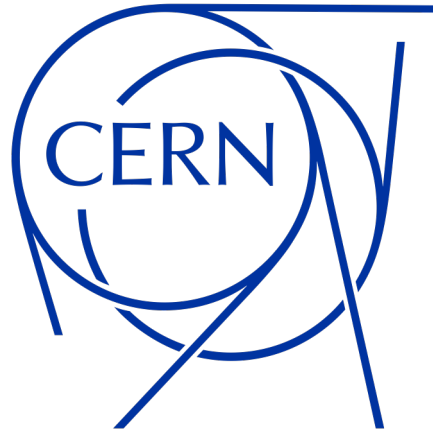




Ferritic stainless steels for next-generation GWT

Carlo Scarcia

2025/09/30

Ferritic stainless steels

ASTM A 240				JIS G 4305				EN 10088-2				
	R _m min	R _{p02} min	A ₅ min		R _m min	R _{p02} min	A ₅ min			R _m	R _{p02} min	A ₈₀ min
409	380	170	20	--	--	--	--	X2CrTi2	1.4512	380-560	220	25
410S	415	205	22	SUS 410	440	205	20	X2CrNi12	1.4003	450-650	320	20
430	450	205	22	SUS 430	420	205	22	X6Cr17	1.4016	450-600	280	18
434	450	240	22	SUS 434	450	205	22	X6CrMo17-1	1.4113	450-630	280	18
436	450	240	22	SUS 436	410	245	20	X6CrMoNb17-1	1.4526	480-560	300	25
439	415	205	22	--	--	--	--	X2CrTi17	1.4520	380-530	200	24
439	415	205	22	--	--	--	--	X2CrTi17	1.4510	420-600	240	23
441	415	205	22	--	--	--	--	X2CrMoNb18	1.4509	430-630	250	18
S44400 (444)	415	275	20	SUS 444	410	245	20	X2CrMoTi18-2	1.4521	420-640	320	20
304	515	205	40	SUS 304	520	205	40	X5CrNi1-80	1.4301	540-750	230	45



Professional griddle, in grade 430.
Picture courtesy of Lincat Limited, Lincoln, UK

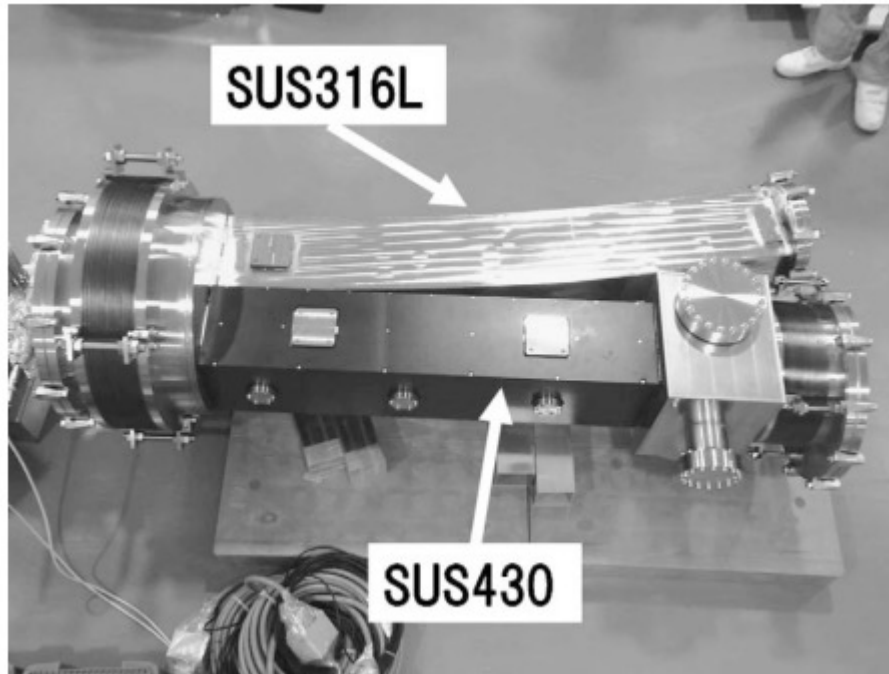


Outer Wall of the Planetarium at the Nagoya City Science Museum
Picture courtesy of the Japan Stainless Steel Association

