

Oxidation of Materials and Coatings at 1000 °C and 250 bar for use in Oxy- Combustion Turbine

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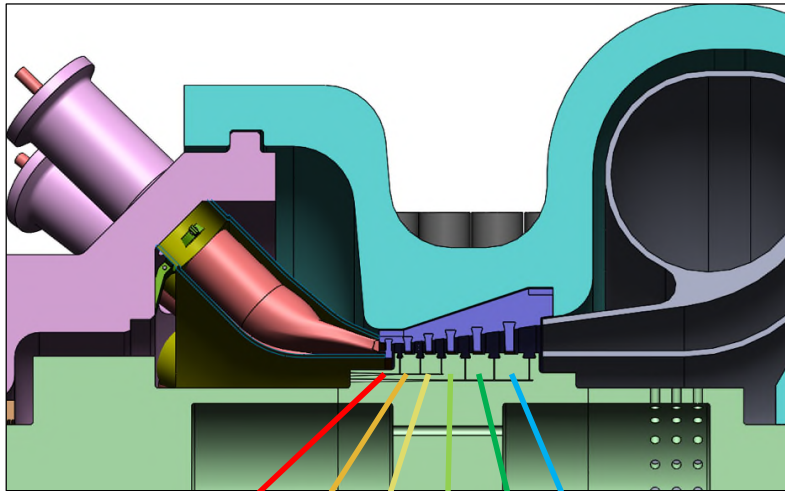
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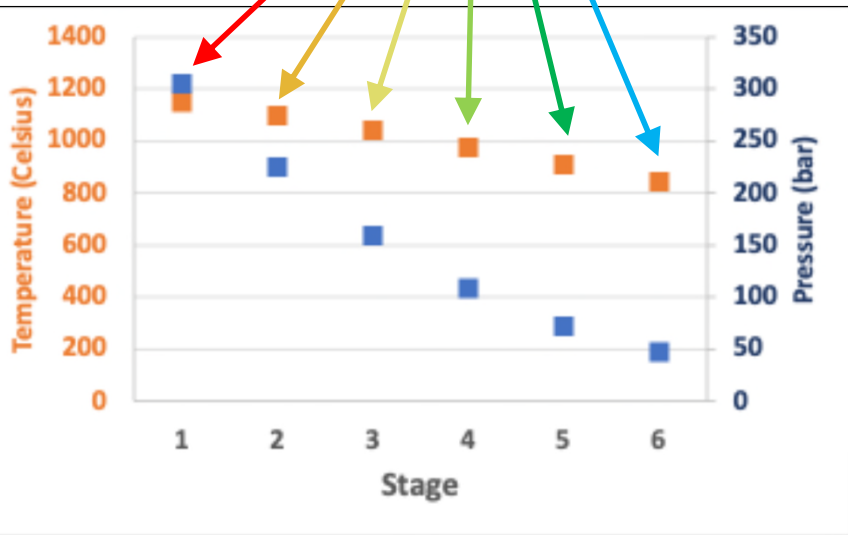
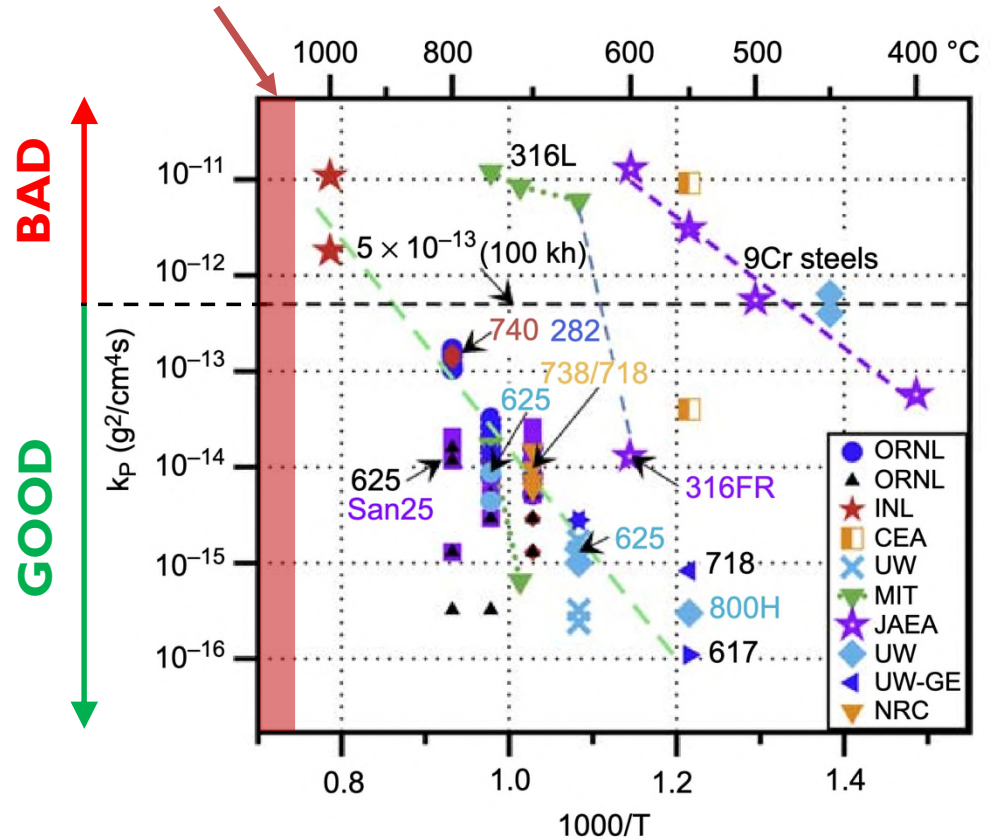
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Pushing materials to their limits

Inlet: 1,150 °C at 300 bar



B..A. Pint and R.G. Brese (2017). High-temperature materials. In K. Brun, P. Friedman, R. Dennis (Eds.), Fundamentals and Applications of Supercritical Carbon Dioxide Based Power Cycles.



