

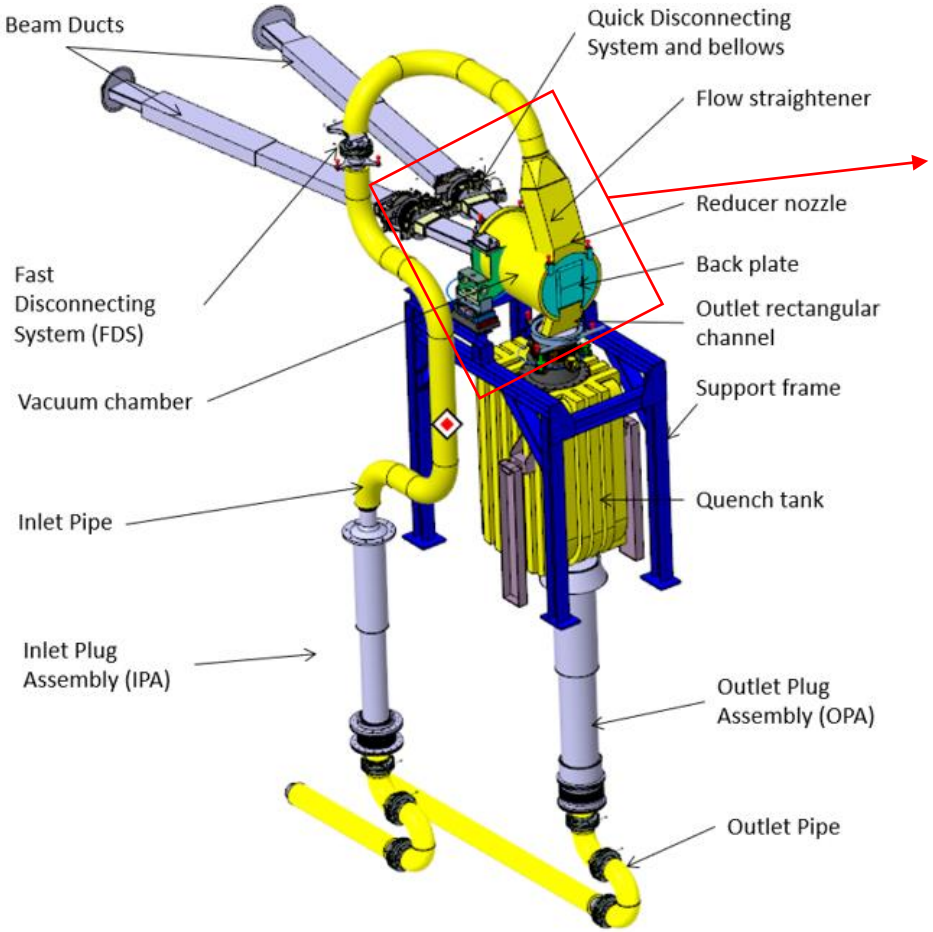
Structural and environmental compatibility of 316L/316Ti–EUROFER97 TIG welds for the DONES Target Assembly Backplate

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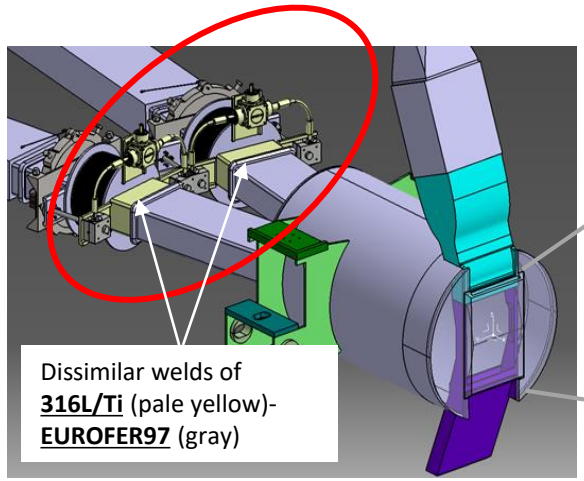
[2]*AVS-Added Value Solution, Polígono Industrial Sigma, Xixilion Kalea, 2, bajo Pabellón 10, 20870 Elgoibar, Gipuzkoa, Spain*

Motivation: welded joints in the DONES Target Assembly/Backplate (TA/BP)

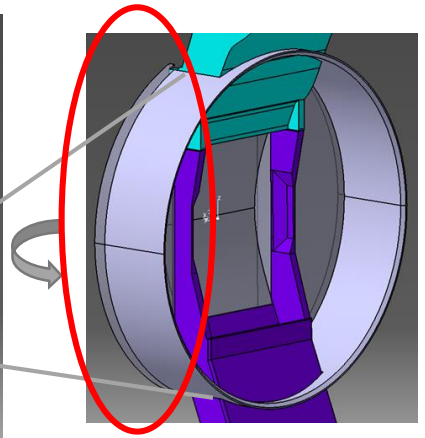


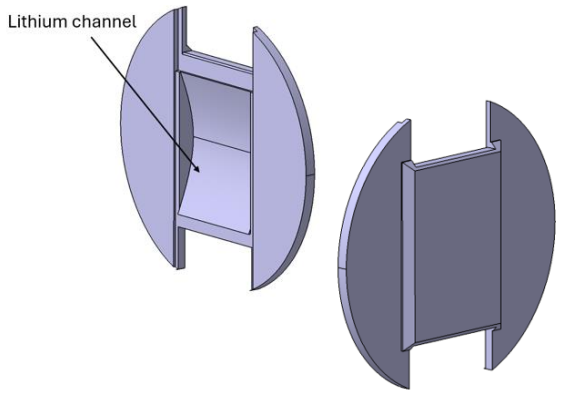
DONES Target System (v2.0, Oct. 2023)

(EFDA_D_2N74W4 v5.0 - Target System Design Description Document (DDD))



TA removable section made from **EUROFER97** → Beam duct bellow, bellows compression and extension components **316L/Ti** → **DISSIMILAR WELDS**





Circular plate made of **EUROFER97**, welded to the vacuum chamber and suitably designed to host the **concave channel** for the **lithium flow** → Alternative design could propose welds between different parts made from **316L/Ti** → **DISSIMILAR WELDS**

WHY IS THIS STUDY RELEVANT?