Source of table and pictures: world stainless association

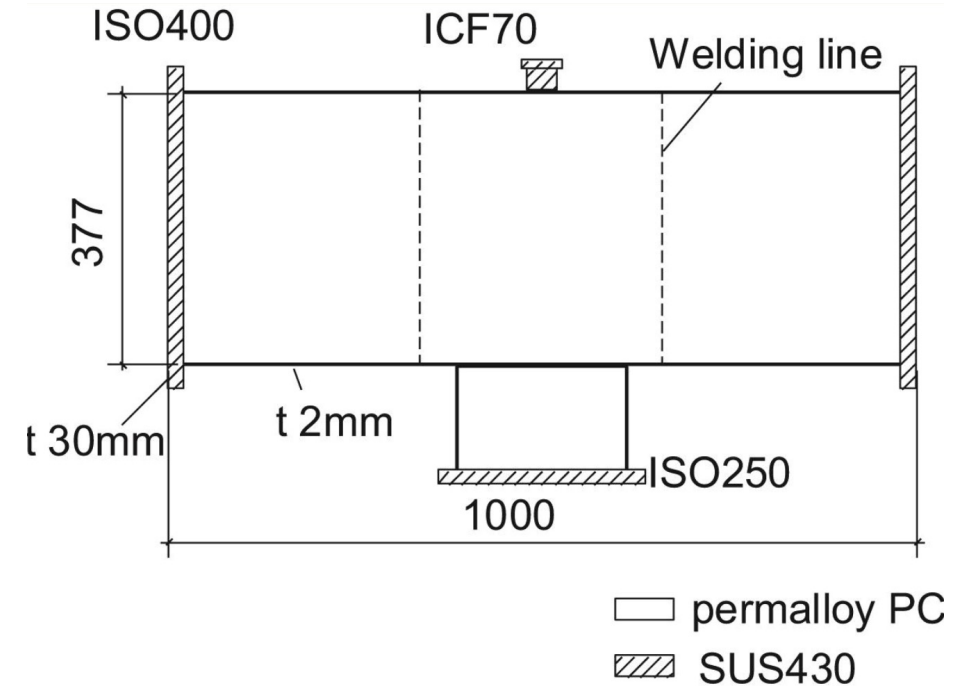
Ferritic stainless steels in UHV applications

Literature review: only two articles (same group) reporting on UHV studies on ferritic stainless steels.



AISI 430 vacuum chamber with magnetic shielding properties (stray magnetic fields)

[1] Kato S. *et al.*, J. Vac. Soc. J. 55, 160–163 (2012).



AISI 430 flanges with magnetic shielding properties (stray magnetic fields)

[2] Kamiya J. *et al.*, Vacuum 98, 12–17 (2013).

Ferritic stainless steels in UHV applications

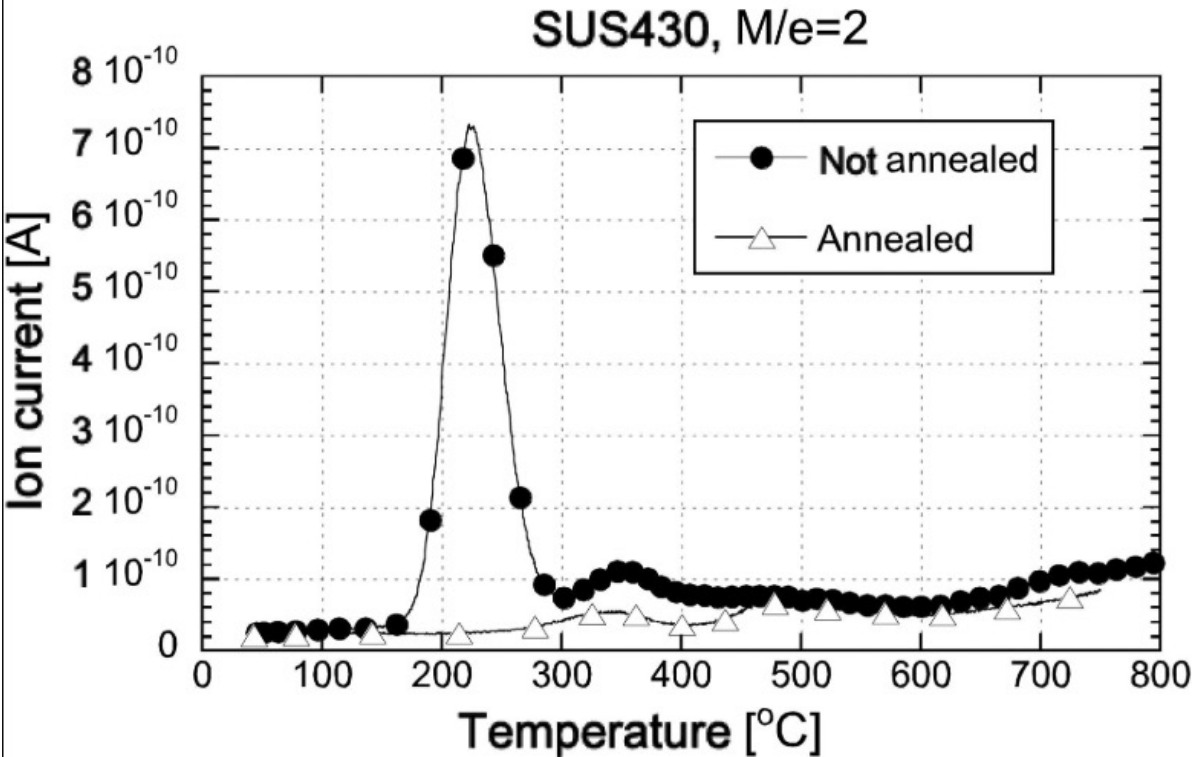
H₂ content [2]

Hydrogen content estimated by the integration of the TDS spectra.

