FUSION-RELEVANT TRITIUM INTERACTIONS WITH SS316L STAINLESS STEEL

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ABSTRACT

- Foils of 316L stainless steel (SS316L) were exposed to a He+0.1% H2/HT gas at temperatures ranging from ambient to 400℃ and HT to HTO reaction was tracked. Temperature dependency of HTO production showed that dynamic flow conditions shift HTO formation to lower temperatures compared to static conditions with full conversion at 300℃.
- Thermal desorption (TDS) experiments with tritium-loaded SS316L samples reveals retention at temperatures larger than 800℃.
- Tritium out-diffusion reaches a plateau after 3-7 days of outgassing at room temperature.

METHODS

PERMEATION/OXIDATION EXPERIMENTS

Stainless steel AISI 316 L foil (l=0,025mm, d=3.7 cm, active area 11,6 cm^2) sample was inserted in a permeation system with sample being fixed between two stainless steel flanges. Permeation system consists of two stainless steel loops: tritium loop (filled with He + 0,1% H_2/HT) and permeation loop (filled with air); permeation system is placed into a furnace. Two types of permeation experiments were carried out – static and dynamic to assess the impact of flow on the tritium permeation and oxidation.

LOADING/THERMAL DESORPTION

After hydrogen pretreatment, He + 0,1% H2/HT gas mixture was supplied to a sample, sealed and heated to 450℃ for 4 h. Afterwards, sample was extracted from the tube and placed in a ceramic vessel within a tube furnace. Inlet of the vessel was supplied with synthetic air, and the outlet was connected to a water bubbler for HTO capture. The sample was heated from ambient to 1000℃ at 5℃ min^{-1} under a constant synthetic-air flow of 10 L h^{-1}. The bubbler was replaced at 200℃ intervals to collect desorbed HTO fractions.

OUTGASING

After loading, the SS316L sample (2x5cm) was continuously purged with synthetic air (3 L/h) to a water bubbler. HTO activity was quantified by liquid scintillation counting.

OUTCOME

PERMEATION/OXIDATION reults indicate HT full conversion into HTO with the introduction of flow shifting conversion to lower temperatures. Results are similar to those reported in [2].

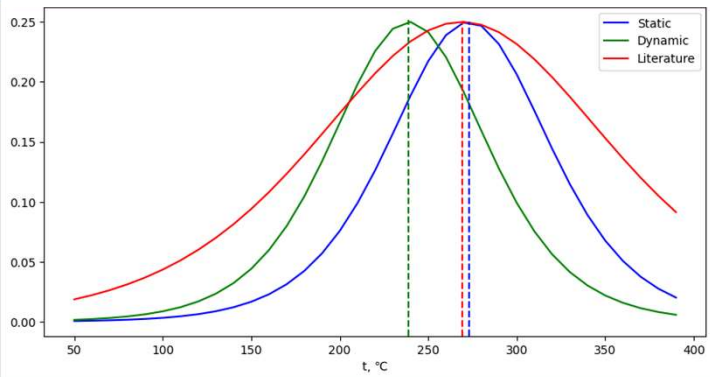

Figure 1. Tritium oxidation by increase in temperature for both static and dynamic experiments compared to literature

REFERENCES

[1] ŞAHIN, S., ÜBEYLI, M., A Review on the Potential Use of Austenitic Stainless Steels in Nuclear Fusion Reactors, Journal of Fusion Energy **27** 4 (2008) 271.
[2] 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** 1–3 (2012) 346.

BACKGROUND

Type 316L and EUROFER stainless steels are materials planned to be used in both ITER and DEMO as structural materials, where they will encounter tritiated gas in ITER test blanket module (TBMs) delivery systems and may also be exposed to tritium due to permeation to vacuum vessel materials [1]. It is crucial to analyse the principal processes occurring when tritium interacts with these materials under conditions similar to those expected in their applications. These results are important for tritium management issues, tritium accountancy, waste conditioning, certification of tritium content in waste, isotopic composition of tritium-containing gases in stainless steel components. Experimental result sof tritium permeation and diffusion can therefore be used in simulations to assess the risk it poses.

OUTCOME

THERMAL DESORPTION reveals a large fraction of tritium being released both at temperatures below 200℃ as well as temperatures above 800℃ - around the threshold for prolonged use. Hot working of SS316L is performed in temperatures ranging from 900 up to 1200℃, while water quenching or rapid cooling for corrosion resistance is done at 1038℃ and might have an influence on tritium desorption temperature.

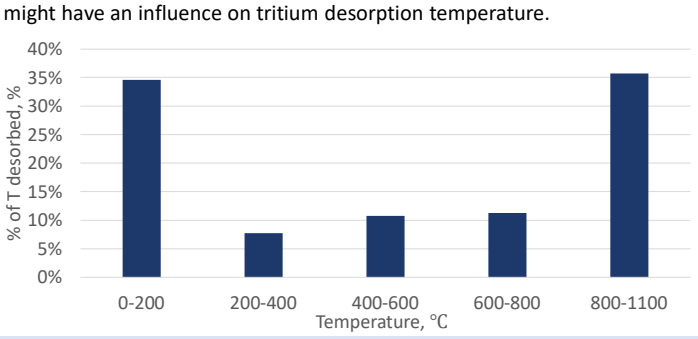

Figure 2. Fractional tritium desorption from oxidized SS316L samples

OUTGASSING reults show tritium desorption reaching a plateau after 3 to 7 days of outgassing in air at room temperature. Thermal desorption results must be considered since significant amount of tritium is still retained and can only be released at temperatures above ambient.

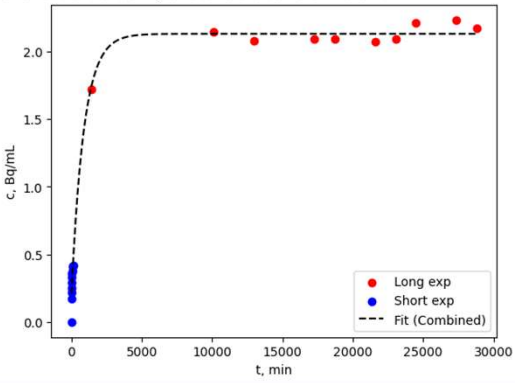

Figure 3. Tritium outgassing from oxidized SS316L samples in time

CONCLUSION

Presence of oxygen at elevated temperatures can lead to tritium gas being oxidized into HTO on the surface of SS316L stainless steel, therefore depending on the oxygen content parts of tritium may be found in oxidized form rather than molecular. Oxidized samples show a significant amount of tritium being retained at temperatures above 800℃, which may lead to increased inventory. Outgassing experiments reveal that a plateau is reached between 3 and 7 days of storage at room temperature, but additional experiments must be performed in the relevant time range.