Fusion-relevant tritium interactions with SS316L stainless steel

Teimane A.S., Pajuste E., Sondars M., Maškova E., Zabolockis R.J.

Due to its high corrosion resistance, relatively low activation, structural integrity and compatibility with plasma-facing components, SS316L stainless steel remains as a fundamental material in fusion energy research. It is used in the vacuum vessel, cooling systems and other structural frameworks. Despite its applicability, concerns regarding its fate when interacting with tritium have been raised given tritium's high diffusivity as well as radioactivity. Interactions with tritium are of high importance and their analysis in conditions relevant to those expected at ITER or DEMO may give valuable insights into tritium accountancy and management.

To investigate these interactions with SS316L, diffusion experiments were conducted, samples of SS316L were loaded with HT containing gas followed by the analysis of tritium outgassing, tritium quantification within the sample as well as the study of its thermal release behaviour.

For the analysis of diffusion coefficient, SS316L plate is placed in a stainless-steel sample holder and fixed between two stainless steel flanges with two stainless steel tubes hermetically attached on both sides. One side of the membrane is exposed to He + 0,1 % H_2 + HT (tritium loop) and the other side rinsed/filled with synthetic air (permeation loop). Therefore, boundary conditions of known concentrations are achieved. Two regimes of experiments have been performed – static and dynamic in order to assess the impact of flow on experimental results. Experiments have been performed at temperatures ranging from room to 400℃.

To study the outgassing kinetics of tritium from SS316L, 2x5cm samples of 0.025mm AISI 316L foil were washed with ethanol, placed in a quartz tube, pre-treated with H2 at 350℃ for 20h and afterwards loaded with He + 0,1 % H_2 + HT gas mixture for 4h at 450℃. Half of the samples were placed in a water bubbler with H2O whilst other half in a bubbler with air, therefore the impact of outbound media can be evaluated. After a select period of days tritium was quantified in air phase for air samples, air phase above water for water samples, as well as water itself and lastly tritium content in the sample was measured. Surface analysis prior loading and after 40 days of outgassing was performed using scanning electron microscopy.

The effective diffusion coefficient of tritium diffusing through 0.025 mm of SS316L at room temperature was found to be $1.7\pm0.4\cdot10^{-10}$ cm^2/s which agrees with previously reported values [2]. Consistent with the finding of Penzhorn et.al. in [1], tritium was mainly found in the oxidized form as HTO. This HTO production was investigated further by fitting the data with a sigmoid function (Figure 1). Results indicate almost complete HTO production at temperatures higher than 300℃ with the introduction of flow shifting full conversion to lower temperatures, indicating a surface activated process.

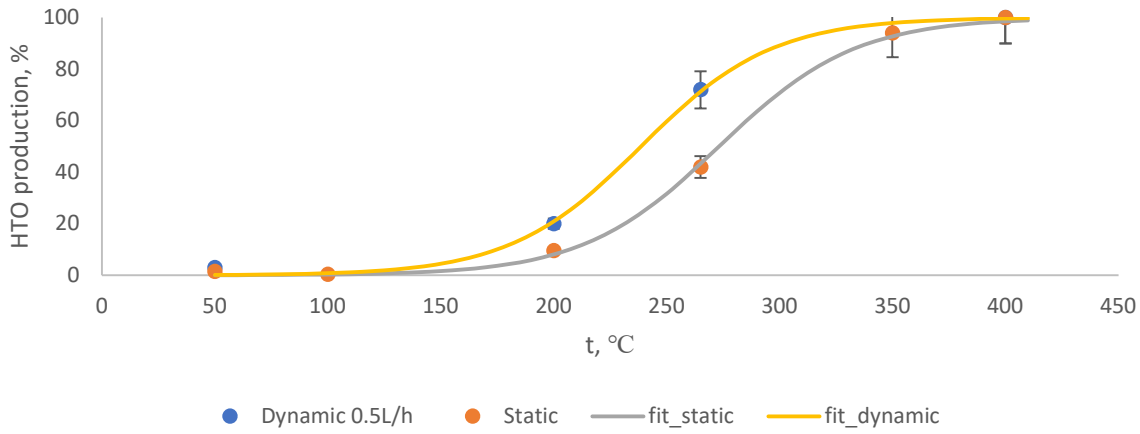

Figure 1. HTO production fraction temperature dependency in tritium loop

Tritium loading and outgassing experiments with different outbound medias were performed and tritium quantified in air, water and sample itself. For tritium quantification in the sample, thermal desorption was performed at temperatures up to 1100℃. Such temperatures are destructive for SS316L structure and can give valuable insight into tritium desorption temperatures. Tritium was collected in water bubbles with a fraction collected every 200℃ of increase in temperature. Preliminary results indicate that about a third of the tritium loaded is outgassed at temperatures higher than 800℃ - above the service temperature of SS316L.

The impact of outbound media on tritium out-gassing remains inconclusive with indications of slightly quicker initiation of out-gassing in water media. Further experiments are needed for more concrete results.

In conclusion, valuable insights in tritium interactions with SS316L have been obtained with the most notable ones being the diffusion coefficient of HT, tracking of HTO production by increase in temperature, as well as the discovery of a tritium trapping site at temperatures larger than 800℃. The results presented here may be used in modelling to assess the tritium accounting as well as needed safety requirements where SS316L stainless steel and tritium are present.

[1] Penzhorn R.-D., Torikai Y., Watanabe K., Matsuyama M., Perevezentsev A. On the fate of tritium in thermally treated stainless steel type 316L. *Journal of Nuclear Materials*, **429**, 346-352 (2012).

[2] Austin, J. H. & Elleman, T. S. Tritium diffusion in 304- and 316-stainless steels in the temperature range 25 to 222 °C. *Journal of Nuclear Materials* **43**, 119–125 (1972).