Evaluating both their structural integrity and liquid- lithium compatibility is crucial to ensure long-term vacuum tightness and nuclear containment.

Objectives and experimental strategy

1 Fabrication of dissimilar joints.



TIG (Tungsten inert gas) welding.

avs
added value solutions

2 Evaluation of their structural integrity through microstructural inspection and mechanical properties.



SEM (scanning electron microscopy) and OM (optical microscopy).

Vickers microhardness and tensile test at room temperature (RT).



3 Analysis of compatibility with liquid lithium.



Static exposure to **liquid Li at different exposure duration (500 h, 1000 h).**

Post-exposure tensile testing, SEM and SIMS (Secondary ion mass spectrometry).



Materials

added value solutions

AISI 316L plates

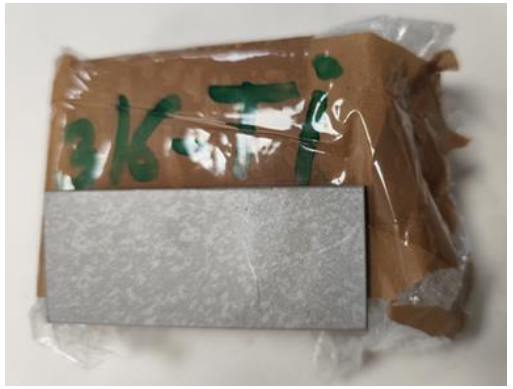




EUROFER97 plates



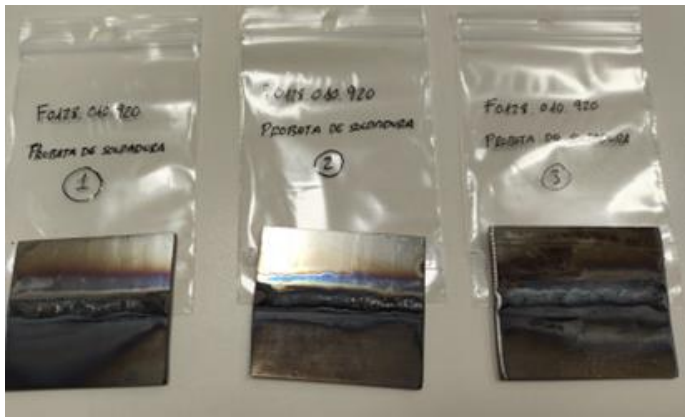
AISI 316Ti plates





JOINT 1 3 coupons

AISI 316L – EUROFER97

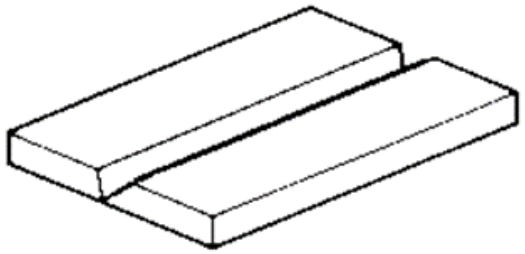


JOINT 2 4 coupons

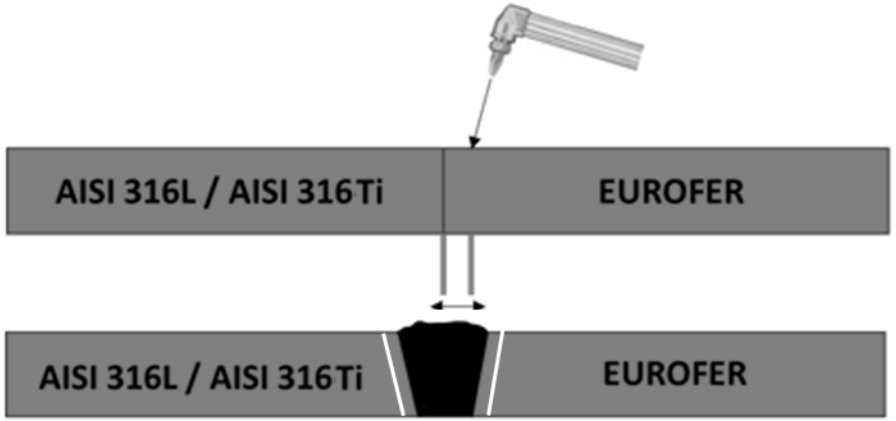
AISI 316Ti – EUROFER97



TIG welding



Welding configuration type 1G flat position.

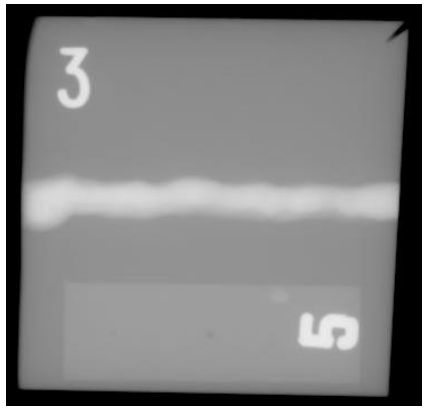


Parameter	Welding condition
Welding process	TIG
Joint configuration	Butt joint, 1G flat position
Plate thickness	2 mm
Filler material	No filler
Welding current	60-70 A

Radiographic Inspection Assessment of weld continuity and internal defect inspection.

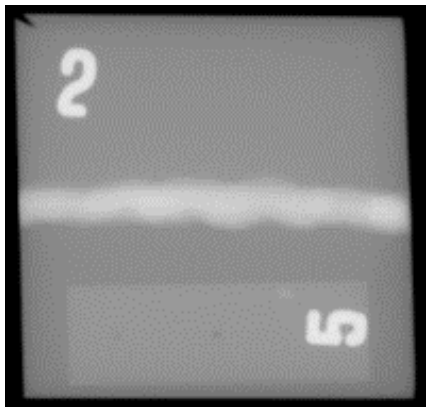
AISI 316L – EUROFER97





AISI 316Ti – EUROFER97



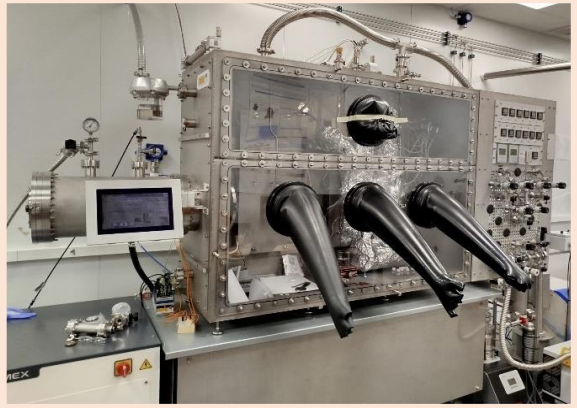


Defect-free welds confirmed by radiography.