Material	H content w/o heat treatment [wt. ppm]	H content after annealing [wt. ppm]
SUS430	0.04	0.01
SUS316L	0.50	0.01

Annealing at 850 °C, 10 h ($P_{\text{max}} \sim 10^{-5}$ mbar) to restore magnetic properties.

Thermal desorption spectroscopy (0.2 K/s)
(thickness 0.2 mm (??))



Ferritic stainless steels for GWD^[3]

Chemical composition and cleaning

Chemical composition in wt. %
AISI 304L chemical composition is to be intended as the maximum content allowed^[4].
CR, cold rolled; HR, hot rolled; RA, recrystallization annealed; and SA, solution annealed.

No Bright Annealed (BA) finishing due to H₂ rich environment during heating (H₂ pick up)

All the alloys were cleaned w/ detergent cleaning bath (alkaline solution)^[5]

	AISI 441	AISI 441	AISI 444	AISI 304L
Forming process	CR	HR	CR	CR
Heat treatment	RA	RA	RA	SA
Surface finish	2B	2D	2D	2D
Shape	Sheet	Sheet	Sheet	Sheet
Thickness (cm)	0.15	0.3	0.15	0.15
C	0.015		0.011	0.03
Mn	0.385		0.3	2.0
Si	0.584		0.38	1.0
S	0.001		0.0014	—
P	0.0029		0.0029	0.03
N	0.014		0.016	0.02
Cr	17.57		18.89	17–20
Ni	0.242		—	10–12.5
Mo	—		1.892	—
Ti	0.16		0.006	—
Nb	0.4		0.566	—
Fe	Remainder		Remainder	Remainder

[3] C. Scarcia *et al.* *J. Vac. Sci. Technol. B* 43, 044203 (2025)

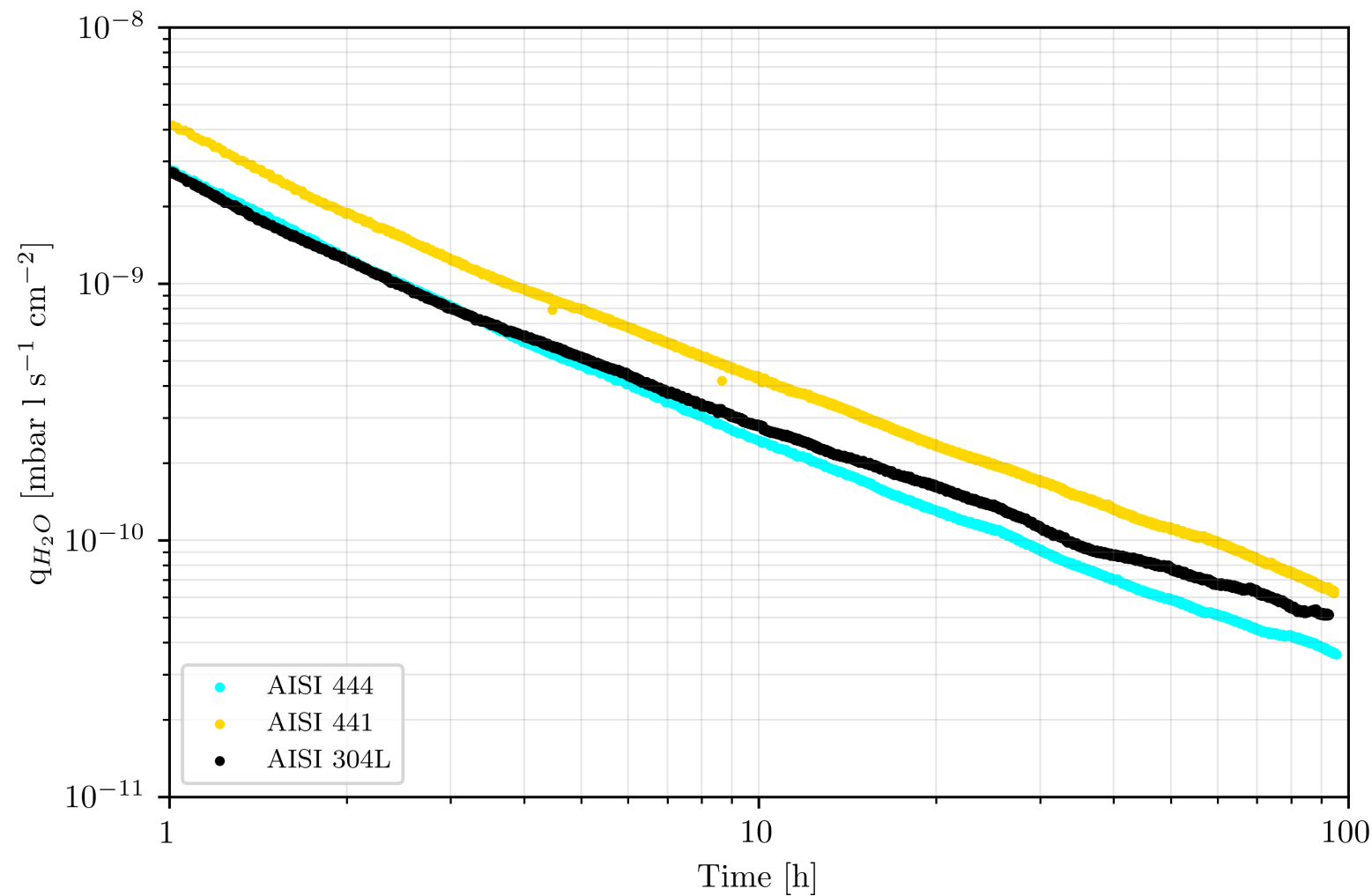
[4] GS-IS & EN-MME, “Stainless steel sheets/plates for vacuum applications,” Technical Specification No. 1004—1.4306, EDMS No. 790767, Technical Report, 2013

