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DOSE FIELD FORMATION IN THIN FILMS IRRADIATED BY ELECTRON BEAMS: COMPARISON OF THE MONTE CARLO SIMULATION WITH DOSIMETRY

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The simulation of the absorbed dose distribution into thin films with different thickness inserted between flat boundaries of two homogeneous materials as well as the absorbed dose distribution near to boundaries of these materials irradiated with a scanned electron beam were fulfilled. Films inserted in multi-layer targets were parallel orientated with an incident electron beam (EB). The simulation was performed by the Monte Carlo (MC) method with utilization of the software ModePEB which was designed for predictions of a dose distribution in heterogeneous targets irradiated by EB with the electron energy range from 0.1 to 25 MeV. Comparison results of MC simulation with dosimetry for electron dose distribution formation in multi-layer targets with thin films is discussed.
KEY WORDS: dose distribution, thin films, electron beam, software ModePEB.

ФОРМИРОВАНИЕ ПОЛЯ ДОЗЫ В ТОНКИХ ПЛЕНКАХ ОБЛУЧАЕМЫХ ПУЧКОМ ЭЛЕКТРОНОВ: СРАВНЕНИЕ РЕЗУЛЬТАТОВ МОНТЕ КАРЛО МОДЕЛИРОВАНИЯ С ДОЗИМЕТРИЕЙ

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Проведено моделирование распределения поглощенной дозы в тонких пленках разной толщины, расположенных между плоскими границами двух гомогенных материалов, а также распределения поглощенной дозы вблизи границы этих материалов, облучаемых сканирующим пучком электронов. Пленки в многослойных мишенях были ориентированы параллельно падающему пучку электронов. Моделирование проводилось методом Монте Карло с использованием программы ModePEB, разработанной для предсказаний распределения дозы в гетерогенных мишенях, облучаемых пучком электронов с энергией от 0.1 до 25 МэВ. Обсуждается сравнение результатов Монте Карло моделирования с дозиметрией для формирования распределения дозы электронов в многослойных мишенях с тонкими пленками.
КЛЮЧЕВЫЕ СЛОВА: распределение дозы, тонкие пленки, пучок электронов, программа ModePEB.

ФОРМУВАННЯ ПОЛЯ ДОЗИ У ТОНКИХ ПЛІВКАХ ОПРОМІНЮЄМИХ ПУЧКОМ ЕЛЕКТРОНІВ: ПОРІВНЯННЯ РЕЗУЛЬТАТІВ МОНТЕ КАРЛО МОДЕЛЮВАННЯ ІЗ ДОЗИМЕТРІЄЮ

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Проведено моделювання розподілу поглиненої дози в тонких плівках різної товщини, розташованих між плоскими границями двох гомогенних матеріалів, а також розподіл поглиненої дози біля границі цих матеріалів, що опромінюються сканованим пучком електронів. Плівки у багатошарових мішенях були орієнтовані паралельно падаючому пучку електронів. Моделювання проводилось методом Монте Карло із використанням програми ModePEB, яку розроблено для передбачення розподілу дози в гетерогенних мішенях, що опромінюються пучком електронів з енергією від 0.1 до 25 МеВ. Обговорюються порівняння результатів Монте Карло моделювання із дозиметрією для формування розподілу дози електронів у багатошарових мішенях із тонкими плівками.
КЛЮЧОВІ СЛОВА: розподіл дози, тонкі плівки, пучок електронів, програма ModePEB.

Process control of absorbed dose for EB irradiated materials is vitally important for quality assurance of radiation processing. The value of an absorbed dose of electrons necessary for the realization of EB processing and the required level of dose uniformity ratio (DUR = D_{max}/D_{min}) in volume of the irradiated product determine the efficiency and productivity of a technological process. In various EB technologies, DUR essentially depends on the boundary anomalies in an absorbed dose distributions of electrons, which appear under irradiation of heterogeneous targets. In practice, such boundary anomalies appear under irradiation by EB of contacting materials (e.g. solid/liquid) with different densities and/or atomic numbers, near the interface of materials with package, dosimeter body and air, etc.

In our previous investigations, the anomalies in absorbed dose distributions in heterogeneous targets irradiated with EB were predicted by computer simulation [1, 2]. The transport and interaction of primary and secondary electrons with target material was simulated by the MC method. The experimental verification of the obtained theoretical predictions for absorbed dose distributions of 10 MeV electrons measured by different types of dosimetric films has been performed on an industrial radiation facility. It was established that the boundary anomalies in an absorbed dose are realized in practice in radiation processing of materials and influence on the quality of radiation technologies.