Liquid lithium exposure procedure

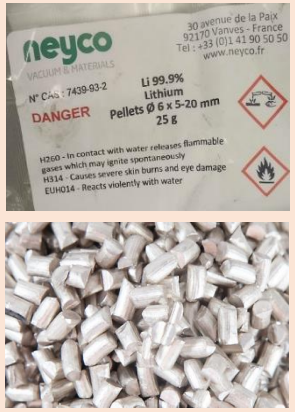
HELIOS: High- Temperature facility for Lithium compatibility with materials



1. LYDER (Lithium system for Yttrium-based Deuterium retention) used for lithium handling



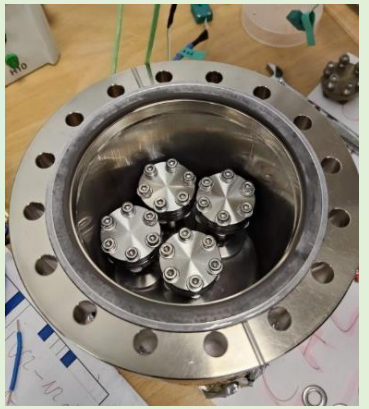
2. Introduction of the specimens into a 316L crucible



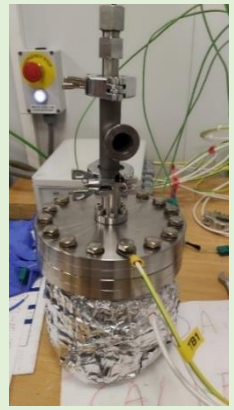
Two lithium pellets per crucible (0,5 g of Li per crucible)



3. 316L crucible containing three specimens and lithium



4. Crucible assemblies placed inside the heating vessel



5. Heating vessel system with Ar over pressure

STATIC EXPOSURE

High-purity Li (99,9 %)

Ar over-pressure

350 °C

500 h
1000 h

POST EXPOSURE CLEANING



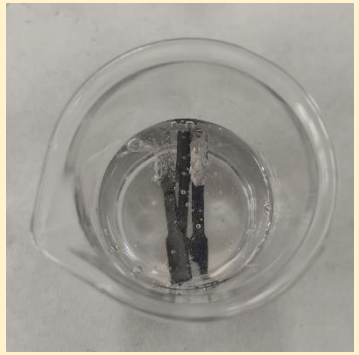
6. Crucible after the exposure period



7. Removal of Li using an ethanol-5% H_20 solution



8. Specimens after extraction



9. Final cleaning (with ethanol-5% H_20)

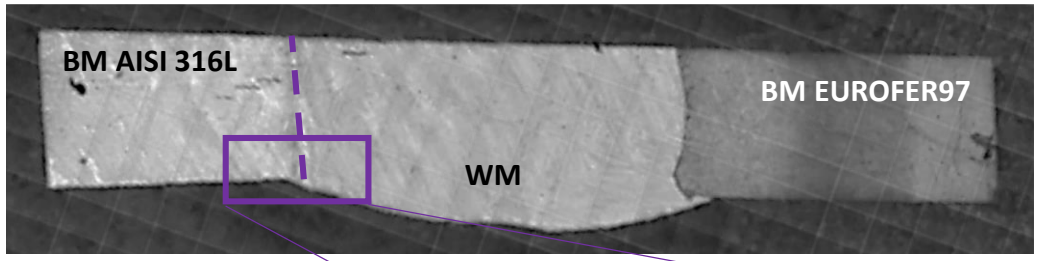


10. Fully cleaned specimens ready for analysis

Microstructural characterization (as-welded condition)

