TRACK STRUCTURE CALCULATION OF THE DOSE ENHANCEMENT IN TISSUE ADJACENT TO IMPLANTS OF HIGH ATOMIC NUMBER.

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Abstract

Present investigations deal with diagnostic x-ray qualities as applied in medical diagnostics. The track structure computer program PARTRAC [1] simulating the coupled photon - electron transport and interactions in complex geometries has been used. Differential cross sections for electrons in gold with primary energies in the range of 100 eV to 100 keV have been derived on the basis of Seltzer model in case of ionizations and excitations with new Hartree-Fock input data. The elastic cross section data were taken from Fink et al. and Riley et al.. These cross sections have been inserted into the existing track structure computer program to provide detailed simulations of electron interactions and to describe above mentioned interface effects. The tracks were simulated in a target volume of gold surrounded by water vapour to represent cell tissue and irradiated by 30 keV and 100 keV photons. The simulated geometry was chosen as in experiments using exoelectron emission. The tracks were calculated for comparison in pure water vapour under the same irradiation conditions.

Introduction

Implants and contrast media in the human body may constitute interfaces between tissue and high-Z materials. Such interfaces lead to dose discontinuities during radiation exposures as known from megavoltage therapy. Significant dose enhancement has meanwhile been found in tissue close to a gold layer by using exoelectron technology with a spatial resolution in the micrometer range as it is shown on the fig. 1 [2].

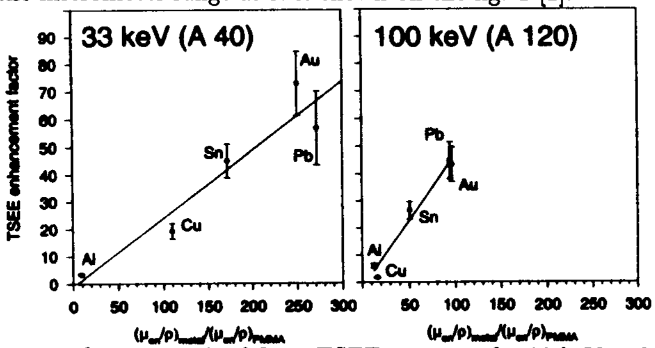

Fig.1 Enhancement factors received from TSEE response for 33 keV and 100 keV x-rays in tissue equivalent material at different metal surfaces under backscatter conditions [2]

Method

The photon-electron transport code **PARTRAC** [1] is used to calculate deposited energy distribution in the vicinity of the tissue - gold interface. The electron track simulation

covers energies from 10 eV to 100 keV. The electron cross sections for water vapour with appropriate density scaling are taken to simulate tissue [1].
New ionization and excitation cross section data for electrons in gold were calculated. Cross section differential in energy were derived for subshells using Seltzer method [3]. New values for the mean kinetic energies of orbital electrons U_j, the expectation values of the electron orbital radius $\langle r_j \rangle$ and the binding energies B_j were obtained from Hartree - Fock calculatins made by P. Indelicato [4]. Results are shown on Fig. 2, 3. Elastic cross section data were taken from Fink et al. [5] and Riley et al. [6].

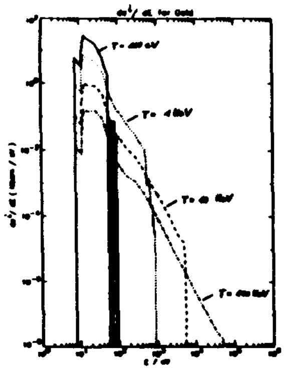

Fig. 2 Differential ionisation cross sections $(d\sigma/dE)^i$ in dependence on the energy transfer E are shown for electron primary energies T=100 eV, 1 keV, 10 keV, 100 keV. Energy edges of the outer shells could be seen (from the left side:6s, 5s,5p, 5d, 4s, 4p, 4d, 4f).