The objective of this study was the comparison of simulation prediction and experimental investigation of EB dose distribution formation in thin films with different thickness inserted between flat boundaries of contacting homogeneous materials and irradiated parallel with the incident EB.

EB FACILITY AND SIMULATION MODEL

Schematic representation of the electron beam facility used for simulation of the electron depth dose distribution (DDD) in the multi-layer target with dosimetric film inserted parallel with an incident EB in the irradiated material is shown in Fig. 1.

Simulation of EB dose distributions in an irradiated heterogeneous target was accomplished by the Monte Carlo method in a two-dimensional (2-D) geometrical model with the program ModePEB [3]. In accordance with the schematic representation of electron beam facility and heterogeneous target presented in Fig. 1, a source of EB, a scanner, a conveyor line, an irradiated target are considered as uniform self-consistent geometrical and physical models. It is meant that determination of geometrical and physical factors which influence on formation of absorbed dose and dose uniformity in irradiated targets are necessary to perform with the same accuracy.

The following processes of interaction of electrons with substance and their modeling conceptions were included in the physical model: electrons lost energy by two basic processes an inelastic collision with atomic electrons and bremsstrahlung; inelastic electron collision with atomic electrons lead to excitation and ionization of the atoms along the path of the particles (model of grouping of the transferred energy); emission of the secondary electrons (model of the threshold energy); electrons participated in elastic collisions with atomic nuclear lead to changes in the electron direction (model of grouping of transferred pulse).

In the default mode of the software ModePEB, the values of energy cut off and threshold energy of electrons are selected in automatic regimes to provide the necessary space distribution for absorbed dose of electrons in thin film.

All physical processes which assure obtaining of results with predetermined accuracy are taken into account at simulation of an absorbed dose distribution of electrons. For example, for EB radiation processing in the energy range of incident electrons from 100keV to 10 MeV and irradiated materials with atomic number $Z \leq 30$, the model uncertainty is less than 5% for calculated dose distribution in the field of the basic EB energy absorption.

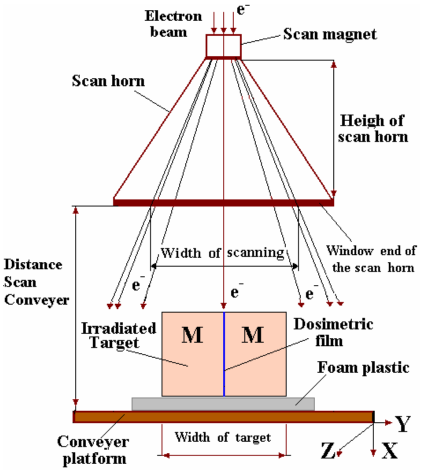


Fig.1. Electron beam and irradiated target geometry.

Arrangement of a multi-layer target with dosimetric film inserted parallel with EB within materials on moving conveyor irradiated with EB and triangular scanning. Axis X - direction of EB incidence, axis Y - direction of EB scanning, axis Z - direction of conveyer motion.

The 2-D dose distribution in an irradiated target is represented as a function of two coordinates: the target depth (axis X) and the target width along the scan direction (axis Y). The conveyer moves along the axis Z. Such conditions are realized in some cases of EB processing when the target is irradiated one- and double-sided on the moving conveyer. The heterogeneous target on a conveyer platform was represented as a set of parallelepipeds unlimited on length along the motion of the conveyer (axis Z). It is supposed that the parallelepiped sides are oriented only parallel with each other, and the material of each element of the target (represented as separate parallelepiped) is homogeneous. Dose fields in the plane of scanning of an electron beam (plane XY) were calculated. Depth dose distributions (depth is measured from the incident surface of target along the axis X perpendicular to the axis Y) were compared at various distances from the boundary of materials with different densities and/or atomic numbers.

Dosimetric film was modeled as a thin sheet unlimited on length along the conveyer motion (axis Z) inserted parallel to the axis of EB between the contacting homogeneous materials in the plane XZ. The requirements for computer modeling were chosen so that in the selected range of absorbed doses the relative root-mean-square statistical error was less than 1%.