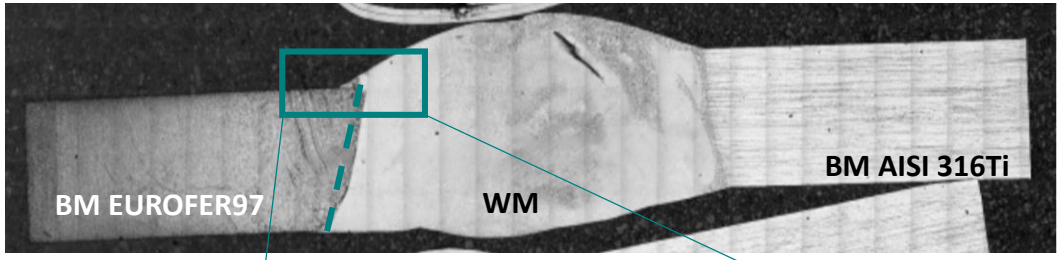
BM: base metal; WM: weld metal

AISI 316L – EUROFER97



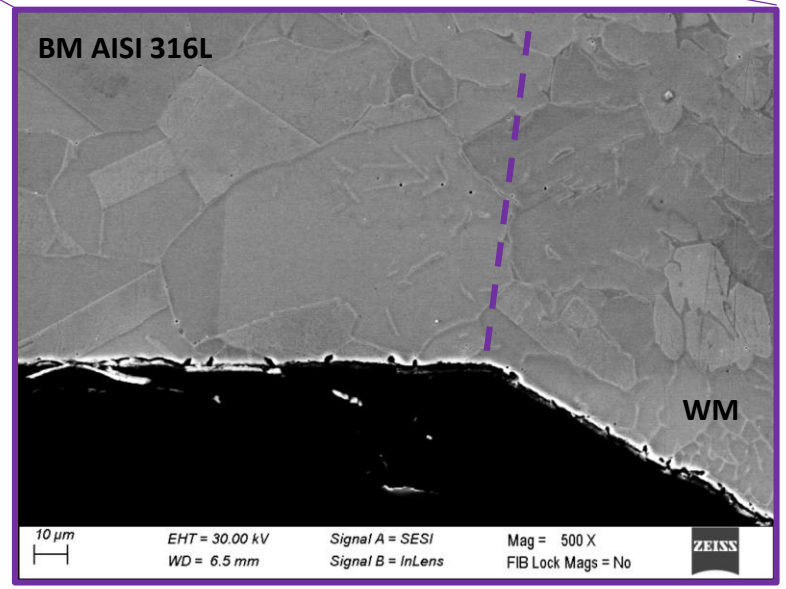
OM macrographs

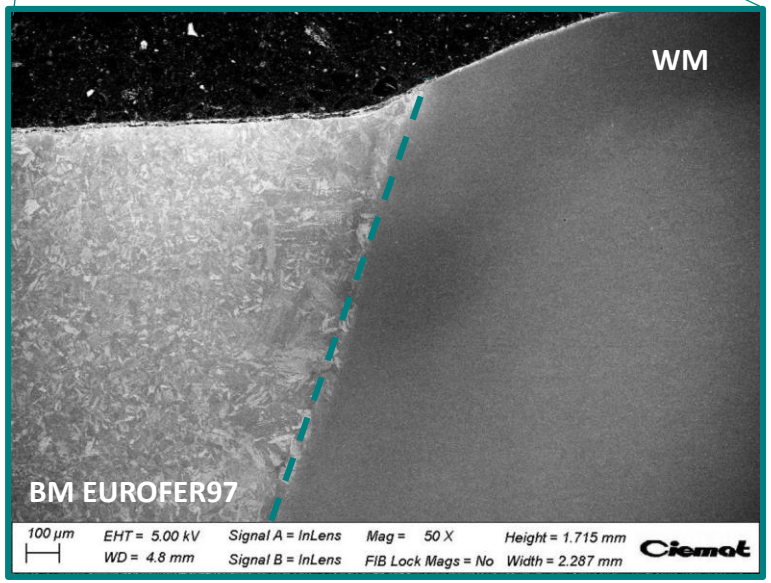
AISI 316Ti – EUROFER97



- ✓ Confirm **fully penetration** and **solid joint** without porosity or cracking, corroborating radiographic results.
- ✓ Clear **metallurgical transition** from austenitic stainless steel matrix to the martensitic structure of the EUROFER97.

SEM micrographs

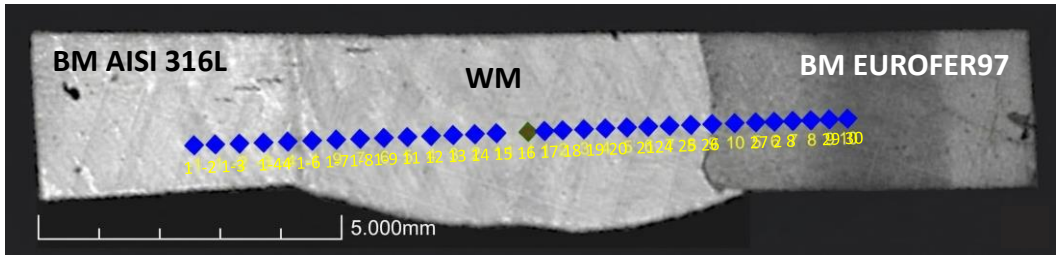


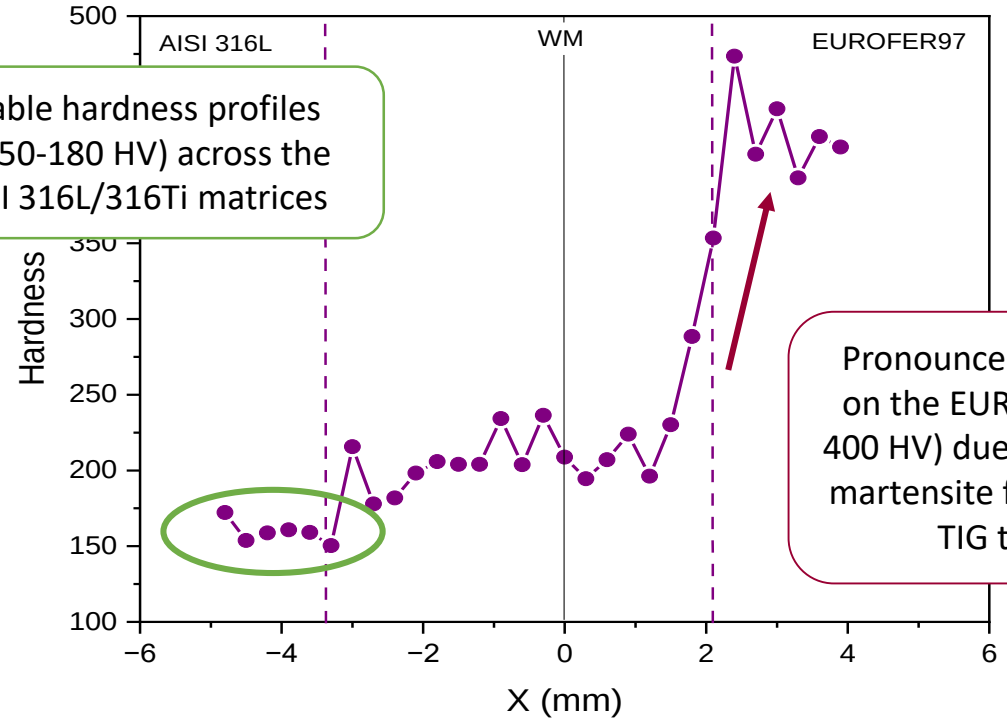


Mechanical characterization (as-welded condition)

Vickers microhardness Microhardness profiles **across the base materials**, **HAZ**, and **weld metal** under a load of 200 gf (HV0.2).