Focusing on oxidation at high temperature

- Three consecutive exposures of 500 hours each
- Supercritical CO₂ at 1,000 °C and 3,500 – 4,000 psi
- Mass change measurements
- 6 alloys
- 3 coatings configurations



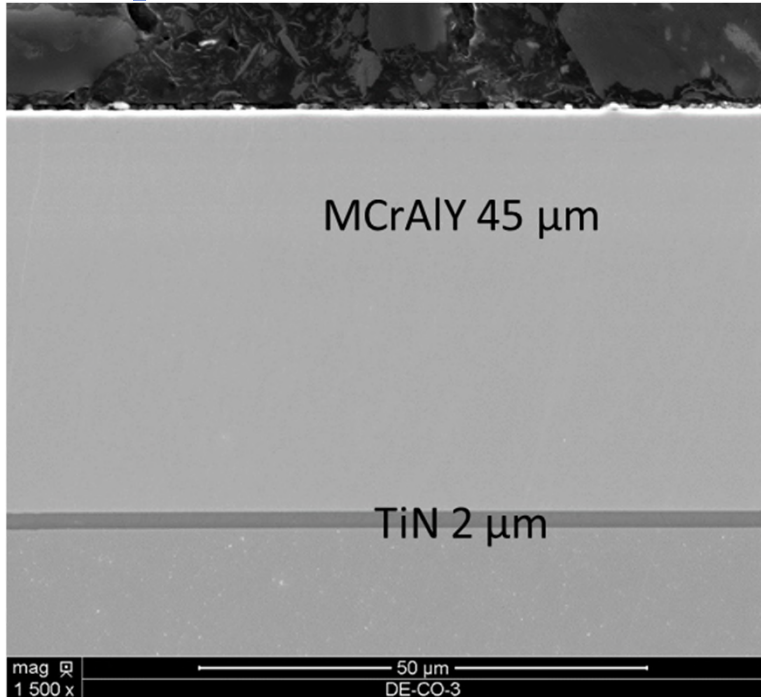
Bare and coated alloys were tested

Alloy (UNS)	Description	Bare	NC BC	NC BC & TBC	TS BC & TBC
740 (N07740)	Age hardened chromia former <u>nickel alloy</u>	3	3	3	3
625 (N06625)	Baseline <u>nickel-chromium alloy</u>	3	3	3	3
282 (N07208)	Wrought, gamma-prime strengthened <u>Ni superalloy</u>	3	3	3	3
APMT Kanthal	Dispersion strengthened <u>ferritic</u> Fe-Cr-Al alloy	3	3	-	-
353 MA (S35315)	Austenitic, chromium-nickel <u>stainless steel</u>	3	3	-	-
Sanicro 25 (S31035)	Austenitic 22Cr25NiWCoCu <u>stainless steel</u>	3	3	-	-