EXPERIMENTAL

Irradiation of the heterogeneous target with thin films was performed on the linear electron accelerator Elektronika

10/10 at INCT, Warsaw with electron beam energy of 10 MeV [4]. Three wooden phantoms with two wooden blocks and thin films with different thickness were used in this study. An experimental setup for a heterogeneous target with dosimetric film on a conveyer platform is agreed with simulation model (see Fig.1). Thin films of different thickness were modeled by a sandwich from the stripes of polyvinylchloride (PVC) dosimetric films (thickness 0.026 cm, width 1.6 cm, length 14 cm, and density 1.3 g/cm^3). Three films with different thickness 0.026 cm (one layer), 0.104 cm (four layers), and 0.26 cm (ten layers) were inserted and tightly pressed together between the two wooden blocks (size 14x14x5 cm and density 0.44 g/cm^3). Wood composition includes 6% hydrogen, 49% carbon, 44% oxygen and 1% nitrogen. The films were inserted between the centers of contacting wooden blocks close to the boundaries of the blocks in plane of block (14x14 cm) parallel with the axis of electron beam. The wooden phantoms with dosimetric films were placed on a foam plate (thickness of 4 cm) in the center of a standard aluminum box (580x460x200 mm) and a wall thickness of 1 mm. The aluminum box with the wooden phantoms and dosimetric films was placed into the central line of the conveyer platform.

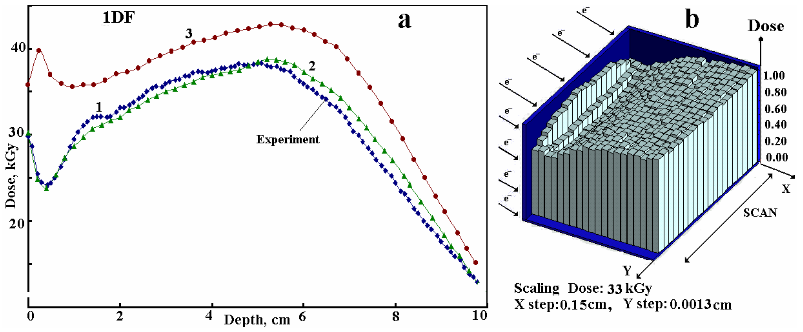
The heterogeneous materials were irradiated with a scanned electron beam of energy 10 MeV, pulse duration 5.6 μs, energy spectrum ±7% (measured at a half width of the curve of electron energy distribution), pulse frequency 370 Hz, average beam current 1.04 mA, scan width 58 cm, conveyer speed was in the range 1-0.1 m/min, scan frequency 5 Hz, angular spread 3 degree. The absorbed dose of irradiated materials was delivered in the range of 15-70 kGy. The relative uncertainty of dose measurement by the PVC dosimetric film for values of doses greater than 10 kGy did not exceed 8% at one standard deviation. The relative uncertainty 8% is characterized by the reproducibility in the measurement of absorbed dose in the PVC dosimetric film located in the wooden phantom and irradiated with EB in a series of experiments. PVC dosimetric film was calibrated against alanine dosimeter which is traceable to National Physical Laboratory, UK. A SEMCO S/E$_c$ spectrophotometer in automatic regimes was used for reading optical density at a wavelength of 394 nm from PVC strip films with a step of 0.1 cm along the film length.

COMPUTER SIMULATION AND EXPERIMENTAL RESULTS

Results of MC simulation and experimental measurements of depth dose distributions (DDD) of 10 MeV electrons in one PVC dosimetric film at a thickness of 0.026 cm inserted between the interface of two wooden blocks in a multilayer target parallel orientated with the incident EB are shown in Figs. 2(a) and (b). Experimental results of depth dose distributions of electrons in PVC film are presented by curve 1, simulation results averaged over the film thickness 0.026 cm by curve 2. The bin size of the 2D-view of dose distributions is 1/50 of the film length (axis X). Results of MC simulation of dose distribution of electrons near the boundary of a wooden block with the PVC film are presented in Fig.2(a) by curve 3. For all film thickness, the simulation results of dose distributions near the boundary of wooden block with the PVC film were averaged over the boundary wooden layer (along axis Y) at a thickness of 0.5 cm.