AISI 316L – EUROFER97

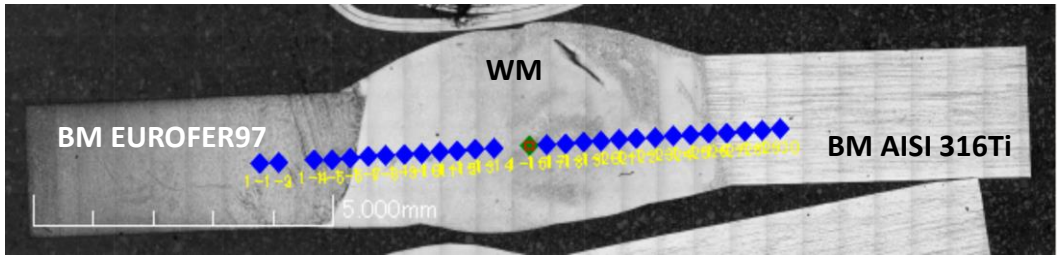


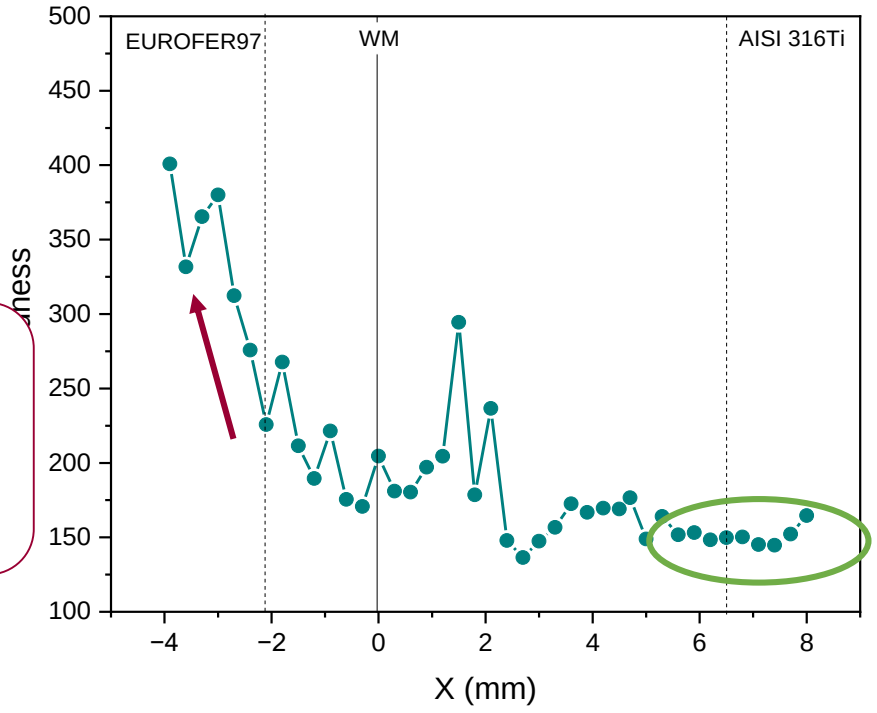


Stable hardness profiles (~150-180 HV) across the AISI 316L/316Ti matrices

Pronounced hardness increase on the EUROFER97 side (~350-400 HV) due to local untempered martensite formation during the TIG thermal cycle.

AISI 316Ti – EUROFER97



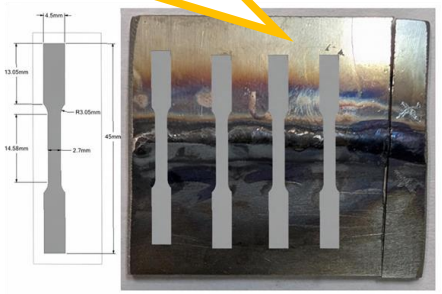


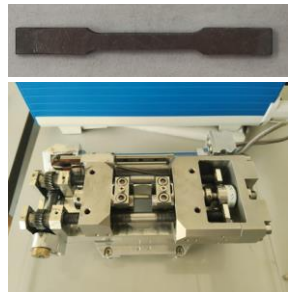
Mechanical characterization (as-welded condition)

Non-standard miniaturized specimen
geometry tailored to
experimental/volume constraint