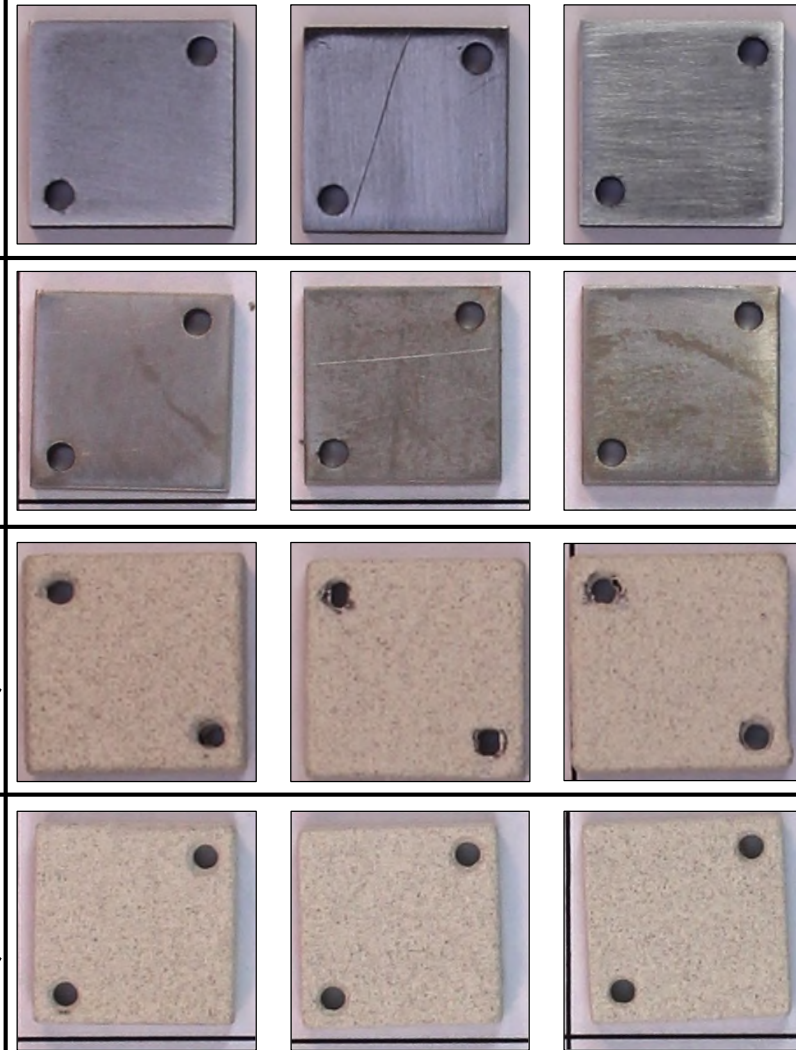
Example of unexposed samples

Alloy 282



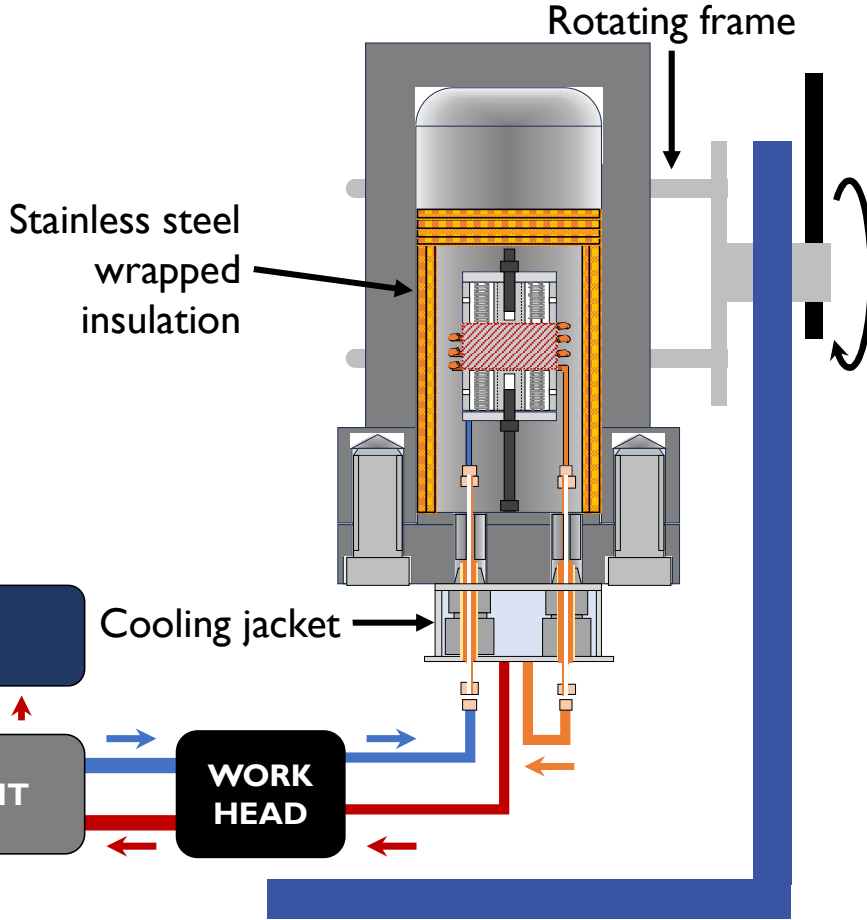
- 2 μm TiN interlayer layer
- Nanocrystalline bond coat by sputtering a $\text{Ni}_{20}\text{Cr}_{10}\text{Al}_{0.15}\text{Y}$ target in Ar.

- Bare
- Nanocrystalline bond coat
- Thermal spray bond coat
- Thermal barrier coating
- Nanocrystalline bond coat
- Thermal barrier coating



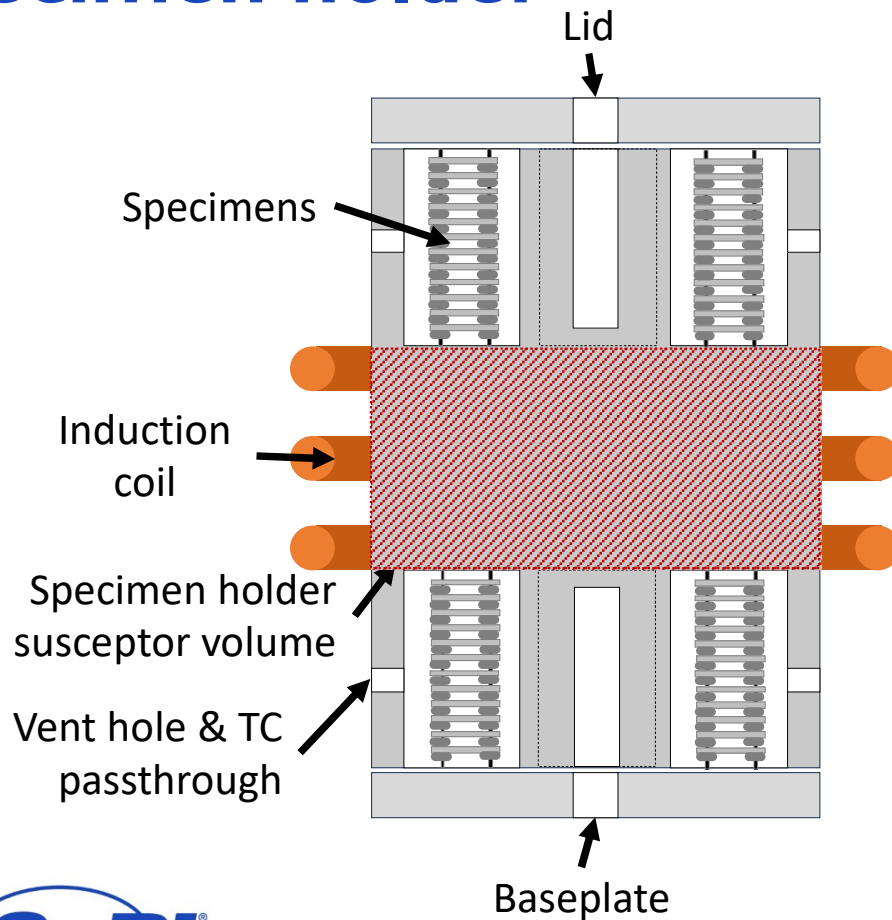
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Using induction heating in pressure vessel



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Maintaining stable $s\text{CO}_2$ conditions with custom specimen holder

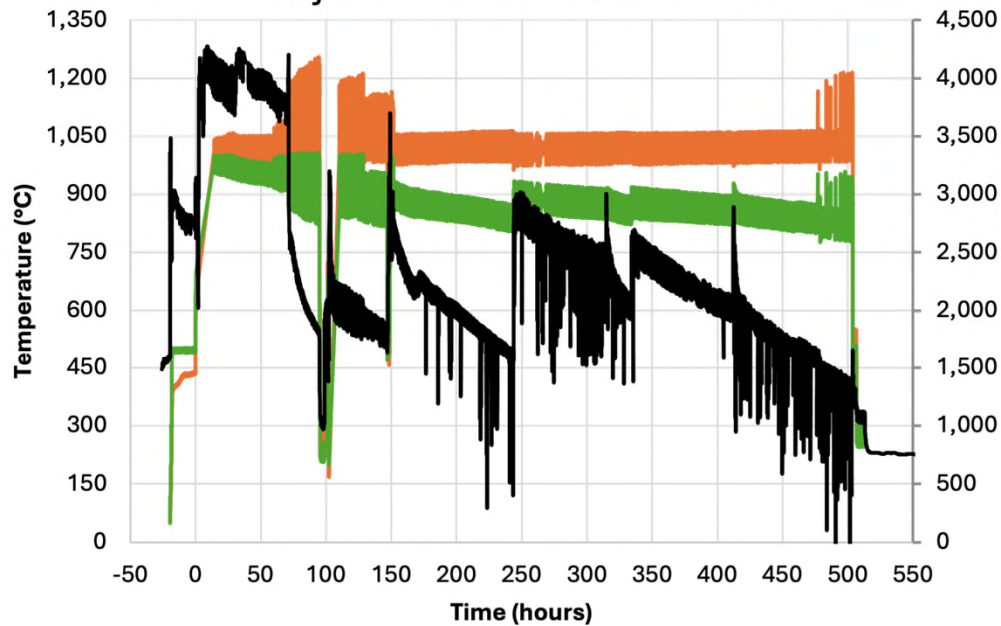


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Achieving temperature and pressure

