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Alumina forming steels for ATF and Gen IV cladding

TS 4 - INNOVATIVE AND PERSPECTIVE MATERIALS SOLUTIONS

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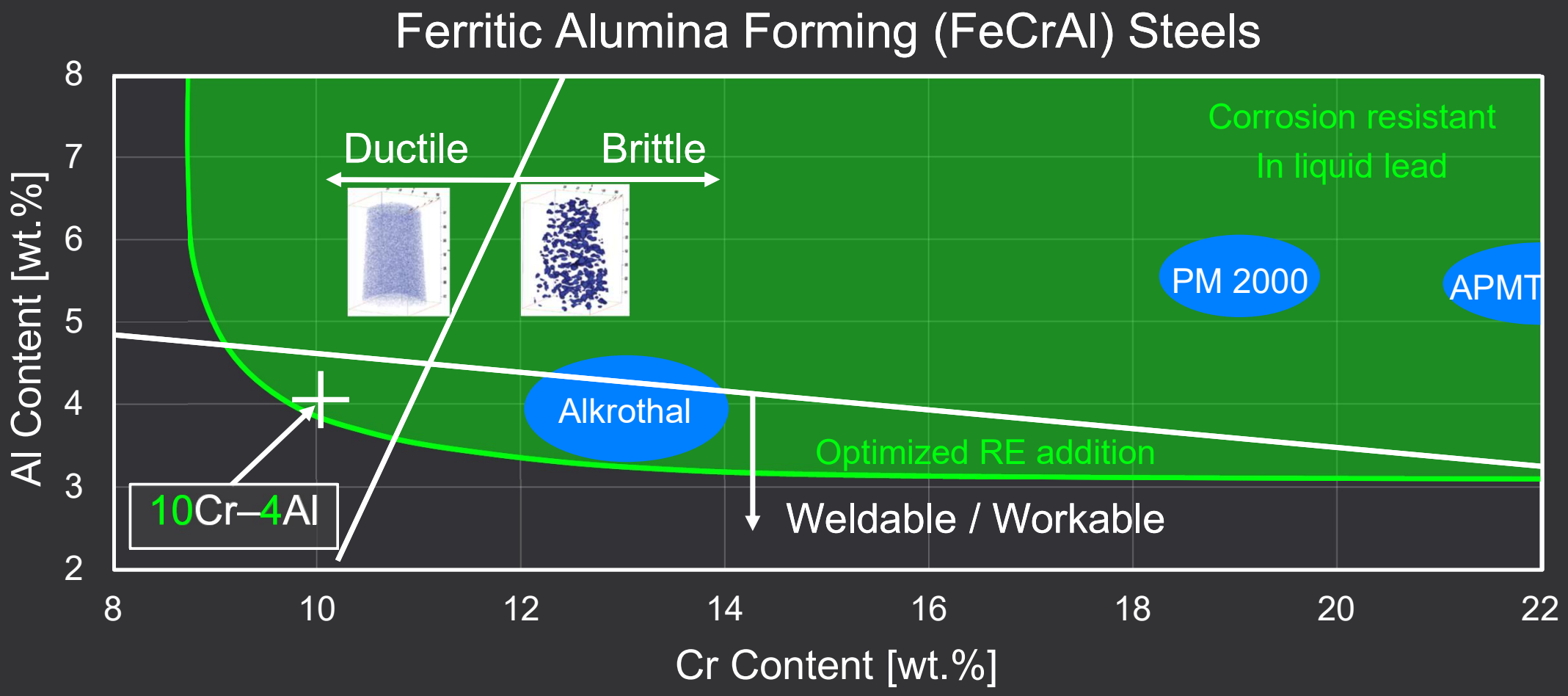
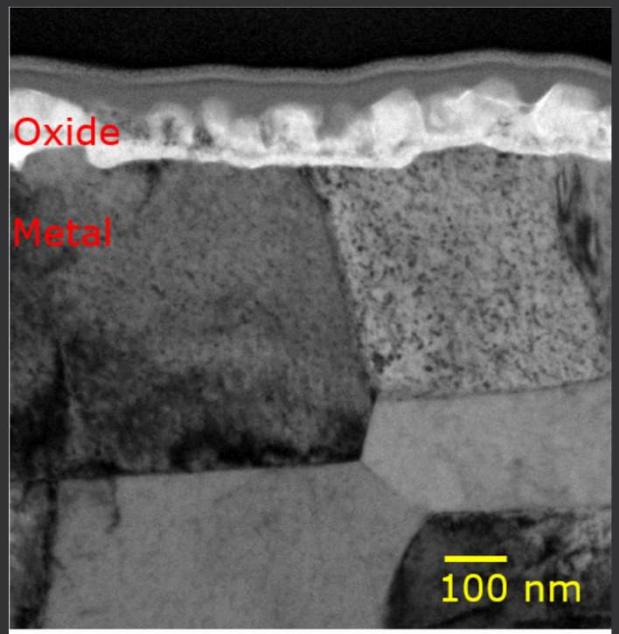
MATERIAL BACKGROUND - FeCrAl



