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Investigation of near-surface radiation defects in Si and W by means of conventional positron lifetime spectrometer with a ^{22}Na positron source

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In this work we studied near-surface defects in silicon irradiated by protons and in tungsten irradiated by W^{+6} ions by means of positron annihilation lifetime spectroscopy (PALS) using a ^{22}Na positron source. These studies require knowledge of positron implantation profiles in matter. We simulated them using GEANT4 toolkit. Positron implantation profiles can be approximated by the sum of two exponential functions:

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

where a=0.11, b=0.012 μm^{-1} for silicon and a=1.52, b=0.11 μm^{-1} for tungsten.

Fig. 1 shows implantation profiles of positrons from ^{22}Na source along with depth distributions of primary radiation defects (Frenkel pairs) calculated using SRIM program.

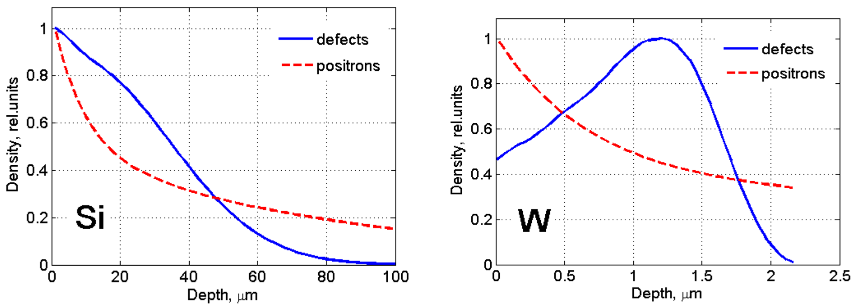

Fig.1. Positron implantation profiles and Frenkel pairs depth profiles in Si and W samples

In silicon irradiated by protons with energies up to 3 MeV with the fluence $\sim 5 \cdot 10^{14}$ cm^{-2}, defects are located within 100 μm near-surface region. According to our calculations 72% of positrons annihilate therein. To describe fate of the near-surface positrons we use the standard two-state trapping model. It yields the lifetime of the trapped positrons about 0.3 ns, which indicate that positrons preferentially annihilate in divacancies. Trapping rate is 0.6 ns^{-1} [1]. Using simulated e^+ implantation profile and spatial distribution of radiation defects, we estimated concentration of divacancies in the near-surface region as 10^{17} cm^{-3}.

In the tungsten samples irradiated by W^{6+} ions (energy 20 MeV, fluence 1.6*10^{12} cm^{-2}) all primary defects (~0.003 dpa) are located within a 2 μm near-surface layer. Assuming that 27 % of all positrons annihilate therein and the defect concentration $C_d \sim 10^{20}$ cm^{-3} exceeds the saturation limit, we determined the lifetime of positrons in the vacancy-type defects as τ_d = 0.22 ns, which is essentially higher than lifetime in monovacancies. It indicates the presence of multivacancies.

[1] Dubov L.Yu., Stepanov S.V., Funtikov Yu.V., Shtotsky Yu.V., *Defect and Diffusion Forum*, Vol. 373, pp 209-212 (2016)