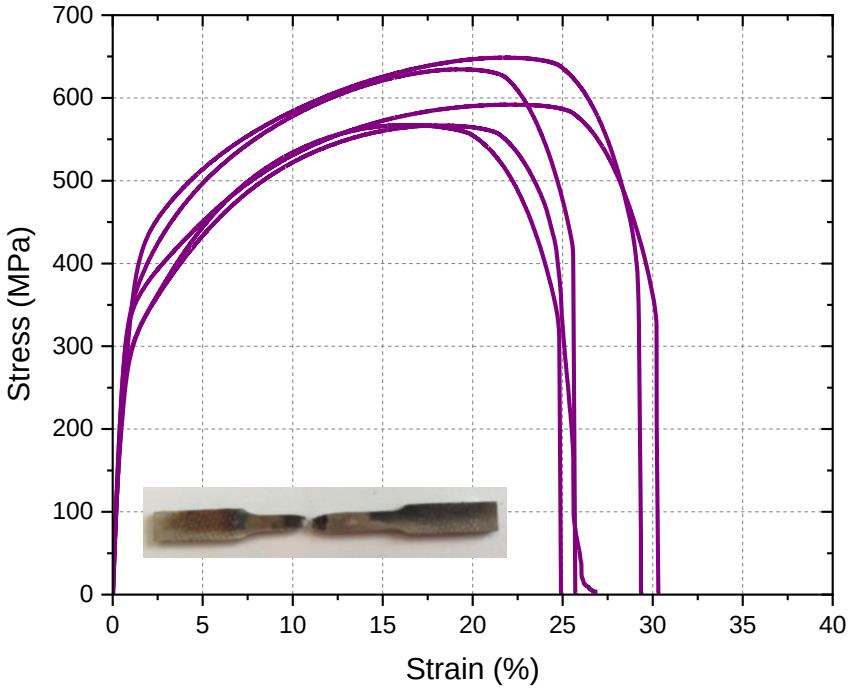


Tensile tests 5 specimens tested per joint as-welded

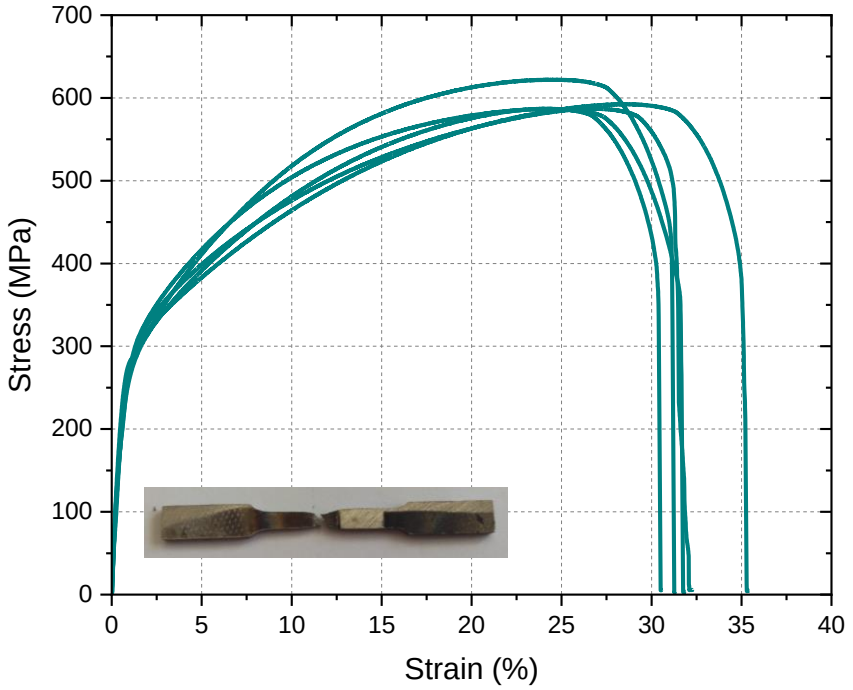




AISI 316L – EUROFER97



AISI 316Ti – EUROFER97



Sample	UTS (MPa)	ε at UTS (%)	ε at fracture (%)
As-welded	601,8 ± 38,0	19,6 ± 2,5	27,4 ± 2,3
As-welded	595,0 ± 15,3	25,6 ± 1,9	32,2 ± 1,8

***mean ± SD**

✓ **Consistent Tensile Behavior:** Highly reproducible tensile behavior for both 316L and 316Ti joints (~600 MPa UTS, good ductility).

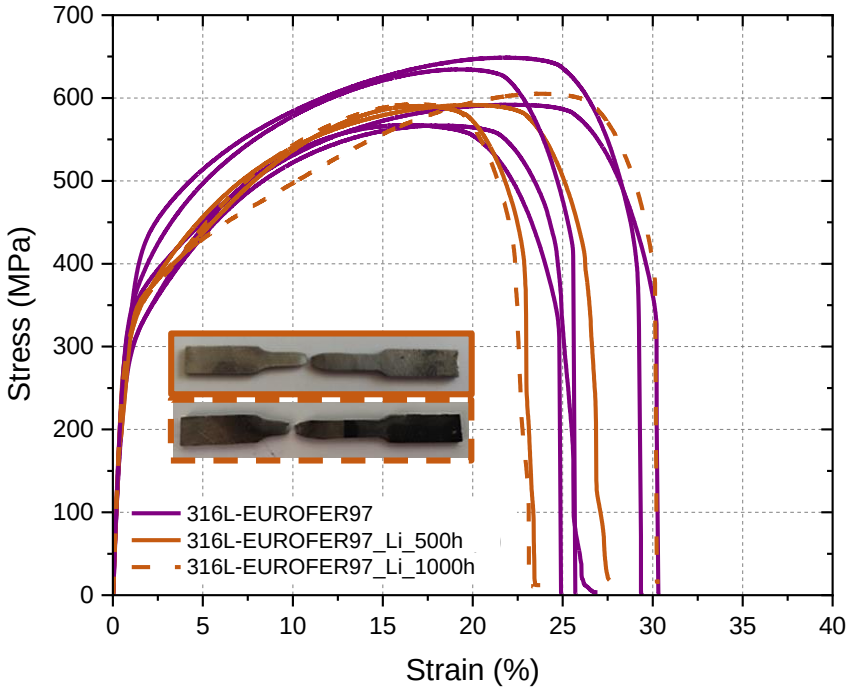
✓ **Failure Localization**: 100% of specimens failed in the austenitic stainless steel base metal (BM).

✓ **Structural Integrity**: The welded joint and interface are not the weakest link, validating initial joint integrity before Li exposure.

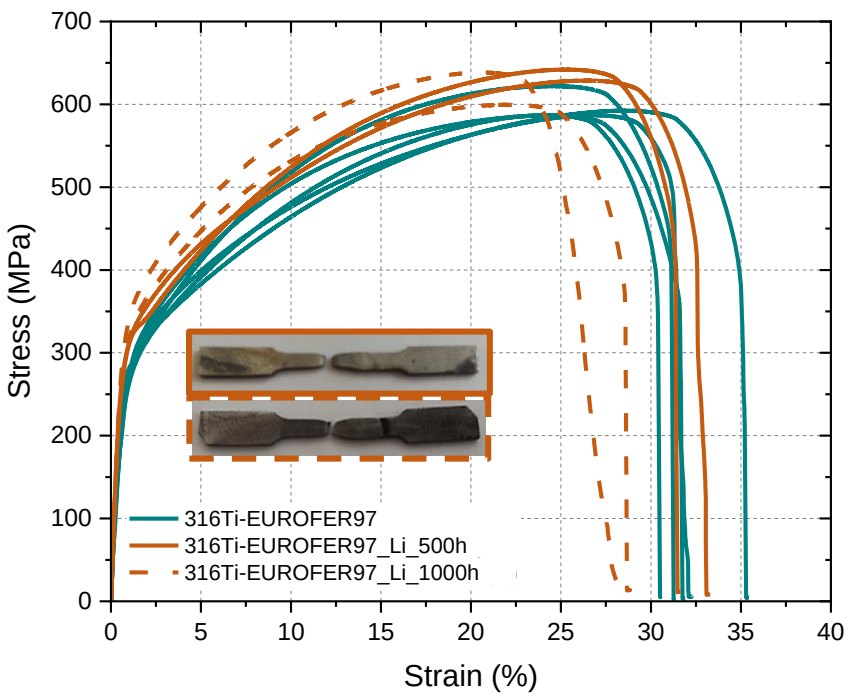
Mechanical characterization (after Li exposure)