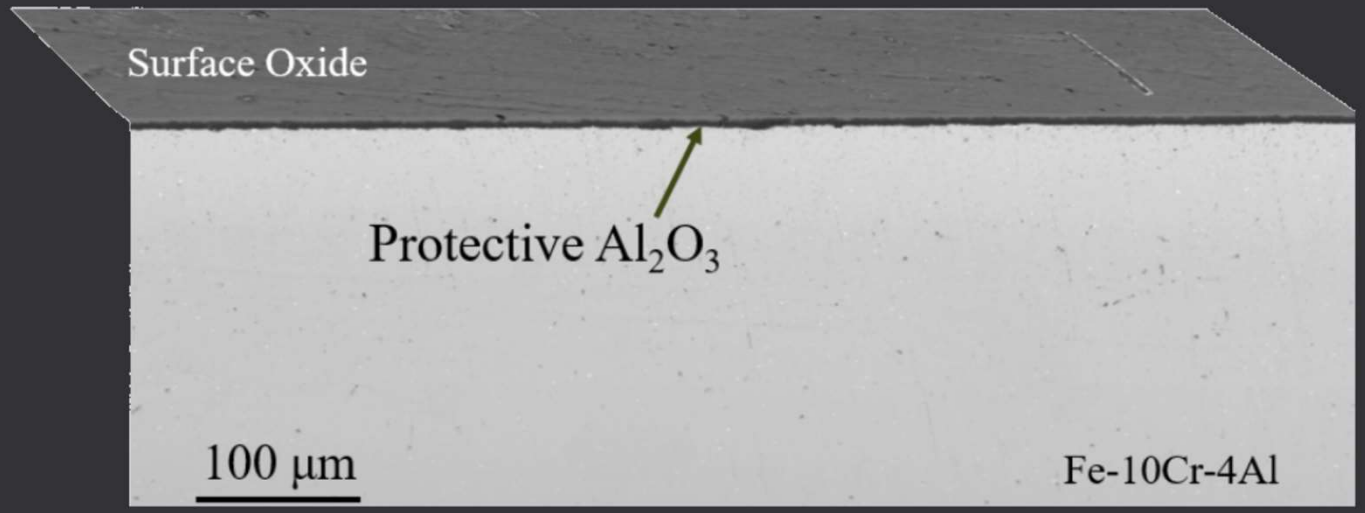
CORROSION TESTING IN LIQUID LEAD

Excellent corrosion properties 400-800°C



TEM image

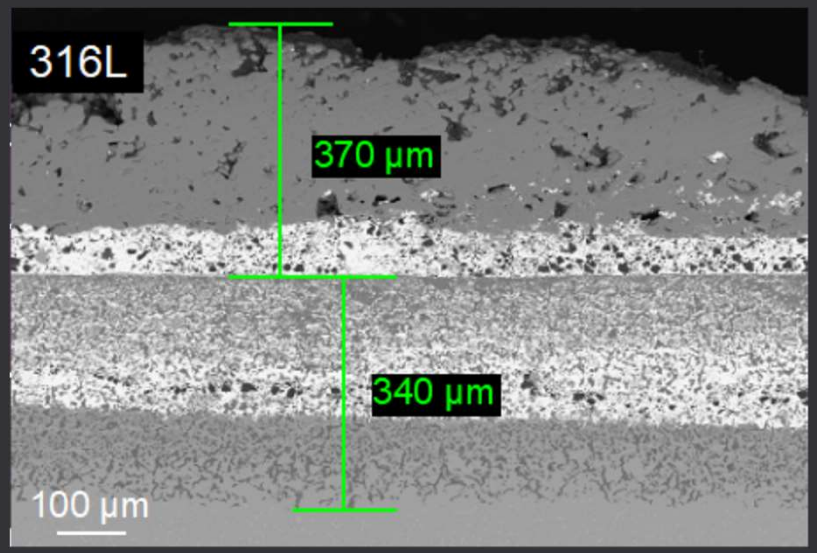
10Cr-4Al-RE exposed 10.000 h @ 550°C



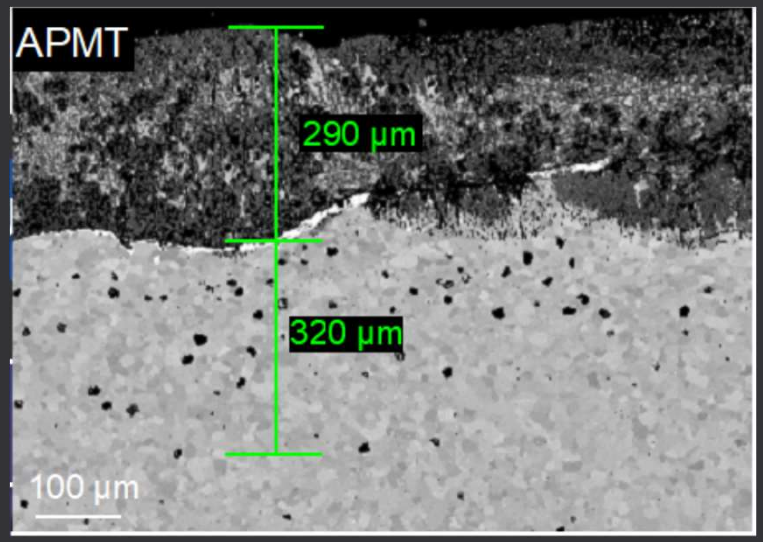
10Cr-4Al-RE exposed 1670 h @ 800°C µm,
only steel that ”survives” in this environment.

CORROSION TESTING IN LIQUID LEAD

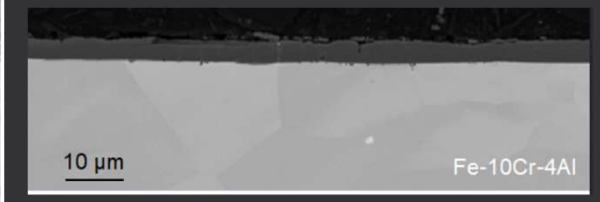
Comparison with other steels 1670h @ 800°C



AISI 316L: Severe corrosion with lead penetration



Fe-23Cr-5,5Al-RE: Severe corrosion with Kirkendall porosity.



