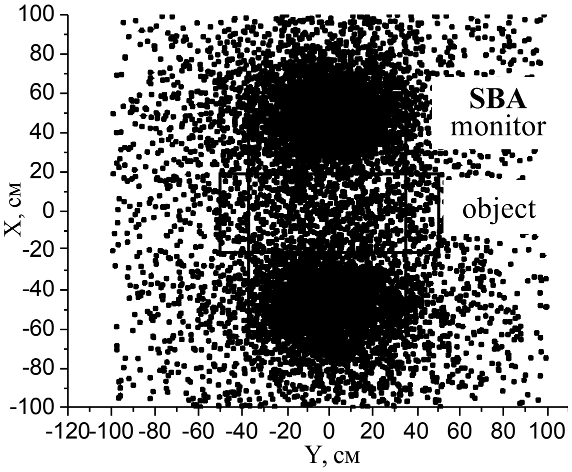

Fig. 2. Particle distribution on the SBA surface in the presence of the object

It is obvious that owing to scattering in air, a part of the beam bypasses both the object and the monitor. In fact, Fig.3 shows the depth distribution of the absorbed charge in the SBA, normalized to the beam charge, as a function of ρ_{surf} of the object. It can be seen from the figure that if $\rho_{surf} = 0$ (no object), then the coefficient of charge collection by the monitor makes 83.9%.

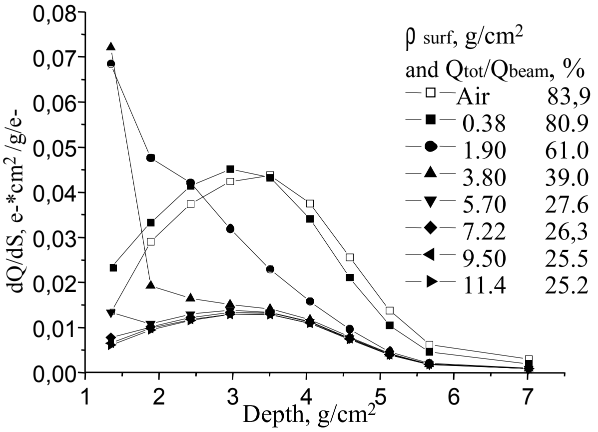

Fig. 3. Depth distribution of the absorbed charge in the monitor at different surface densities of the object under irradiation. 10 cm scanning

3.2. Figure 4 shows the charge absorbed in the monitor (normalized to the beam charge) as a function of the absorbed energy in the object at different surface densities of the object, ρ_{surf}. It can be seen that in the real range $0 < \rho_{surf} \leq 5.7$ g/cm^2 the function is linear (at a constant scanning amplitude).

By measuring the integral current of the monitor and the conveyor velocity it appears possible to control the maintenance of the assigned average value of the absorbed dose in the products during their treatment.

3.3. With a variation in the electron energy, there occurs a displacement in the absorbed charge distribution in the SBA plates. Thus, figure 5 shows the ratio of the total charge in several plates to the total deposited charge in the SBA versus the electron energy. In the case, where the plates 1 to 6 are connected, the net relative charge in them varies with the electron energy by the law close to linear.

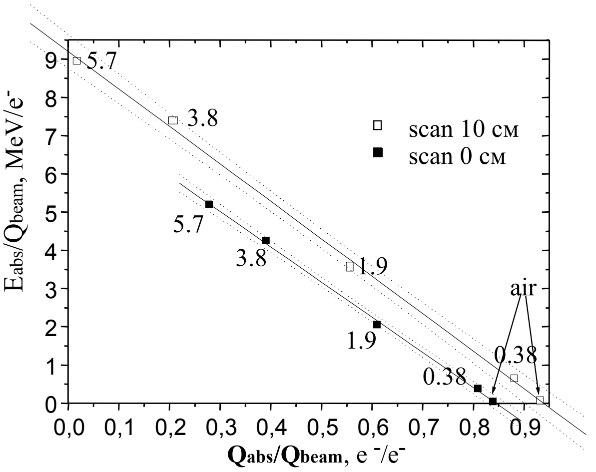

Fig. 4. Energy absorbed in the object versus normalized deposited charge in the monitor (figures show **ρ** *surf, g/cm²)*

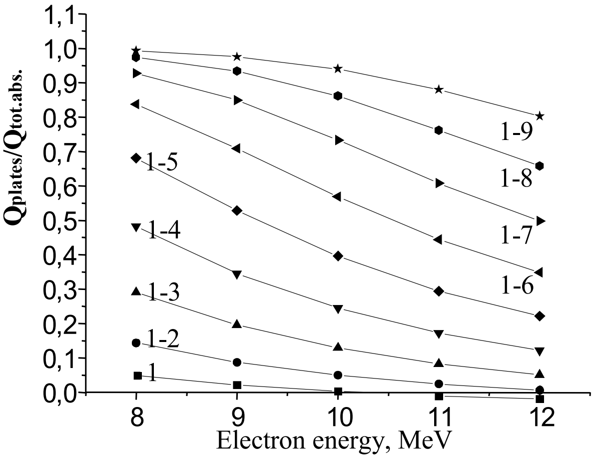

Fig. 5. Normalized deposited charge in the groups of connected plates of the SBA versus beam energy. The plates are connected, starting from the first plate. 10 cm scanning (figures – the range of connected plate)

From the data presented in Fig.6 it also follows that this function is independent of the beam scanning amplitude in its practical range from 0 to 10 cm.

