A practical method to estimate positron implantation profiles

Angelo Ostinelli[1], Marta Duchini[1], Milena Frigerio[1], Marco Cacciatori[1], Rafael Ferragut[2], Paola Folegati[2], Valerio Toso[2]
(1) Medical Physics Department, ASST Lariana, Como, Italy (2) Positron Laboratory of Como VEPAS, Politecnico of Milan, Italy

Purpose: The possibility of obtaining clinical information from the analysis of the annihilation photons, produced by positrons implanted in biological tissues, requires an adequate knowledge of the stopping depths from which they are originated. The present work aims to characterize the interaction of 10÷100keV positron beams with biological tissues. Since scientific literature do not provide positron depth dose transmission curves, a stopping power (S_T) data approach is proposed.

Materials and Method: The interpolating function of S_T values was calculated to estimate the progressive energy degradation of a single positron travelling through water. S_T was used as the derivative of the E(x) function, which describes the gradual transfer of positron energy in the absorber. The energy dissipated along each elementary step was given by $\varepsilon(x+\delta x)=E_x\text{–}dE/dx\Delta x$, where $dE/dx=S_T$. Since the energy released by a light charged particle is the result of a large number of interactions with matter, this approach refers to the beam transmission only along a short path. After an initial plateau, the curve describing the number of positrons crossing the absorber undergoes a straight decrease in the central portion, which ends with an exponential decrement. Consequently, the convolution of the single positron energy deposition function with the transmission of a generic low energy positron beam was carried out. The derivative of the function describing this curve gives the positron implantation depths. The 20 keV positron beam, produced by the ^{22}Na source of the Positron Laboratory VEPAS of Como, was used for calculation purpose.

Results: The curve representing the depth distribution of a 20keV positron beam implanted in a biological sample was obtained. The positron implantation range was 1÷7µm, which is in good agreement with the simulation provided by Monte Carlo method (Penelope). An estimate of the order of magnitude of the local doses imparted to micrometric structures was performed, considering that a variability up to 5-6 orders of magnitude might occur. This work shows that for a 20mGy mean dose released by 20keV positrons, the local dose to structures of about 0.2µm can exceed 1mGy.

Conclusions: Many factors can contribute to the uncertainty of the proposed method for positron dose estimation in biological structures of very small dimensions, together with the intrinsic statistical nature of the observed phenomena. The main factors are: the energy straggling, the interpolation method of the positron S_T values, the simplifications of the positron transmission model in water.

Keywords: light charge particle stopping powers, positron implantation, positron energy deposition in tissue, positron dosimetry