Fe-10Cr-4Al-RE: Protective self-healing alumina scale

J. Nucl. Mat Vol.531, p.152022 (2020) "Corrosion studies of a low alloyed Fe–10Cr–4Al steel exposed in liquid Pb at very high temperatures"

INDUSTRIAL BREAKTHROUGH

ATF and Gen IV cladding

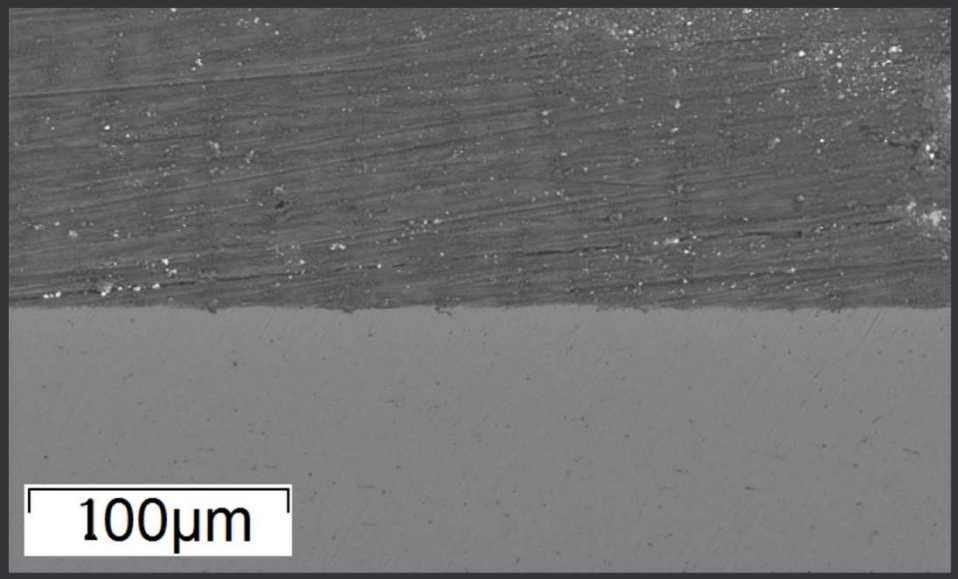
AISI 316L tube, ∅13.1mm, t = 0.6mm.
Laser weld overlay with Fe-10Cr-4Al-RE,
∅0.2 mm weld wire

Weld overlay thickness: 210-220 µm
Excellent ductility: bend test 180°

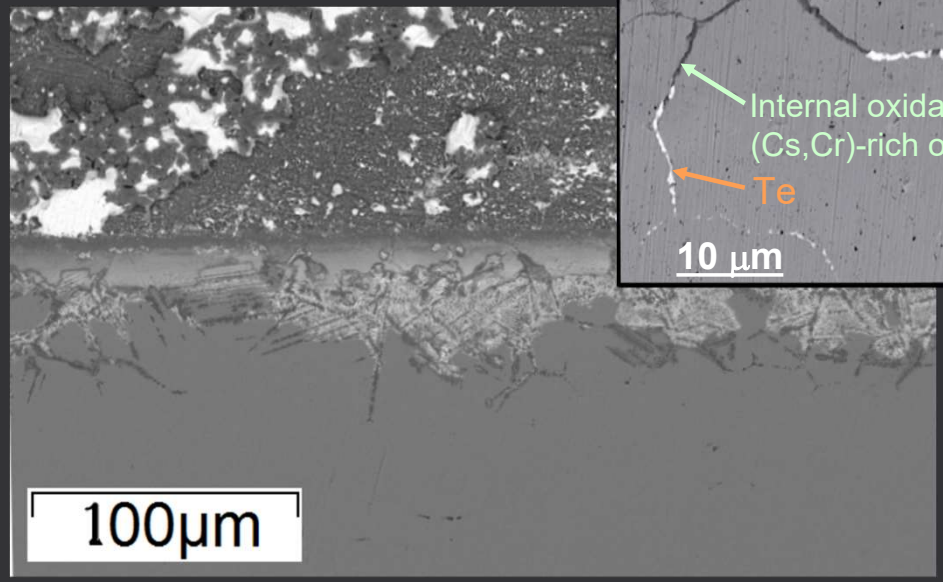
Accepted for publication in **Annals of Nuclear Energy**
"Development of a welding process to overlay FeCrAl alloy on a thin wall austenitic stainless steel tube"