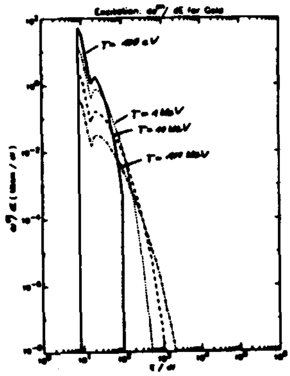

Fig. 3 Excitation differential cross sections $(d\sigma/dE)^{ex}$ in dependence on the energy transfer E are shown for electron primary energies T = 100 eV, 1 keV, 10 keV, 100 keV.

These cross section data have been implemented into the existing track structure computer program.
The experiment to be simulated consists of a PMMA slab ($100x100x5mm^3$), a 100 μm layer of tissue (the region for tracing the secondary electrons) in front of a 100 μm gold layer . The experiment was simulated for 30 keV resp. 100 keV monoenergetic photons.

Results

The results of our calculations are shown in Figures 4 - 5. The energy deposition is found to be considerably higher for the same irradiation conditions in tissue in front of the gold foil than in pure tissue. This can be explained by the large differences in photon interaction cross sections for gold and for tissue and by the different character of interaction. The photoeffect dominates in gold and the Compton effect dominates in tissue causing different structures of secondary electron spectra.
The maximum of the energy deposition occurs at a distance of several micrometers from the gold - tissue interface caused by a larger number high energy electrons emitted from the gold into the tissue. Different to experiments build up maximum of energy deposition is observed for 100 keV photons at a distance of 20 μm from the gold surface, for 30 keV at about 2 μm (Fig. 4 and 5).

Conclusion

The track structure modelling was performed at tissue - gold interfaces for X-ray energies of 30 keV and 100 keV using the **PARTRAC** code under backscatter conditions. This code allows a persecution of electron histories down to 10 eV also for non-equilibrium exchange of secondary electrons across the transition zone of the media interface. Significant enhacement of energy deposition was found in tissue layers adjacent to the gold surface as compared with a homogeneous tissue phantom. The enhacement depends on the primary photon energy. Also the range of enhanced energy deposition was found to depend on the primary photon energy that reaches about 17 μm for 30 keV and about 130 μm for 100 keV. A build up maximum of energy deposition was found for 100 keV primary photons at a distance of about 20 μm from the interface, for 30 keV photons at about 2 μm. There is a wide distribution of electron energies up to the primary photon energies originating from gold which is not present for pure tissue conditions. These preliminary results indicate that the PARTRAC code offers a large potential to analyze enhanced energy deposition in tissue close to materials of higher atomic number what is useful for X - ray diagnostics.

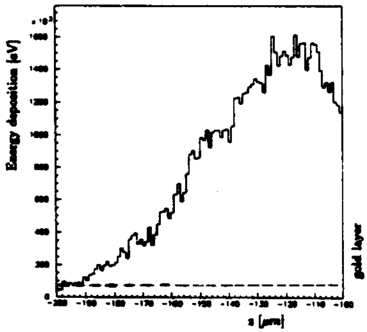

Figure 4 Depth distribution of electron energy deposition in front of the gold foil. The gold - tissue interface is at z = -100 μm. The y-axis are energy depositions in eV normalized to number of photon histories. The broken line shows the level of energy deposition if there is tissue instead of gold. Primary energy of photons: 100 keV.

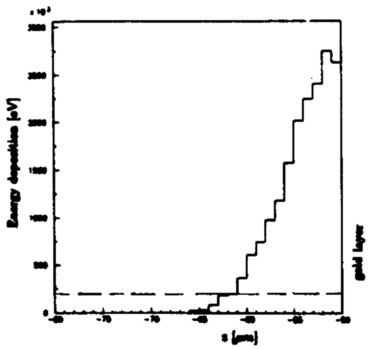

Figure 5 Depth distribution of electron energy deposition in front of the gold foil. The gold - tissue interface is at z = -50 μm. The y-axis are energy depositions in eV normalized to number of photon histories. The broken line shows the level of energy depositions if there is tissue instead of gold. Primary energy of photons: 30 keV.

References

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