Run 1:

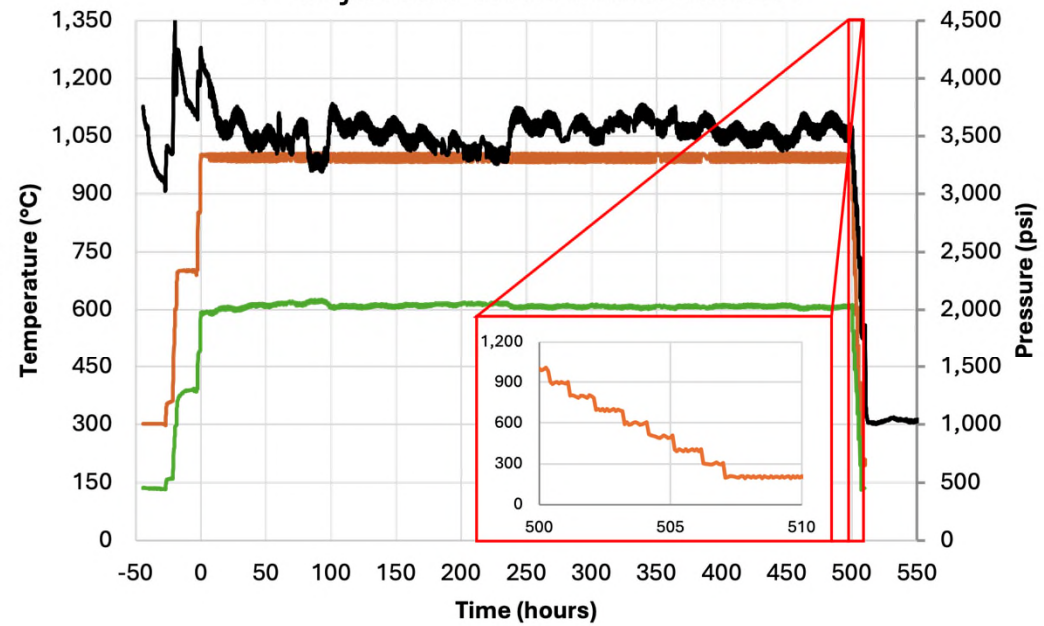
- Leakage at coil fitting → P decreased
- $\Delta T \sim 75 \text{ }^\circ\text{C}$
- P adjusted with accumulator



— High temperature (°C) — Mid temperature (°C) — Pressure (PSI)

Run 2:

- Reduced leakage
- More stable T & P ($\Delta T \sim 20 \text{ }^\circ\text{C}$)
- P adjusted with accumulator