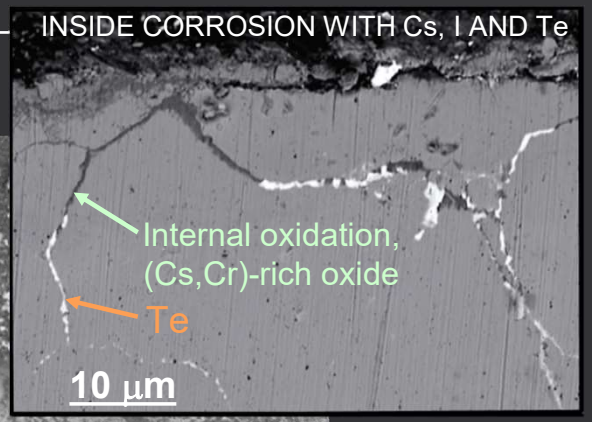
AFA FOR LFR CLADDING TUBES

Alumina Forming Austenite cope with both outside and inside corrosion



Lean AFA (2,5Al-12Cr-16Ni-2,6Mn-1Cu) exposed (~500 h @ 700°C) . Excellent corrosion properties in Pb, 400-700°C.

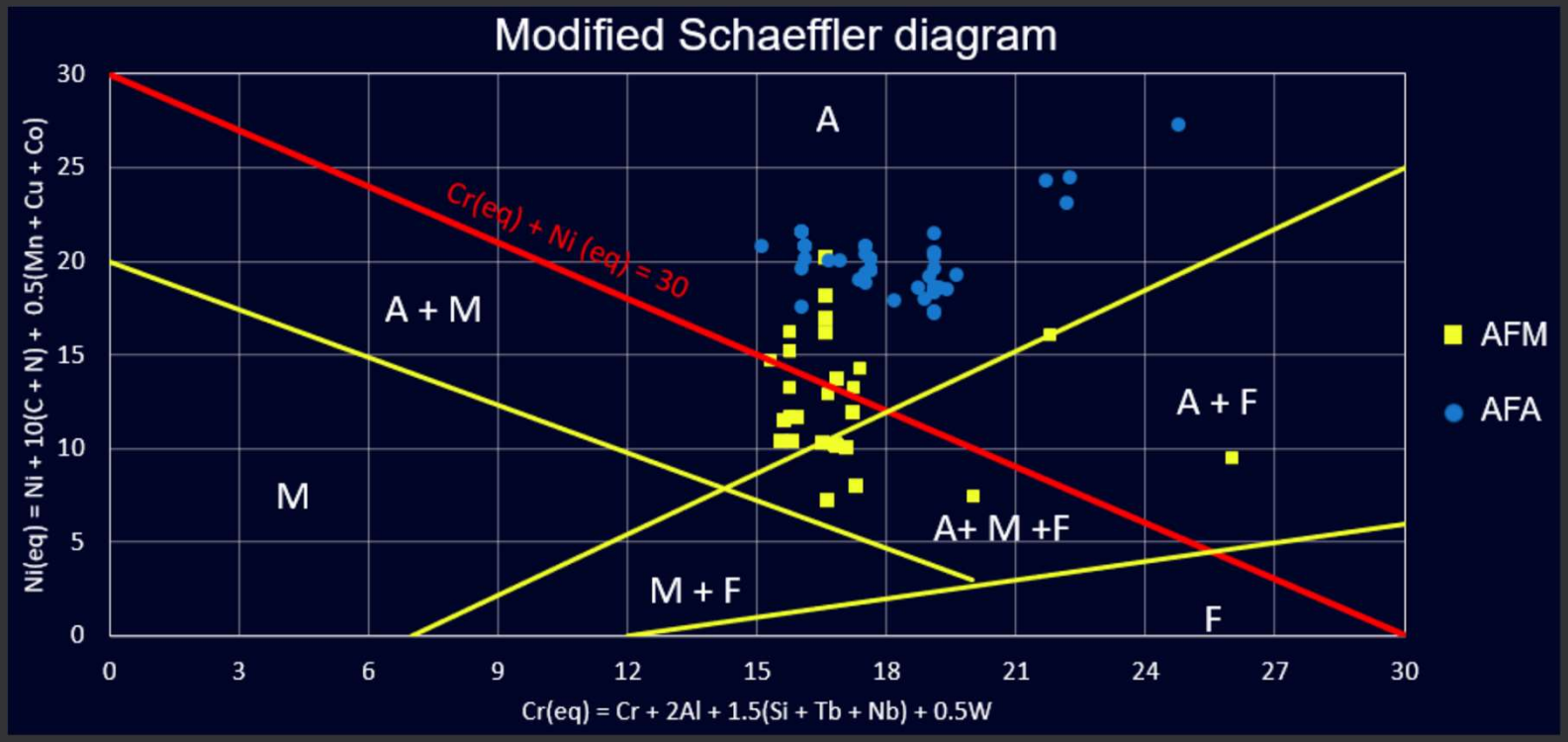


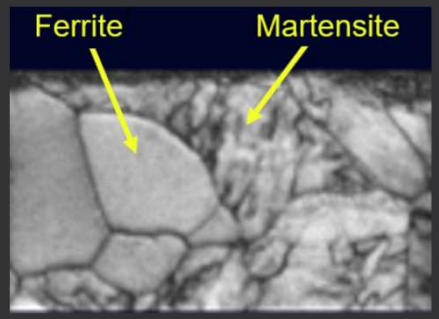


Reference steel: AISI 316L , severe lead penetration and grain boundary oxidation (~500 h @ 700°C)

ALUMINA FORMING MARTENSITES (AFM)