[5] M. Malabaila and L. Ferreira, “Operating procedure for chemical degreasing of parts for high-vacuum and ultra-high-vacuum applications,” EDMS No. 1390437 v.3, Technical Report, 2022

Ferritic stainless steels for GWD^[3]

Throughput method

Sample	$q_{10h} (x 10^{-10})$ [mbar l s ⁻¹ cm ⁻²]
AISI 444	2.4
AISI 441	4.3
304L	3.3

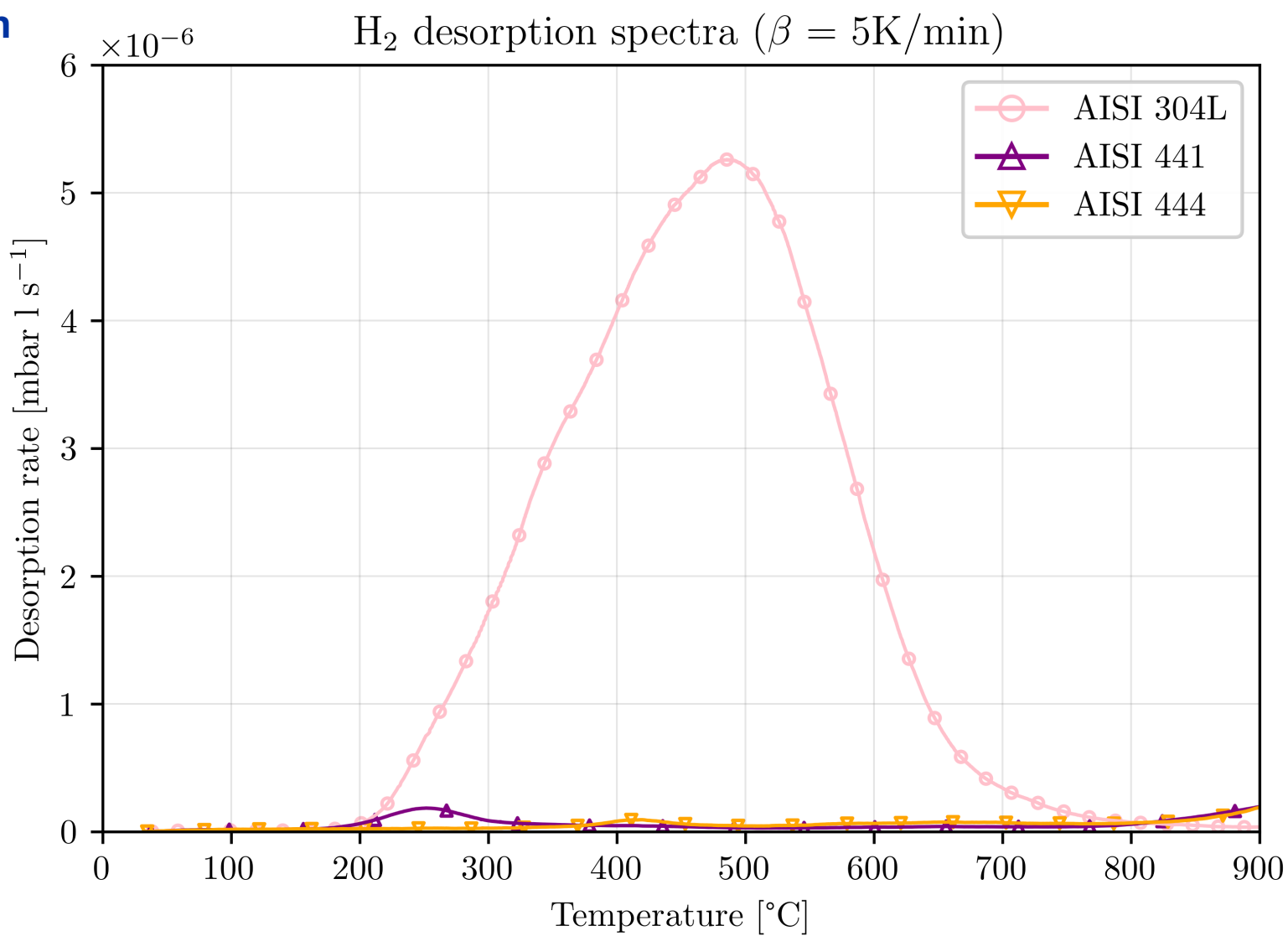


Ferritic stainless steels for GWD^[3]