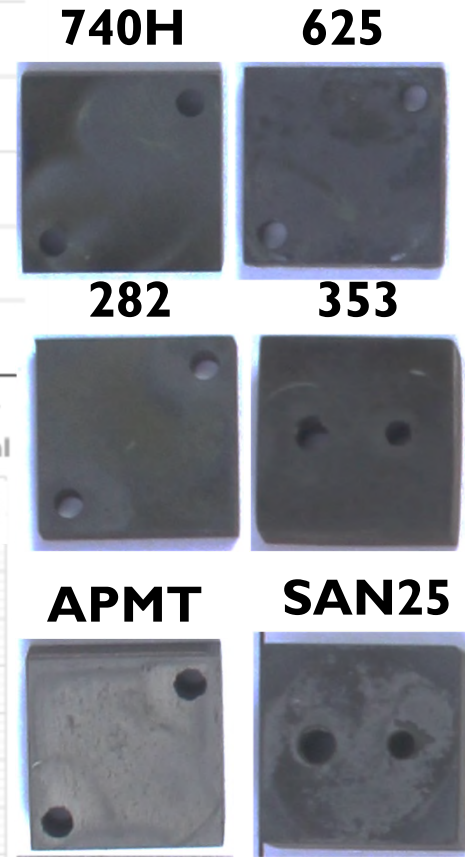
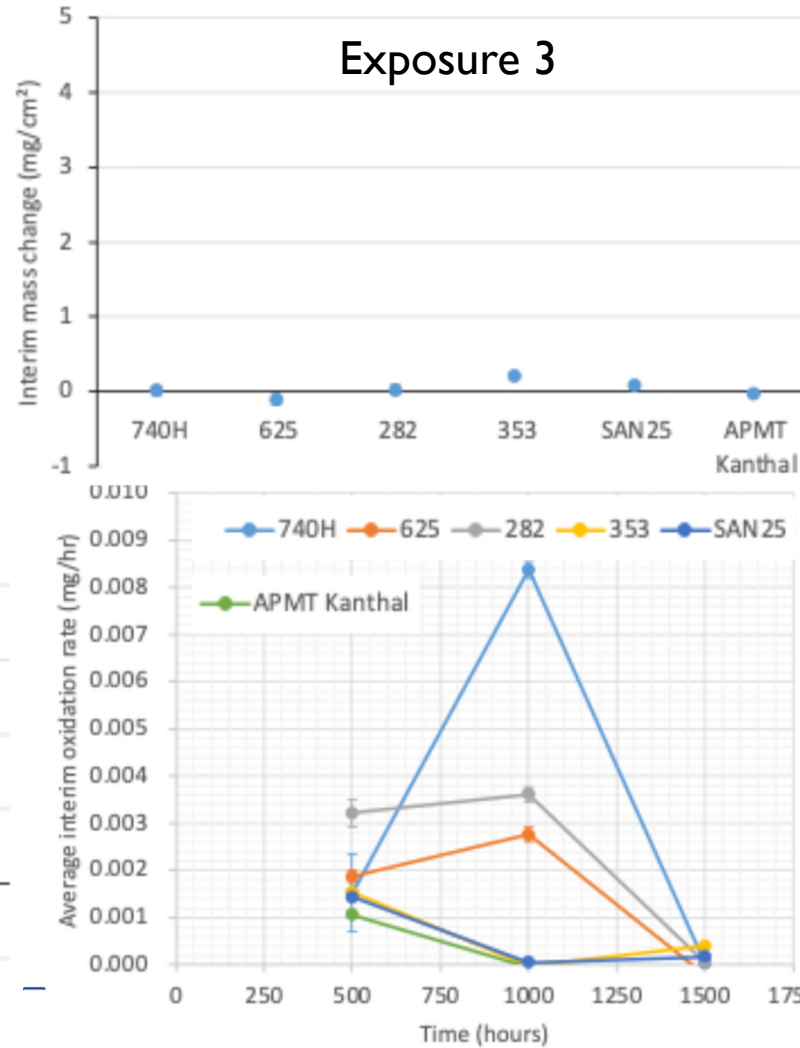
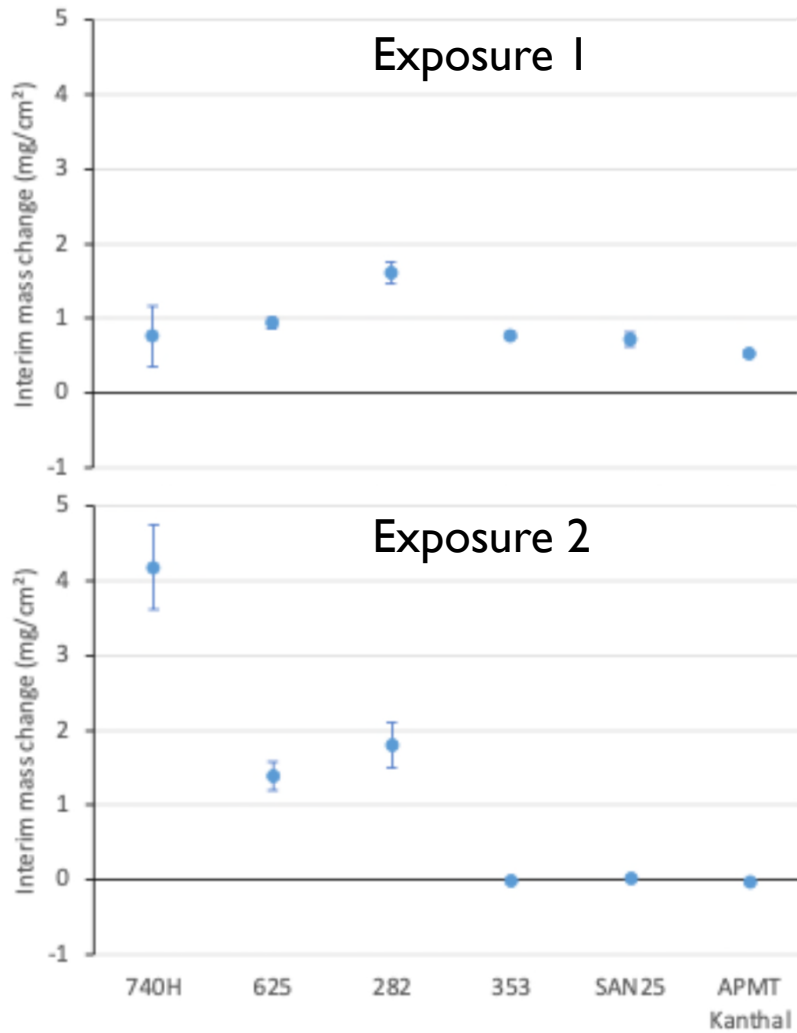


— High temperature (°C) — Mid temperature (°C) — Pressure (psi)