The 3D-view of the depth dose distribution of electrons in PVC film inserted between two wooden blocks is presented in Fig. 2(b). The bin size of the 3D-view of dose distributions is 1/20 of the film thickness (axis Y) and 1/20 of the film length (axis X). As it is seen from Fig.2, the local minimum on the curve of DDDs of electrons near the entrance surface appears for the PVC film inserted between the two wooden blocks, as well as the local maximum appears on the curve of DDDs of electrons for the wooden block near the interface with the PVC film (curve 3).

The calculated DDD of electrons for wooden block near the interface with the PVC film (curve 3) essentially differ in value and form from the DDDs in the PVC film (curves 1, 2). Differences in value of the absorbed doses of electrons are determined by the difference of stopping power for the wooden and PVC materials. Various forms of the absorbed doses of electrons testify that the dose field formation by electrons into the PVC film and near the interface of contacting material (wood) are different because of non-equilibrium distribution of electrons near the interface of contacting materials.



Scaling Dose: 33 kGy
X step:0.15cm, Y step: 0.0013cm

Fig.2. DDD of 10 MeV electrons in a PVC film of thickness 0.026cm inserted between two wooden blocks:
(a) 2D-view of DDD of electrons in the PVC film of length 10cm (axis X):
1- Experimental results of DDD in PVC film,
2 - Simulation results of DDD averaged over film thickness 0.026 cm,
3 - Simulation results of DDD near the boundary of wooden block with the PVC film.
(b) 3D-view of the DDD in PVC film of thickness 0.026 cm (axis Y) and length 3 cm (axis X).

The analogous results were obtained for the simulation and measurement of the DDDs of 10 MeV electrons for a package of four and ten layers of PVC films inserted between the interfaces of two wooden blocks. The packages of four and ten layers of PVC films were modeled as homogeneous PVC materials at a thickness of 0,104 and 0.26 cm, respectively. Figs. 3(a) and (b) represent the results of MC simulation and measurements of the DDDs of electrons for the package of four layers of the PVC films (thickness 0.104 cm).

Simulation results of the dose distribution near the boundary of wooden block with the PVC film were averaged over the boundary wooden layer (along axis Y) at a thickness of 0.5 cm. The 3D-view of the DDD of electrons in the package of four layers of PVC films located between the two wooden blocks is shown in Fig. 3(b).

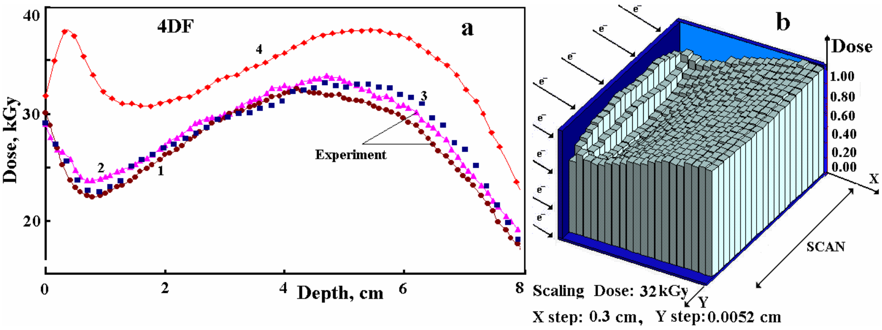


Fig.3. DDD deposited by 10 MeV electrons in a package of four layers of PVC film with thickness 0.104 cm:
(a) 2D-view of DDD in the PVC film of length 8cm (axis X):
1- Experimental results of DDD in the 1st and 4th layers of PVC films, which were contacted with wooden blocks.
2 - Experimental results of DDD in the 2nd and 3d layers of PVC films which were located in the central part of the package.
3 - Results of MC simulation of DDD for a package of four layers of PVC films averaged over a package thickness of 0.104 cm.
4 - Simulation results of DDD of electrons near the boundary of wooden block with a package of four layers of PVC films.
(b) 3D-view of DDD in the package of four layers of PVC films with thickness of 0.104cm (axis Y) and length 6 cm (axis X).

Analysis of results in Figs. 3(a) and (b) shows that the local minimum on the curve of DDDs of electrons in PVC film and the local maximum on the curve of DDDs of electrons for wooden block near the interface with PVC film are expanded and shifted to larger depths in comparison with the case of PVC film at a thickness of 0.026 cm.