Temperature programmed desorption
(TPD)

Steel grade	H ₂ content [ppm at.]	Thickness [cm]
304L	70	0.15
AISI 441	1.7	
AISI 444	1.5	

Concentration calculated from quantity of H₂
(considered to be uniformly distributed) extracted with TPD
(up to 850°C).
Background removed.

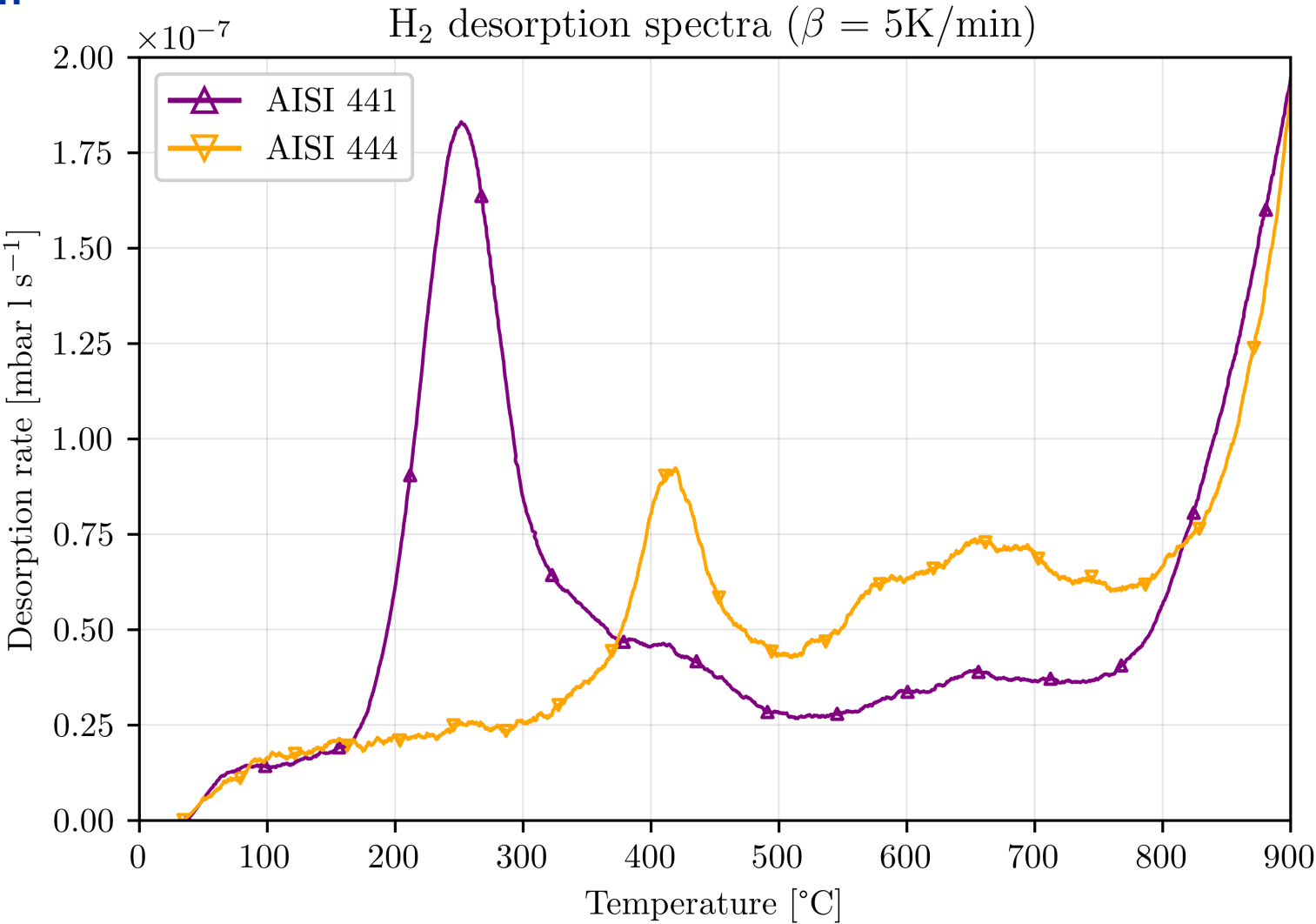


Ferritic stainless steels for GWD^[3]

Temperature programmed desorption
(TPD)

Steel grade	H ₂ content [ppm at.]	Thickness [cm]	Surface finishing
AISI 441	1.7	0.15	2B
AISI 444	1.3		2D

Concentration calculated from quantity of H₂
(considered to be uniformly distributed) extracted with TPD
(up to 850°C).
Background removed.