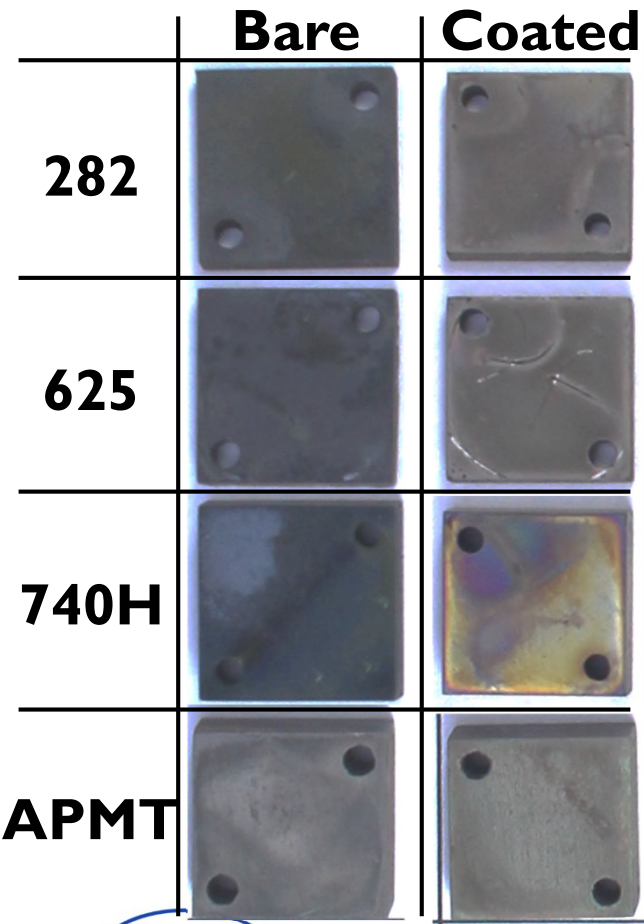


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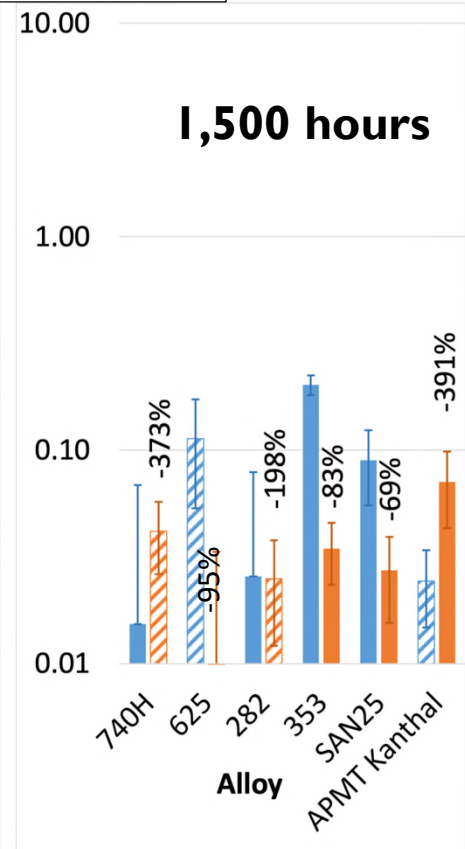
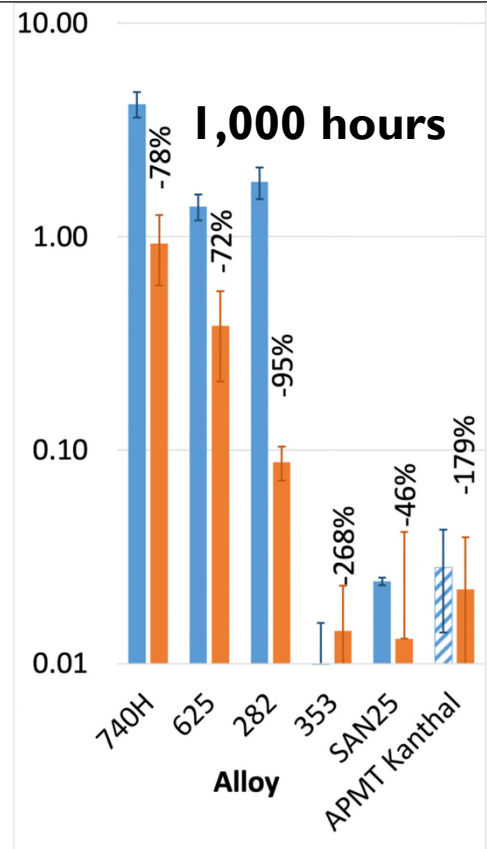
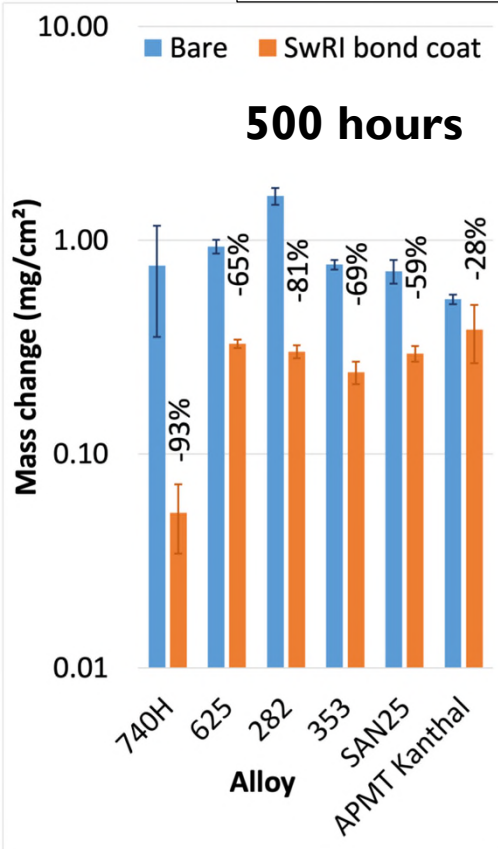
More oxidation found on bare Ni alloys than Fe alloys