Tensile tests 2 specimens tested per joint after Li exposure

AISI 316L – EUROFER97



AISI 316Ti – EUROFER97



Sample	UTS (MPa)	ε at UTS (%)	ε at fracture (%)
As-welded	601,8 ± 38,0	19,6 ± 2,5	27,4 ± 2,3
Li 500 h	591,1 ± 0,8	18,3 ± 1,9	25,5 ± 2,9
Li 1000h	598,6 ± 8,9	20,4 ± 4,8	30,3 ± 0,1
As-welded	595,0 ± 15,3	25,6 ± 1,9	32,2 ± 1,8
Li 500 h	635,3 ± 9,3	25,7 ± 1,0	32,3 ± 1,1
Li 1000 h	619,0 ± 27,5	21,2 ± 0,9	28,7± 0,1

***mean ± SD**

✓ **Failure location unchanged:** All post-exposure specimens continued to fracture in the austenitic base metal (316L / 316Ti), far from the fusion zone.

✓ **Key takeaway:** Under our testing conditions, static liquid Li does not compromise the structural integrity of the welded joints.

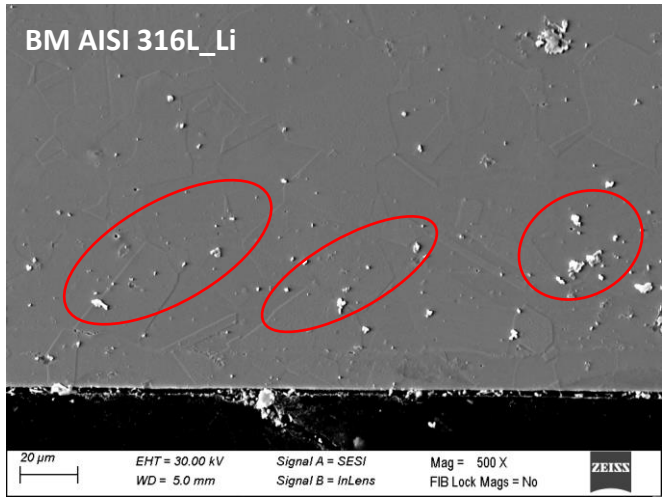
✓ **Preserved tensile behavior:** UTS and elongation remain essentially unchanged after 500 h and 1000 h of Li exposure compared to as-welded state.

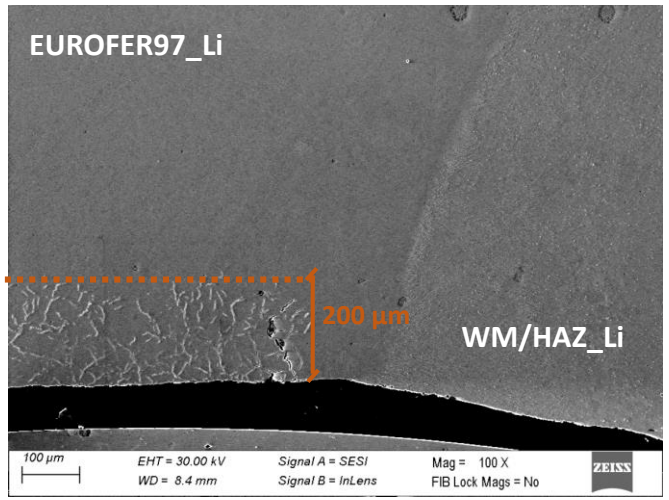
Microstructural characterization (after Li exposure)