Figs. 4(a) and (b) represent the results of simulation and measurement of the DDDs of 10 MeV electrons for the package of ten layers of PVC film (thickness 0.26 cm). Curves 1 and 2 are the experimental and simulation values of DDDs for the 5th (6th) layer, respectively. These film layers are located in the central part of the package of ten layers of PVC films along the axis X. Curves 3 and 4 are the experimental and simulation values of depth dose distributions in the 1st (10th) layer, respectively. These film layers contact with the wooden blocks. The curves of DDDs of 3rd, 4th and 7th, 8th film layer (not shown in Fig. 4(a)) are symmetrical in relation to the central part of the package and located between the curves of DDDs of film layer 1(2) and 3(4). We can see in detail the calculated structure of the EB absorbed dose extremes along the length and thickness for the packages of ten layers of PVC film.

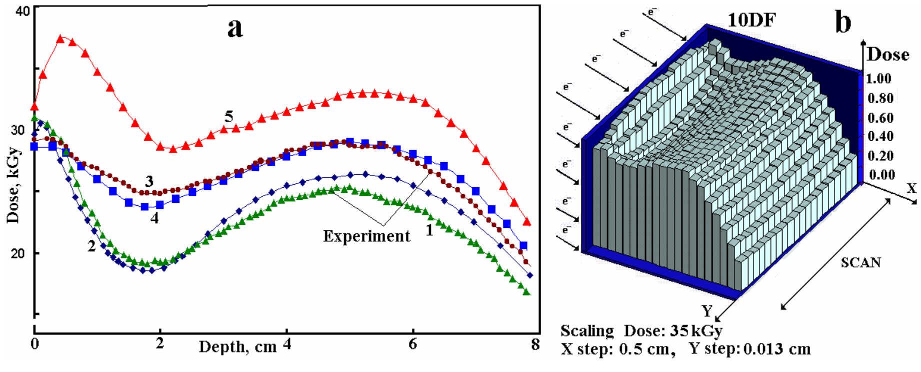


Fig. 4. DDD deposited by 10 MeV electrons in a package of ten layers of PVC film with thickness 0.26 cm:
(a) 2D-view of DDD in the PVC film of length 8 cm (axis X):
1 - Experimental results of DDD in the 5th and 6th layer which were located in the central part of the package of ten layers film.
2 - Results of MC simulation of DDD in the central part of the PVC film of thickness 0.26 cm.
3 - Experimental results of DDD in the 1st and 10th layer of PVC films which were located near the boundary with wooden blocks.
4 - Results of MC simulation of DDD in the PVC film with thickness 0.26 cm near the boundary of film with wooden block.
5- Simulation results of DDD in the wooden block near the boundary of block with the package of ten layers of PVC films.
(b) 3D-view of the DDD in a package of ten layers of PVC film of thickness 0.26cm (axis Y) and length 10cm (axisX).

The strong difference in the shape and values between the depth dose distributions of electrons in the film center and near the interfaces of the film with wooden blocks (first and last rows on the 3D-view along depth) are observed in Figs. 2(b), 3(b) and 4(b). With increasing film thickness the difference between the value of dose distribution of electrons in the film center and near the interfaces of film with the wooden blocks is increased. The absorbed dose of electrons near the interfaces of film with the wooden blocks is greater than the dose in the film center because of the greater absorption of electrons near the surface layers of film contacting with the wooden blocks.

Comparison of results in Fig. 2(a), Fig.3 (a) and Fig.4 (a) shows that in the selected range of target depths the measurement results of the DDDs of electrons in PVC film are in good agreement, in the range of an experimental relative uncertainty 8% by the shape and absolute value, with the results obtained on the basis of the MC simulation.

THEORETICAL ANALYSIS OF RESULTS

Comparative analysis of simulation and experimental results of DDDs of 10 MeV electrons in PVC films with different thickness as well as in wooden blocks near the interfaces with PVC films was performed. As it is seen from Figs. 2(a), 3(a) and 4(a) with increasing thickness of PVC films, the local minimum on the curves of DDDs of electrons for PVC films near the incident surface expands and shifts to larger depths. The local maximum near the incident surface on the curves of DDDs of electrons for the wooden blocks near the interfaces with PVC films has a similar tendency. The appearance of the local minimum on the curves of DDDs of 10 MeV electrons for the PVC films near the entrance surface of EB into the heterogeneous target can be explained by the balance disruption of primary scattered electrons near the boundary of contacting materials in the lateral direction to the incident EB. The balance of flux of primary scattered electrons is disrupted mainly due to the densities difference in contacting materials.