Nanocrystalline MCrAlY bond coat improved oxidation resistance

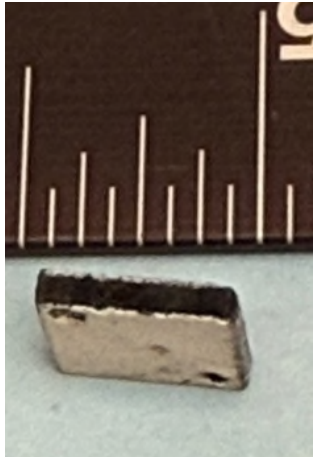


Legend: Plain: mass gain Pattern: mass loss

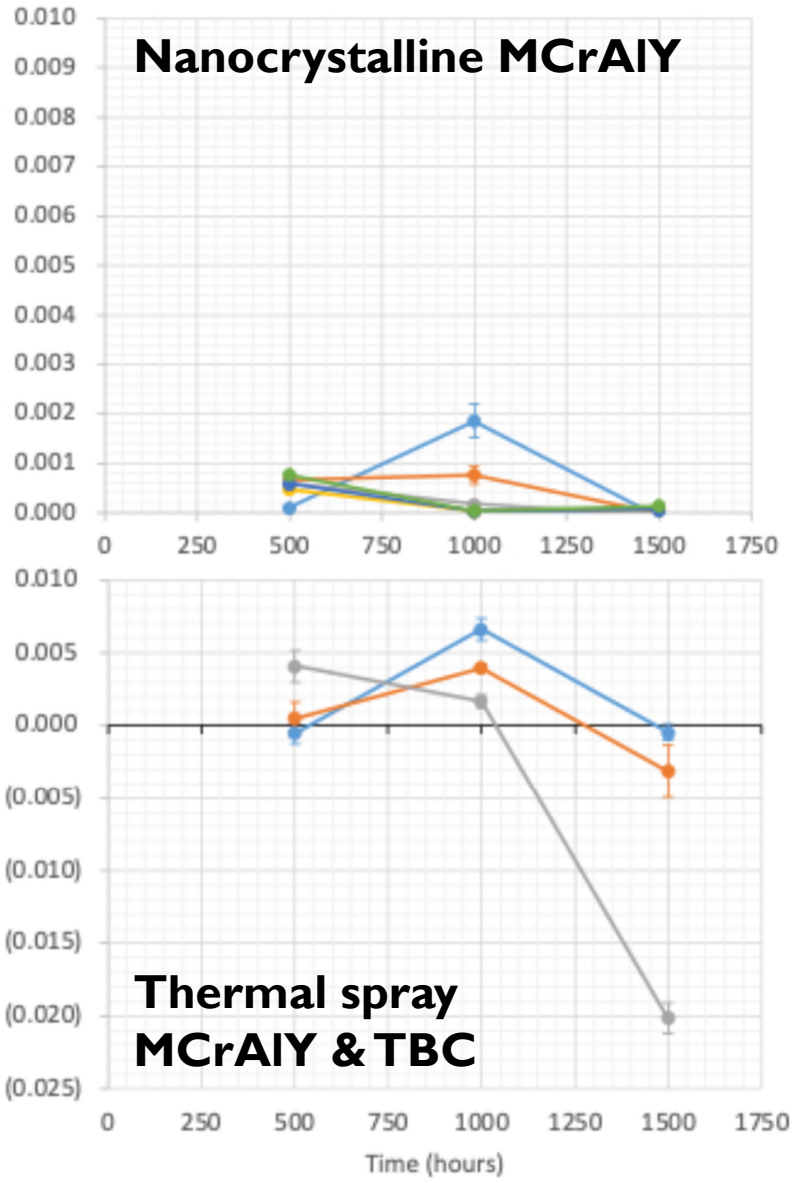
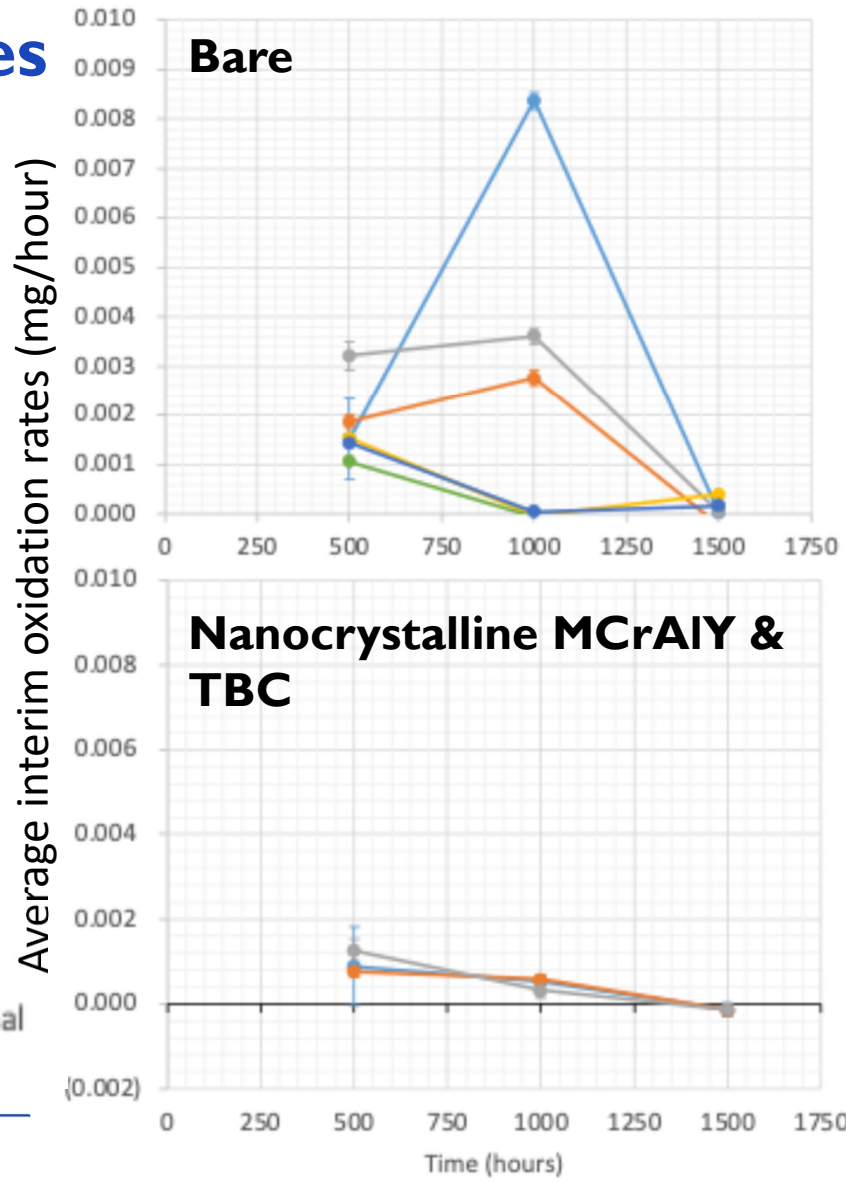


