Evaluation of e^+ implantation profile for ^{22}Na positron source

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To employ positrons emitted from isotope sources for analysis of near-surface layers of solid-state materials one needs to account for their range, which usually varies from tens to hundreds of microns. Therefore using isotope sources for positron annihilation lifetime spectroscopy (PALS) requires accurate information on positron implantation profiles (PIPs). Usually PIPs are described as monoexponential distributions, however in some publications [1] the authors note that these profiles have more complex shape.

In current work we present the results of Geant4 simulation of PIPs for materials with different densities (Fig. 1). We simulate a standard geometry for PALS measurements: the positron source is placed between two 1 mm thick samples. The source represents a radioactive NaCl layer of 1 μm thickness covered by a 8 μm kapton films.

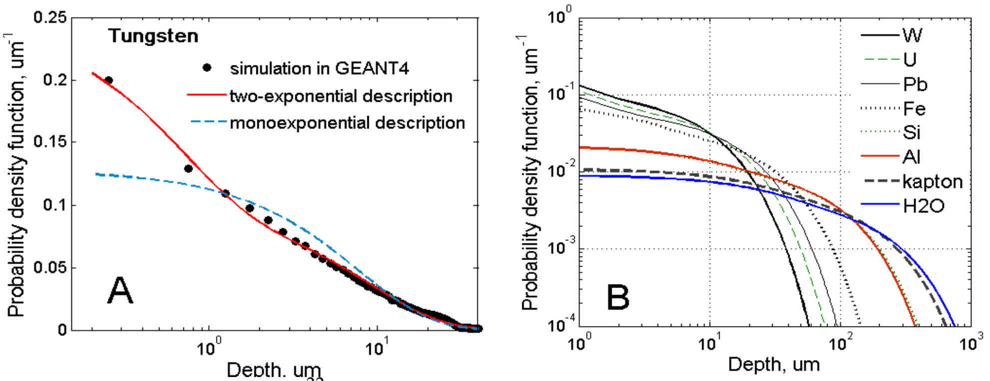

Fig.1. Implantation profiles for ^{22}Na source: A) comparison of conventional and two-exponential description for tungsten; B) materials with different densities.

The shape of PIP depends on both energy and angular distributions of the positrons entering the sample. The results of simulation show that the positron probability density function can be described by the sum of two exponential components (Fig. 1a). The fraction of a short-depth component for all studied materials is found to be around 11% and thus implantation profiles can be expressed as follows:

$$f(x) = 0.11 \cdot a \cdot e^{-ax} + 0.89 \cdot b \cdot e^{-bx}, \quad (1)$$

where x [μm] is the depth of the sample and prefactors a and b [μm^{-1}] can be approximated as functions of the studied materials density ρ [g/cm^3] as:

$$a = 0.0024 \cdot (\rho - 0.3)^2 + 0.045 \cdot (\rho - 0.3), \qquad b = 0.0056 \cdot (\rho - 0.2), \quad (2)$$

Finally, we verify our Geant4 simulations experimentally by measuring the fraction of the positrons passed through the thin films using PALS technique and confirm the proposed model of PIP.

[1] J. Dryzek and K. Siemek J. Appl. Phys. 114, (2013)