New type of steel with promising properties





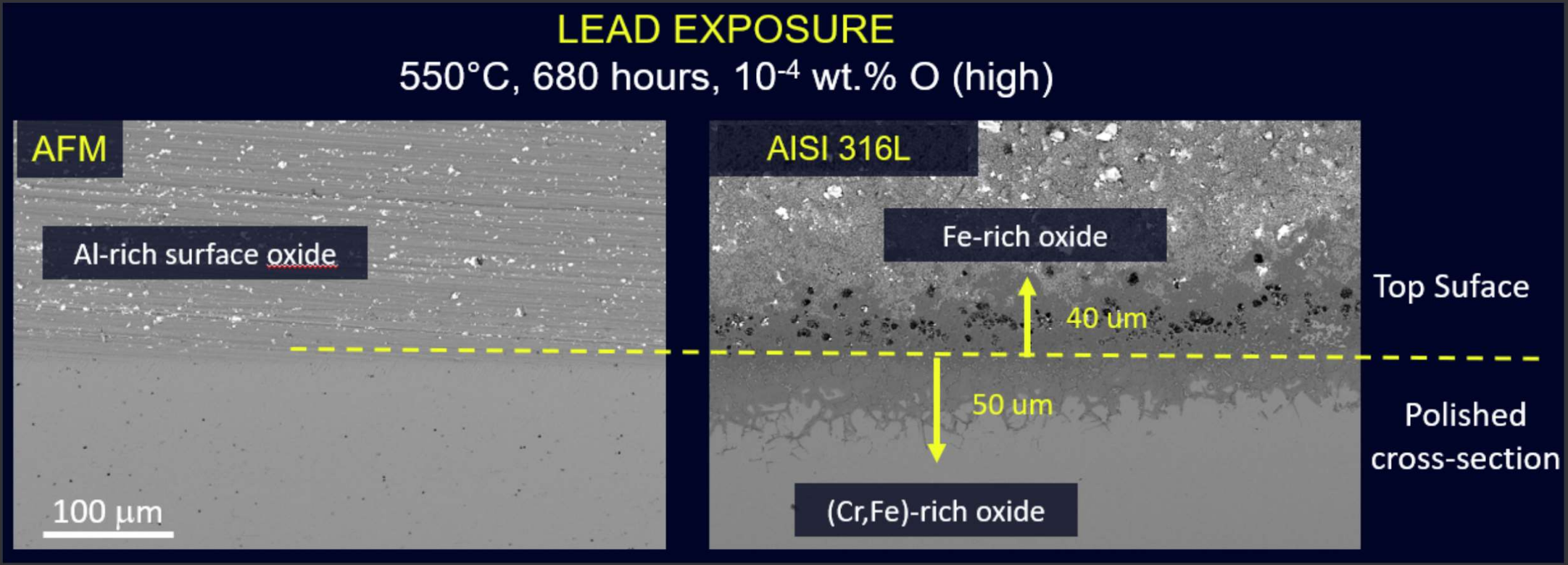
Ni(eq) = 8.5
Cr(eq) = 17.0

~ 80% Martensite