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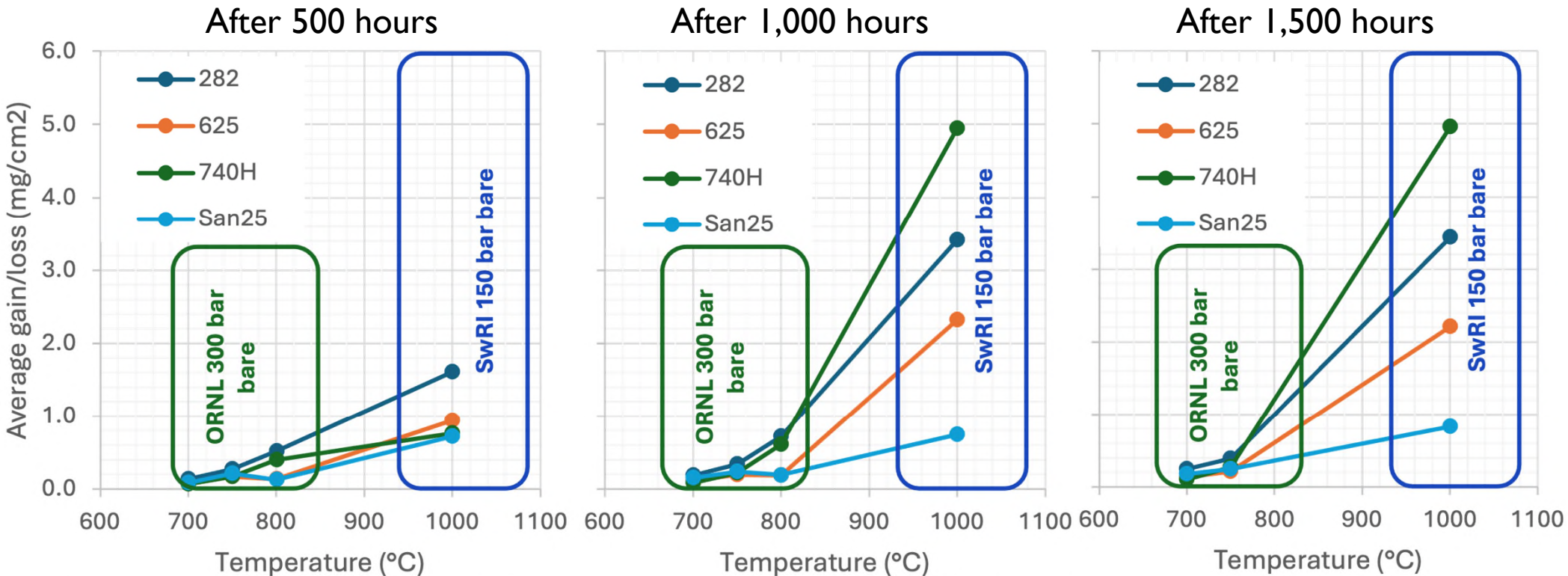
TBC damages dependent on bond coat



- 740H ● 625
- 282 ● 353
- SAN 25 ● APMT Kanthal



Trends and ranking are similar to published data



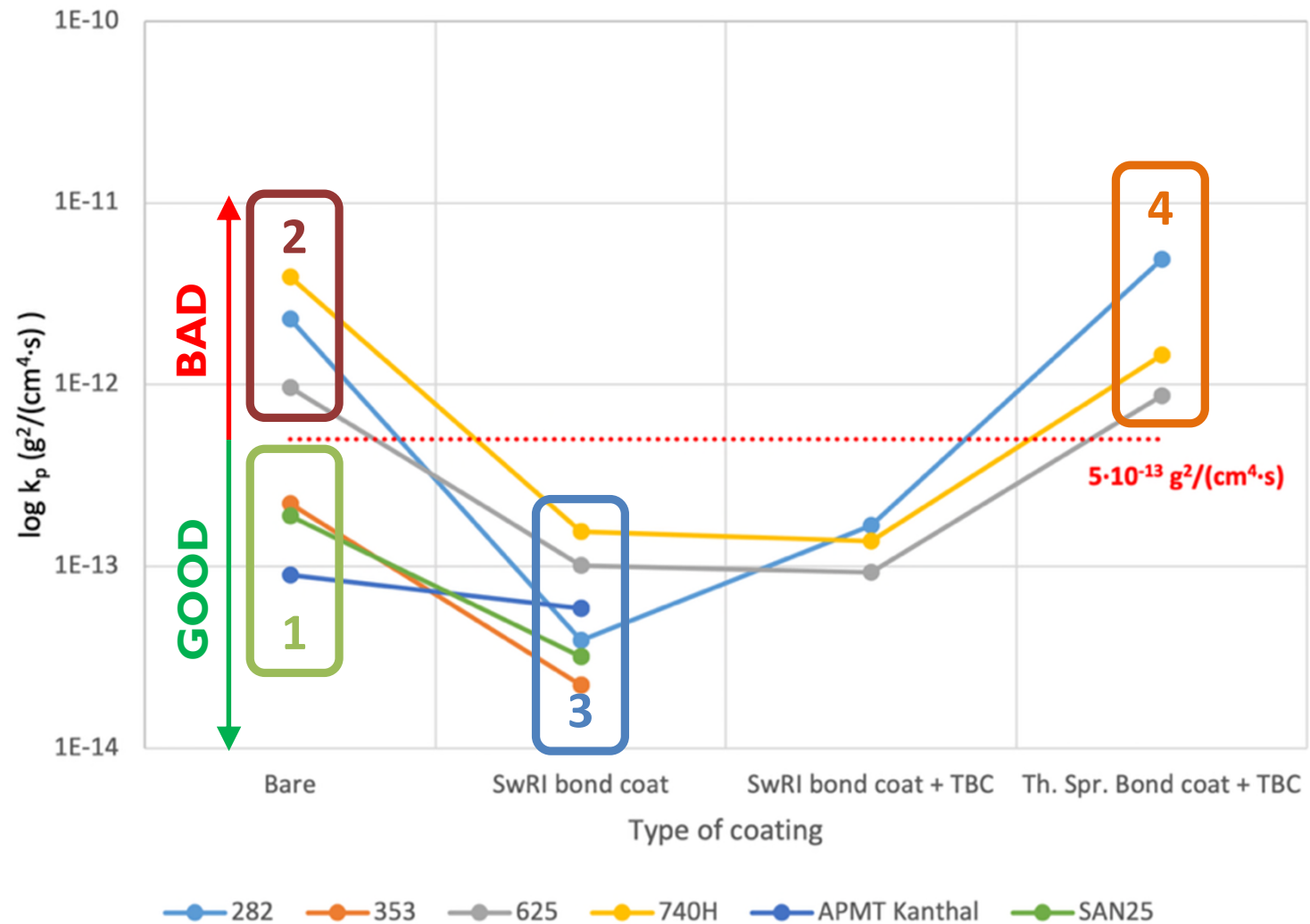
Data from Oak Ridge National Laboratory in CO₂ (CESL015 DE-EE0001556)



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Summary

1. Bare steels behaving well
2. Bare Ni alloys underperforming
3. MCrAlY improves all alloys
4. TBC behaves worse with the thermal spray bond coat



Acknowledgements

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