The absorbed dose distribution of electrons in the film is formed both by the flux of primary electrons normally incident up on the film and electrons flux released from the surfaces of contacting wooden blocks with the film. Due to the multiple scattering of primary electrons in the heterogeneous target, angular spread of primary electrons on the fixed depth is greater in the material with greater density (dosimetric film) than in the material with lower density (wood). Thus, at certain depth near the entrance surface of EB in the heterogeneous target, the flux of scattered electrons released from the film is greater than the incoming flux of scattered electrons into the film from the contacting wooden blocks. So, at a certain depth in the film, a local minimum appears on the curves of DDDs of electrons. Appearance of the local maximum on the curve of DDDs of electrons in the wooden block can be determined by the flux of primary and secondary electrons released from the film and incoming via the interface surface the into wooden block.

MC simulation allows to separate the contribution of electron flux incident up on the film and electrons released from the contacting wooden blocks into dose distribution in thin films. This can be realized by a change of regime in EB scanning, which is regulated by the time dependence of beam current in scan magnet. Fig. 5 represent the results of MC simulation of the 2D-view for the DDD of 10 MeV electrons near the entrance surface in the area of appearance of the local minimum for one layer of the PVC film of thickness 0.026 cm (a), for the package of four layers of the PVC film of thickness 0.104 cm (b), and for the package of ten layers of the PVC film of thickness 0.26 cm (c).

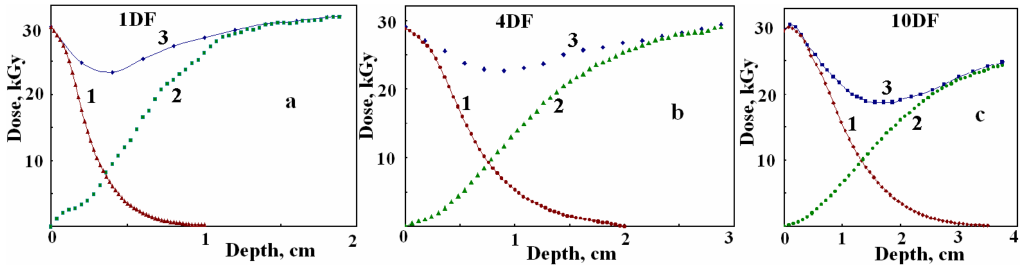


Fig.5. Results of MC simulation for the DDD of 10 MeV electrons
(a) - one, (b) – four, (c) - ten layers of PVC films inserted into a wooden phantom:
1 - DDD in the films irradiated with a flux of primary electrons normally incident up on the film;
2 - DDD in the films irradiated with an electron flux released from two contacting wooden blocks;
3 - DDD in the films as sum of the two above fluxes of electrons.

Fig.6 represent the results of MC simulation of the 3D-view for the DDD deposited by 10 MeV electrons in the package of ten layers of PVC films of thickness 0.26 cm (axis Y) inserted into the wooden phantom: the dose distribution in the film irradiated only with primary electrons (a); the dose distribution in the film irradiated only with electrons released from the two contacting wooden blocks (b); the dose distribution in the film as a sum of the two above fluxes of electrons (c). Schemes of irradiation are presented in Fig. 6 (a), (b), and (c) above of the figures.

The curves 1, 2 and 3 of dose distributions in Fig.5 (c) are taken from the central part along the film depth (axis X) of 3D-view for DDD in the package of 10 layers of PVC films: curve 1 is taken from Fig. 6(a); curve 2 from Fig. 6(b); curve 3 from Fig. 6(c). The DDD in the films is formed by the primary electrons and electrons flux released from the surfaces of contacting with the films wooden blocks as can be seen in Fig. 5 in the range of depth from 0 to 1 cm for 1 layer of the film, from 0 to 2 cm for 4 layers of the film, and from 0 to 3.5cm for 10 layers of the film. In the depth range greater than 1 cm for 1 layer of the film, greater than 2 cm for 4 layers of the film, and greater than 3.5 cm for 10 layers of the film, the DDD into the films is formed only by the electron flux released from the wooden blocks.