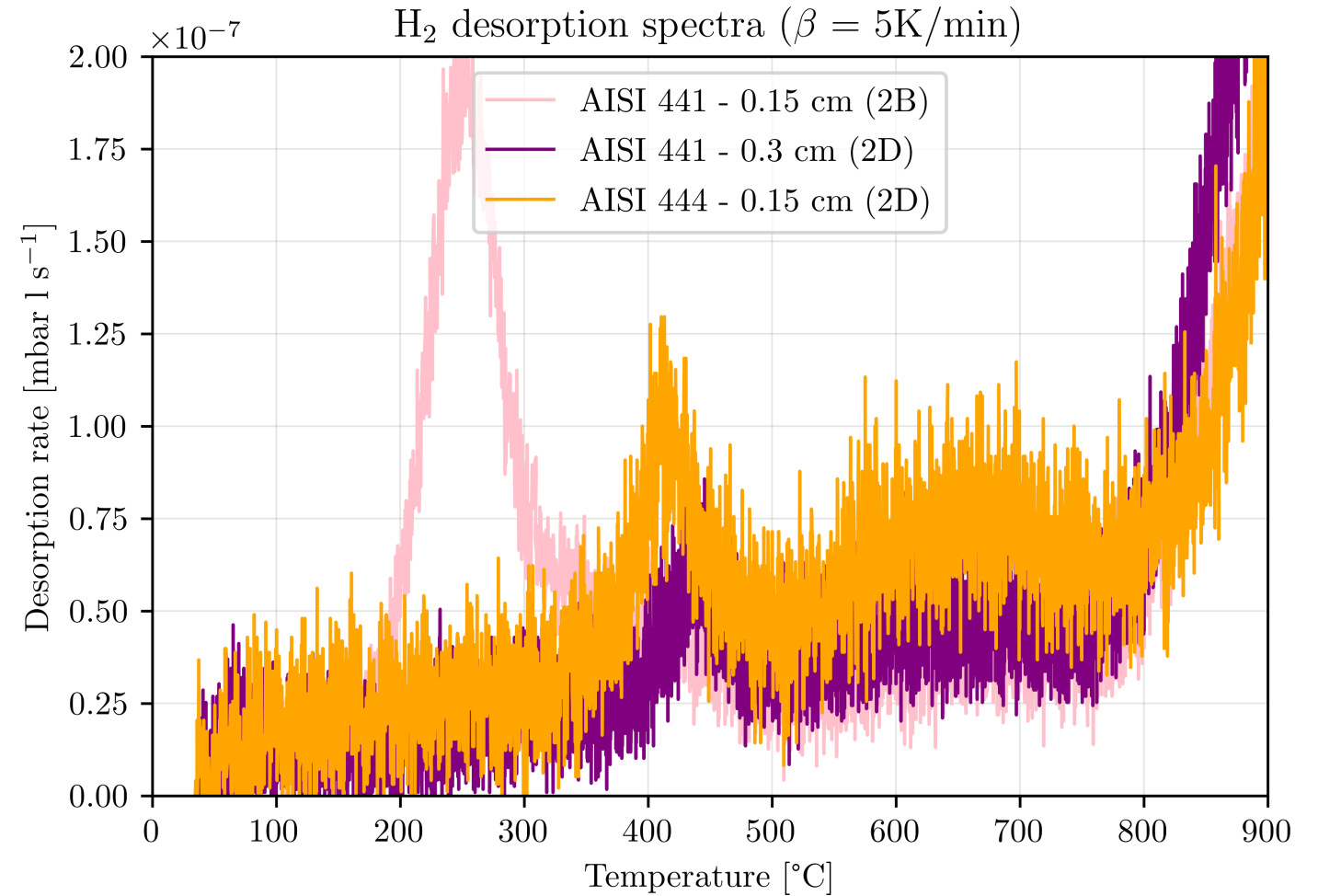


Ferritic stainless steels for GWD^[3]

Temperature programmed desorption
(TPD)