AISI 316L – EUROFER97

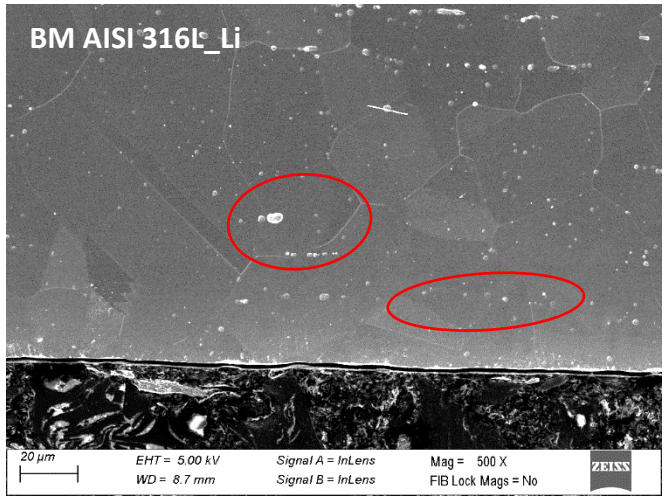
AISI 316Ti – EUROFER97

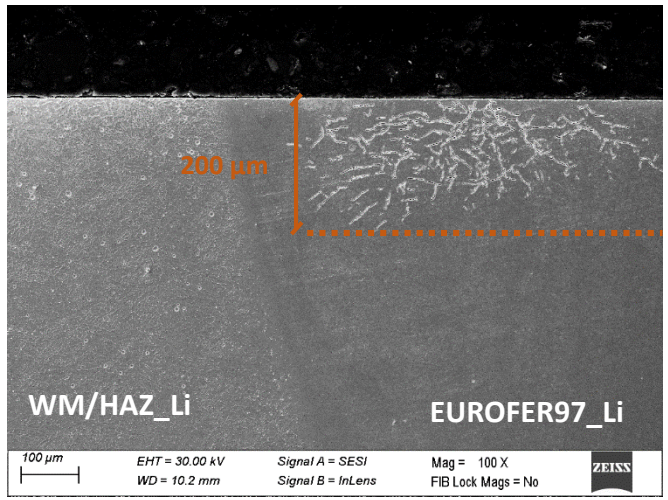
500 h





1000 h





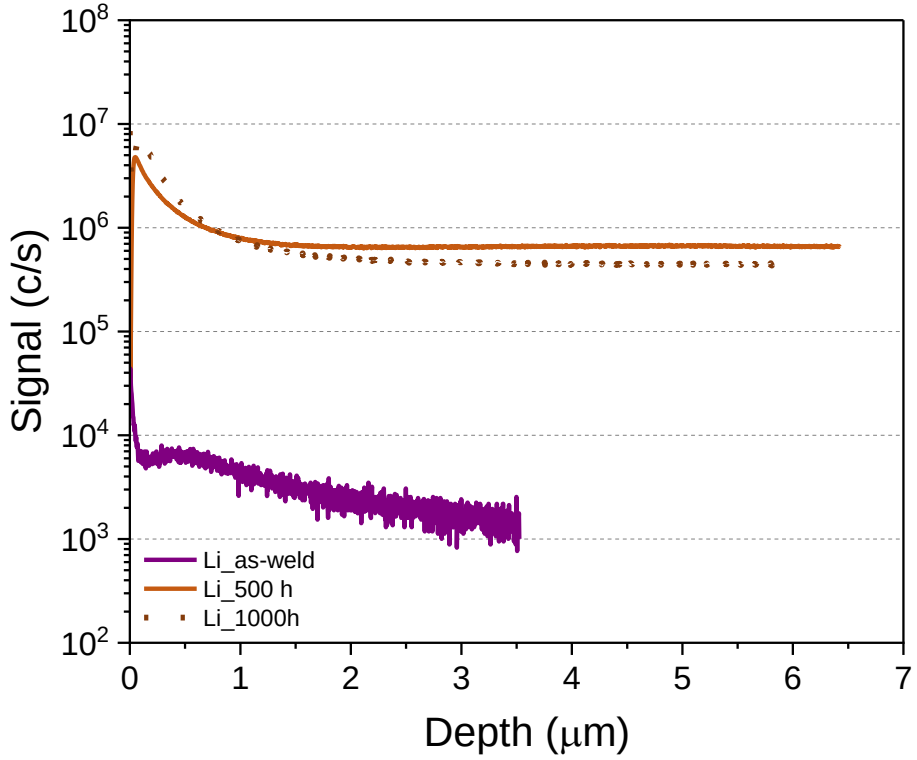
- ✓ **Austenitic side (316L shown):** Identical behavior across both 316L and 316Ti at 500 h and 1000 h → fine layer of precipitates confined to the surface.
- ✓ **EUROFER97 side (focus on 316Ti–EUROFER97)**: Distinct localized network of micro-cracks (not observed as clearly in 316L).
- ✓ **Open question:** Is this caused by liquid Li diffusion or assisted attack? We need to verify if Li actually penetrated → leads into SIMS.

SEM cross sections

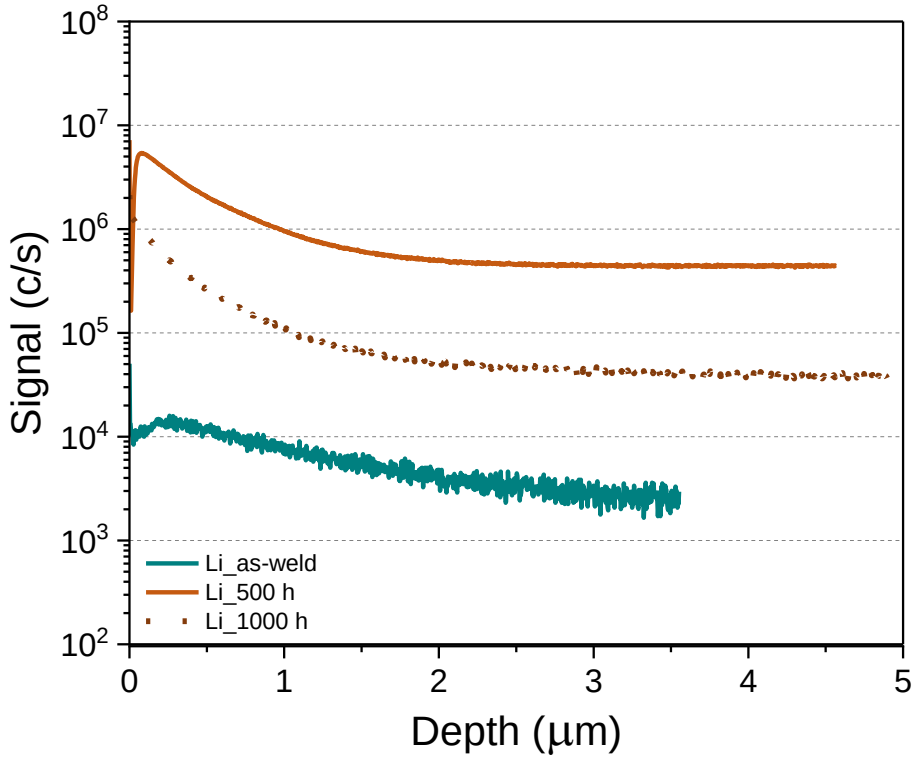
Compositional characterization (after Li exposure)

SIMS (Secondary ion mass spectrometry)

AISI 316L – EUROFER97



AISI 316Ti – EUROFER97



- ✓ **Lithium incorporation detected by SIMS:** profiles confirm a significant two-order-of-magnitude increase in lithium signal intensity at the surface compared to the as-welded baseline.
- ✓ **Depth Penetration**: Detection of lithium penetrating within the first shallow microns before the signal stabilizes → Proved Li is actively present.

Conclusions and future outlook

Preserved joint integrity

- Defect-free dissimilar welds with mechanical properties fully preserved before and after Li exposure (500 h / 1000 h; failure always in the austenitic base metal).

Confirmed surface Li uptake (SIMS)

- SIMS verified active interstitial Li penetration in the near-surface layer, confirming environmental interaction without macroscopic bulk degradation.

Wettability & protocol refinement

- Incomplete Li wetting during static exposure highlights the need to optimize the crucible loading protocol in HELIOS to guarantee uniform immersion. Localized crack-like features observed in 316Ti–EUROFER97 joints, requiring deeper microstructural investigations (e.g., EBSD/TEM).

Crack mechanism clarification

- Further advanced microstructural analyses (EBSD, TEM) are required to investigate the origin of localized micro-cracks in 316Ti joints.

Irradiation campaigns

- Future campaigns must evaluate these joints under neutron irradiation to benchmark against full DONES operating conditions.



Thank you for your attention!

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National Fusion Laboratory - CIEMAT

RODAS

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EUROfusion

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