4. CONCLUSION

The computer simulation results for the interaction between the electron beam being scanned and the object under treatment as well as the sectionalized beam absorber, following the object, have demonstrated that such a probe can be used for real-time nonperturbing monitoring of both the accelerated electron energy and the absorbed energy (dose) in the object under treatment. It will be sufficient in this case to make an absorber even of no more than 2 plates, each being 1.5 cm thick (in the aluminum case). The ratio of plate currents makes it possible to determine the electron energy values, and the ratio of the net current from the plates to the beam current – to determine the absorbed radiation energy in the object.

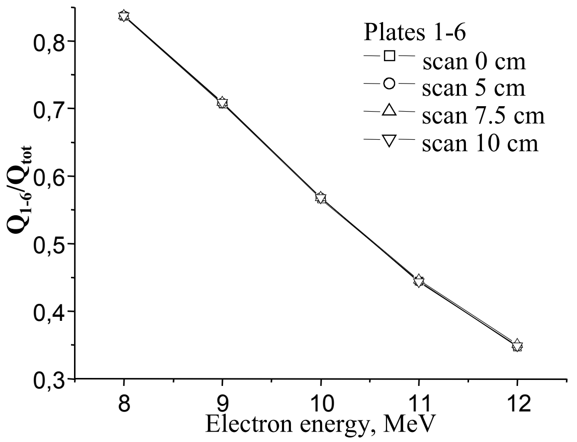

Fig. 6. Relative charge of the first six plates of the monitor versus beam energy at different scanning value

REFERENCES

1. The Sub-Committee on Radiation Dosimetry of the American Association of Physicists in Medicine. "Protocol for the Dosimetry of high-energy electrons" // *Phys. Med. Biol.* 1966, v.11, p.505
2. Standard ANSI/AAMI/ISO 11137-1994. *Sterilization of Health Care Products – Requirements for Validation and Routine Control – Radiation Sterilization.*
3. K.I. Antipov, M.I. Ayzatsky, Yu.I. Akchurin et al. Electron Linacs in NSC KIPT:R&D and Application // *Problems of Atomic Science and Technology. Ser. "Nuclear Physics Investigation".* 2001, №1(37), p.40-47.

О ВОЗМОЖНОСТИ НЕВОЗМУЩАЮЩЕГО МОНИТОРИРОВАНИЯ ПОГЛОЩЕННОЙ ДОЗЫ ЭЛЕКТРОННОГО ИЗЛУЧЕНИЯ В РАДИАЦИОННО - ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССАХ

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Значительная часть современных радиационных технологий с использованием ускорителей электронов включает процедуру перемещения продукции через зону облучения нормально плоскости сканирования пучка. Основной контролируемой характеристикой такого процесса является поглощенная в обрабатываемом объекте доза электронного излучения. В сообщении предложен метод невозмущающего мониторирования поглощенной дозы, а также энергии электронного излучения в режиме реального времени. Метод основан на анализе распределения токов с пластин секционированного поглотителя заряда пучка. Поглотитель размещен за конвейером и периодически перекрывается от пучка облучаемым объектом. Предварительный анализ метода выполнен при помощи компьютерного моделирования.

ПРО МОЖЛИВІСТЬ НЕЗБУРЮЮЧОГО МОНІТОРУВАННЯ ПОГЛИНЕНОЇ ДОЗИ ЕЛЕКТРОННОГО ВИПРОМІНЕННЯ В РАДІАЦІЙНО - ТЕХНОЛОГІЧНИХ ПРОЦЕСАХ

С.П. Карасьов, В.І.Никифоров, Р.І. Помацалюк, А.Е. Тенішев, В.Л. Уваров, В.А. Шевченко, І.М. Шляхов, Є.Б. Малець

Значна частина сучасних радіаційних технологій з використанням прискорювачів електронів включає процедуру переміщення продукції через зону опромінення нормально площині сканування пучку. Основною контрольованою характеристикою такого процесу є поглинена в оброблюваному об'єкті доза електронного випромінювання. У повідомленні запропонований метод незбурюючого моніторування поглиненої дози та енергії електронного випромінювання в режимі реального часу. Метод заснований на аналізі розподілу струмів із пластин секційованого поглинача заряду пучка. Поглинач розміщений за конвеєром і періодично перекривається від пучка об'єктом, що опромінюється. Попередній аналіз методу виконаний за допомогою комп'ютерного моделювання.