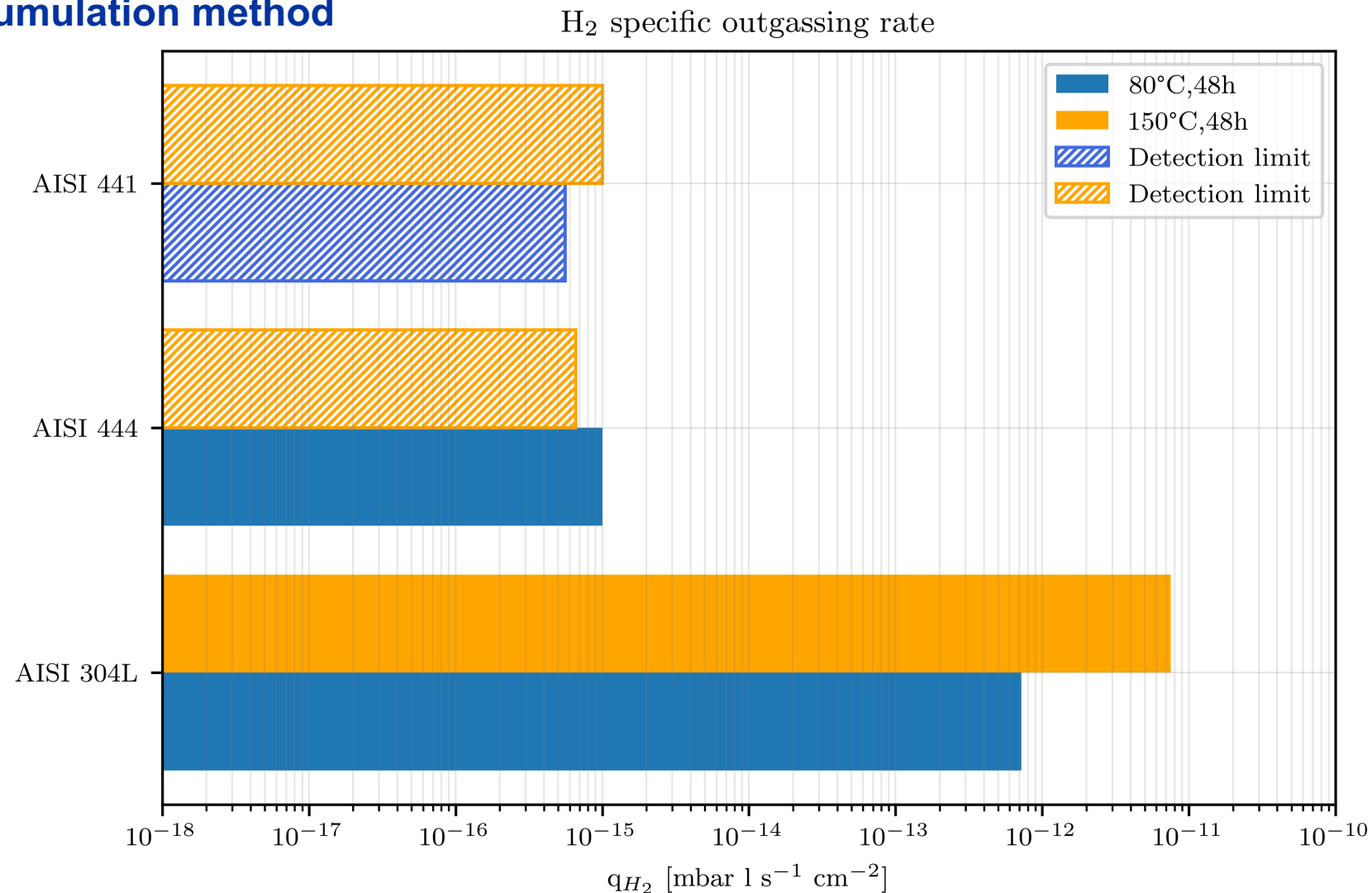
De-trapping desorption process.

Minor influence, but present, of different
surface finishings.



