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Radiation damage assessment of the seventh SINQ target irradiation program based on MCNPX simulation

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The SINQ Target Irradiation Program (STIP) is one of the crucial research projects performed by the Paul Scherrer Institute (PSI). The seventh experiment of the SINQ Target Irradiation Program (STIP-VII) was conducted in SINQ Target 10 during 2013 and 2014 and the total proton charge received by the target is 11.7 Ah. A radiation damage assessment was performed by using the Monte Carlo N-Particle eXtended (MCNPX) code to obtain the key irradiation parameters, i.e., displacement damage (dpa), helium (He) and hydrogen (H) concentrations.

After irradiation, the gamma mapping was performed at the entrance window of proton beam and provided the distribution of the proton fluence for the initial proton source definition. In the MCNPX simulation, the fluences of proton and neutron along the target as well as the energy deposition were calculated. Corresponding to the average current 1.45 mA of proton beam, the maximum proton and neutron fluxes obtained are 2.3e14 p/(cm2·s) and 5.6e14 n/(cm2·s), and the maximum energy deposition in the Zircaloy-2 cladding tubes is about 500 W/cm3. The irradiation parameters of six selected materials (9Cr-1Mo, Zry-2, Al, SiC, Ta and W) in each of 16 specimen rods were evaluated by multiplying the proton and neutron fluences with the corresponding cross section data. The maximum displacement damage was calculated for Zircaloy-2 in Row 2 with a value of 44.8 dpa (displacement per atom). The maximum value of helium concentration was calculated for tantalum in Rod 1 with a value of 2560 appm and the maximum hydrogen concentration was calculated for tungsten in Rod 1 with a value of 13050 appm. This assessment will be used as a reference in the subsequent post-irradiation examination of the STIP-VII specimens.

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