As film thickness increases, the increasing contribution of primary electrons to dose field formation to greater depth is observed. The primary electrons mainly released from the thin film into the contacting materials at a certain depth from the entrance surface when a lateral straggling of electrons due to scattering becomes comparable or greater than the film thickness. Therefore, with increasing film thickness the local minimum on the DDD of electrons in the film shifts to larger depths. Increase of contribution of primary electrons into dose field formation for a film with increasing thickness is the reason for expanding a local minimum along the depth of DDD of electrons in the film.

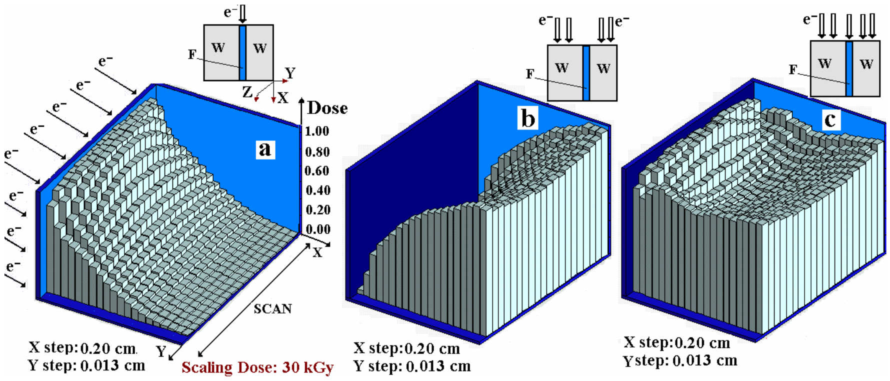


Fig.6. Results of MC simulation of 3D-view of dose distribution deposited by 10 MeV electrons in a package of 10 layers of PVC films of thickness 0.26 cm (axis Y) and length 4cm (axis X)inserted into a wooden phantom:
(a) 3D-view of dose distribution in the film irradiated with a flux of primary electrons normally incident up on the film;
(b) 3D-view of dose distribution in the film irradiated with an electron flux released from two contacting wooden blocks;
(c) 3D-view of dose distribution in the film as a sum of the two above fluxes of electrons.

Analysis of experimental and simulation results related with the position of local minimum on the DDD of 10 MeV electrons in films with different thickness shows that the local minimum on the DDD for the package of four layers of the film shifts to a larger depth by about 2 times and for the package of ten layers of the film shifts to larger depth by about 3.5 times relative to the position of local minimum of the first layer. A correlation is observed between the position of local minimum on the DDD of electrons and the film thickness $X_{LM} \sim h^{1/2}$. This is in general agreement with the above analysis.

For comparison, the results of MC simulation experiment of the absorbed dose field formation deposited by 10 MeV electrons in the PVC film of thickness 0.26 cm which is inserted between two aluminum blocks of thickness 3 cm (axis Y) and length 2.5 cm (axis X) are shown in Figs. 7 and 8. This is the case when the density of the film is lower than the density of contacting material.

Fig. 7 represents the results of MC simulation of the DDD of electrons in the center line (along axis X) of PVC film inserted between the two aluminum blocks (curve 3), the depth dose distribution in the PVC film, which is formed only due to the flux of primary electrons normally incident up on the film (curve 1, along axis X), and the DDD in the PVC film which is formed only due to the flux released from the two contacting aluminum blocks (curve 2).

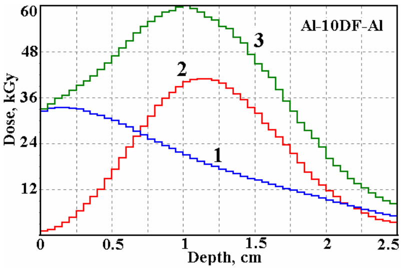


Fig.7. Results of MC simulation of DDD deposited by 10 MeV electrons in the center of a package ten layers of PVC films inserted between two aluminum blocks:
1 - DDD in the film irradiated with a flux of primary electrons normally incident up on the film;
2 - DDD in the film irradiated with an electron flux released from two contacting aluminum blocks;
3 - DDD in the film as sum of the two above fluxes of electrons.

Fig.8 represents the results of MC simulation of 3D-view of the absorbed dose distribution deposited by 10 MeV electrons in the package of ten layers of PVC film of thickness 0.26 cm (axis Y) inserted between two aluminum blocks. Schemes of irradiation are presented in Fig. 8 (a), (b), and (c) above of the figures for dose distributions.