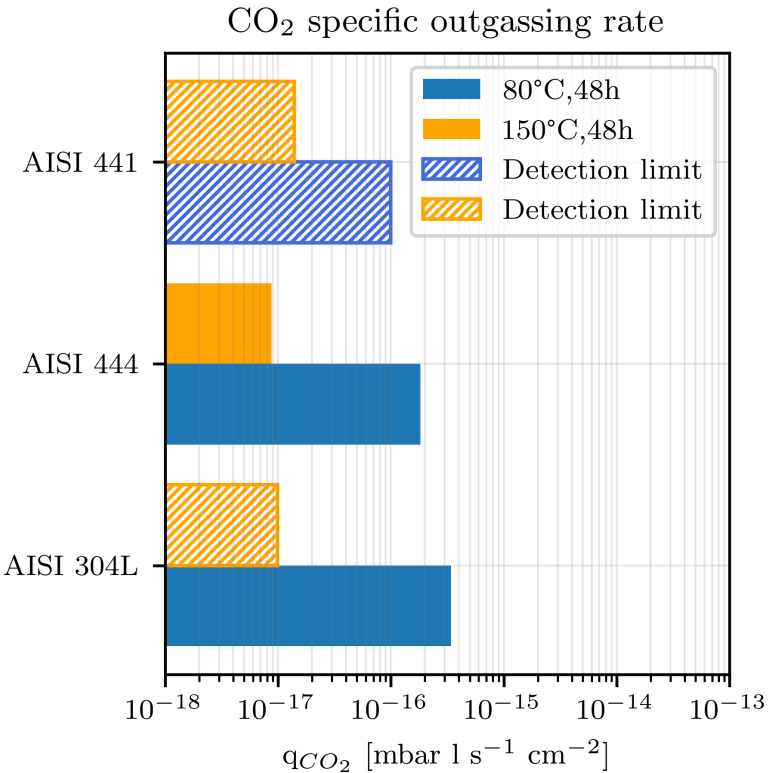
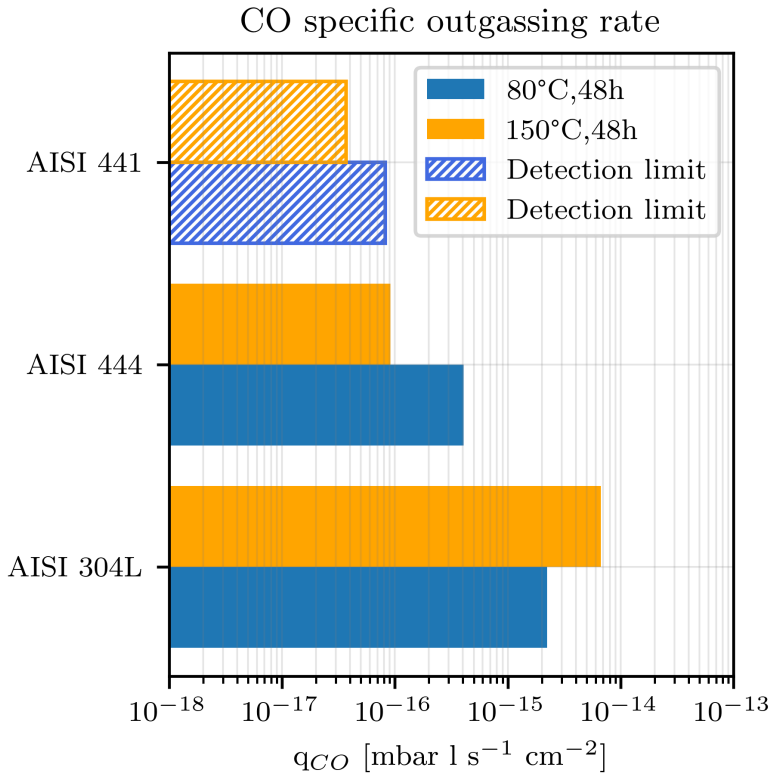
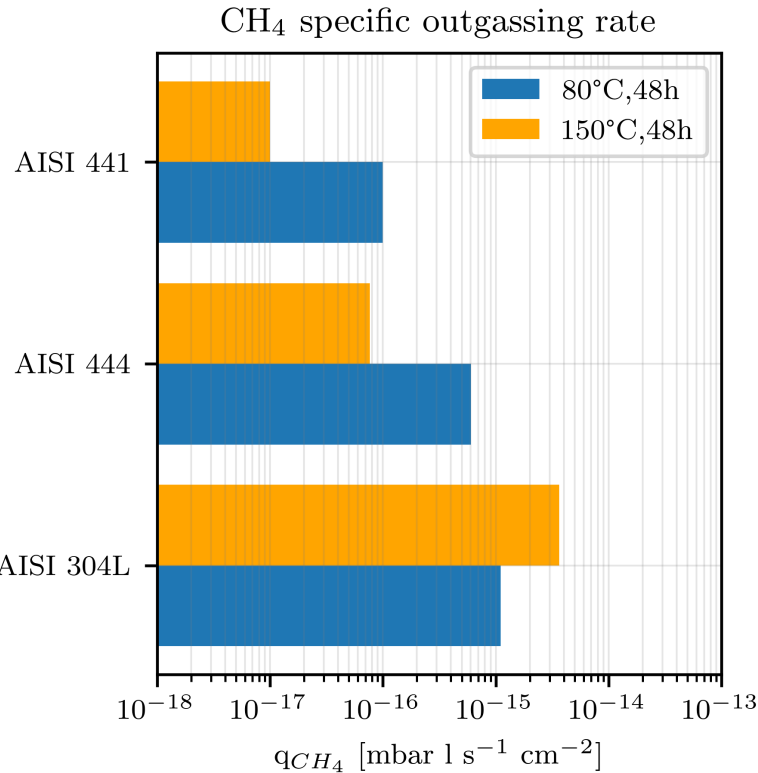
Ferritic stainless steels for GWD^[3]

Throughput-accumulation method



Background removed. Measurement error: ±40%; Detection limit: 50% of background.

Ferritic stainless steels for GWD^[3]



Background removed. Measurement error: $\pm 40\%$; Detection limit: 50% of background.



Conclusions

- **Ferritic stainless steels are compatible with UHV applications.**
As received, their bulk H₂ outgassing rates outperform the austenitic stainless steels currently used in GWDs by several orders of magnitude.
 - **Outgassing rates of ferritic alloys are more susceptible to surface quality rather than bulk.**
 - **H₂ desorption de-trapping limited**

The application of ferritic stainless steels as structural material for next-gen GWDs beampipes is now mainly dictated by construction and operational aspects (formability, weldability and corrosion resistance).

Thanks for your attention



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