Figs. 7 and 8 demonstrate that in a heterogeneous target with a thin film, when the density of contacting material (aluminum) is greater than density of film material (PVC), the local minimum on the DDD of electrons in the films is absent. As is evident from Figs. 7 and 8, the flux of primary electrons normally incident up on the film and flux of electrons released from two contacting aluminum blocks contribute significantly to the summary dose over whole film length. Therefore, the local minimum is not formed in the depth dose distribution of PVC film irradiated with electrons under glancing angles. The results of simulation of depth dose distribution of electrons in the heterogeneous target Al(block)-DF(PVC)-Al(block) agreed with the experimental measurements [1].

The anomalies in the depth dose distribution of 15 MeV electrons in a thin dosimetric film inserted between the flat boundaries of aluminum blocks and air gaps between the film and aluminum blocks were studied by [5].

Appearance of the anomalies in the depth dose distribution of electrons was explained by lack of homogeneity due to the air gap and streaming effect of the incident electrons through air gaps. In our investigations the lack of homogeneity of irradiated materials is appearing because of the different density of solid contacting materials. The results of [5] are the limiting case when density for one of contacting materials tends to zero.

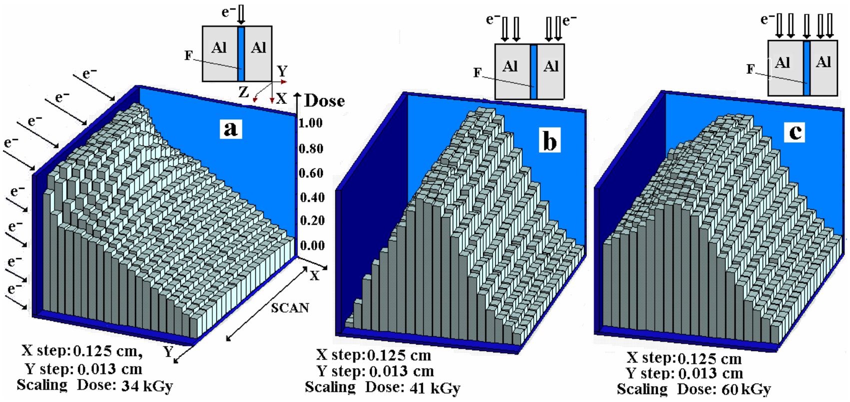


Fig.8. Results of MC simulation of 3D-view for dose distribution deposited by 10 MeV electrons in a package of ten layers of PVC dosimetric films of thickness 0.26cm (axis Y) and length 2.5 cm (axis X) inserted between two aluminum blocks:
(a) 3D-view of dose distribution in the film irradiated with a flux of primary electrons normally incident up on the film;
(b) 3D-view of dose distribution in the film irradiated with an electron flux released from two contacting aluminum blocks;
(c) 3D-view of dose distribution in the film as sum of the two above fluxes of electrons.

CONCLUSION

The measurement results of the absorbed dose distribution of 10 MeV electrons in PVC film are in good agreement within the range of the experimental relative uncertainty 8% at one standard deviation by the shape and absolute value with the results obtained on the basis of the simulation of an irradiation process by MC method.

The comparison of experimental and simulation results in the heterogeneous target Wood(block)-DF(PVC)-Wood(block) have shown an appearance of anomalies in the depth dose distributions of electrons near the interface of contacting materials. The comparison results and theoretical analysis of mechanism for an EB dose field formation

have shown that in the heterogeneous targets with thin films of various thickness, when the density of a film is greater than the density of contacting materials, the following features of the dose distribution of electrons will be observed:

- Appearance of anomalies, such as the local minimum, in the absorbed depth dose distribution of electrons near the entrance surface for thin films, as well as a local maximum on the curve of depth dose distribution of electrons for contacting materials near the interface with the film;
- Formation of the local minimum in the depth dose distribution of electrons in thin films is mainly determined by multiple scattering of primary electrons normally incident up on the film and flux of electrons released from the contacting materials with the film;
- Appearance of the local maximum on the curve of depth dose distribution of electrons in the contacted with film material is determined by a flux of primary and secondary electrons released from the film and incoming into the contacted material;
- Local minimum on the depth dose distribution of electrons in films expands and shifts to larger depths with increasing of film thickness;
- Position of the local minimum at a certain depth from the entrance surface on the depth dose distribution of electrons is proportional to the square root of film thickness $X_{LM} \sim h^{1/2}$ in the range of investigated film thickness.

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