(AFM patent granted)

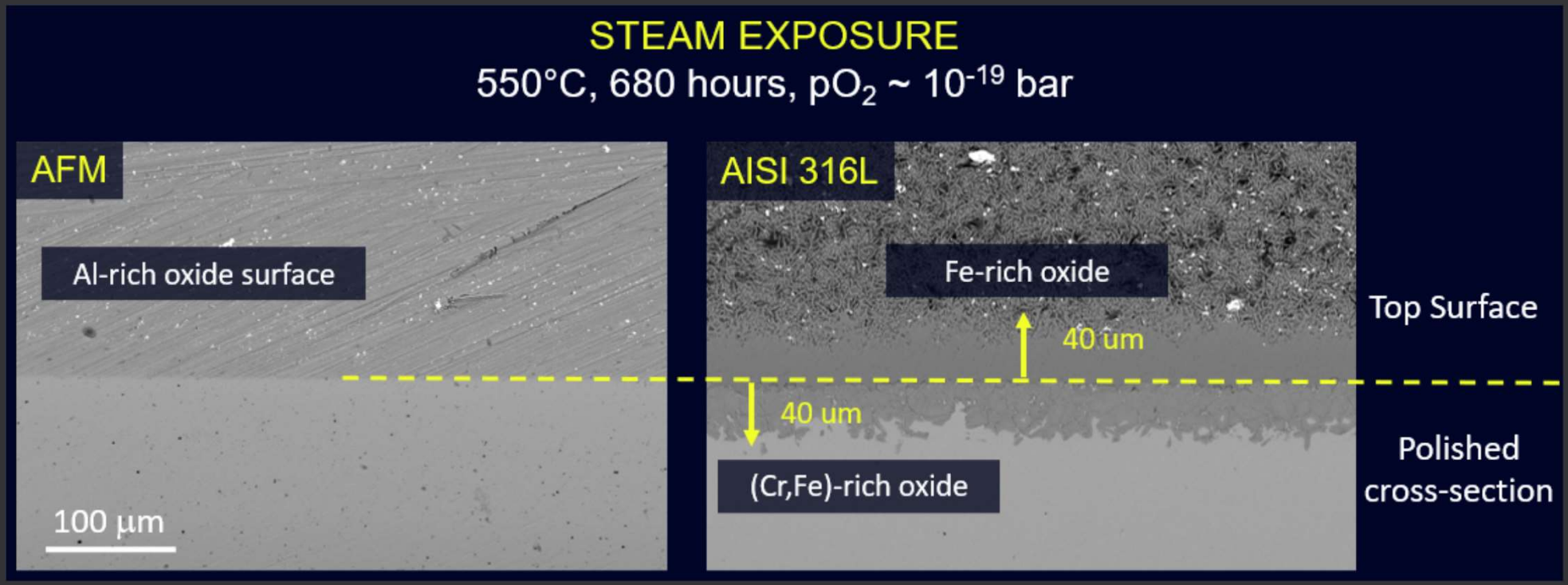
ALUMINA FORMING MARTENSITES (AFM)

Excellent corrosion properties < 650°C in Pb



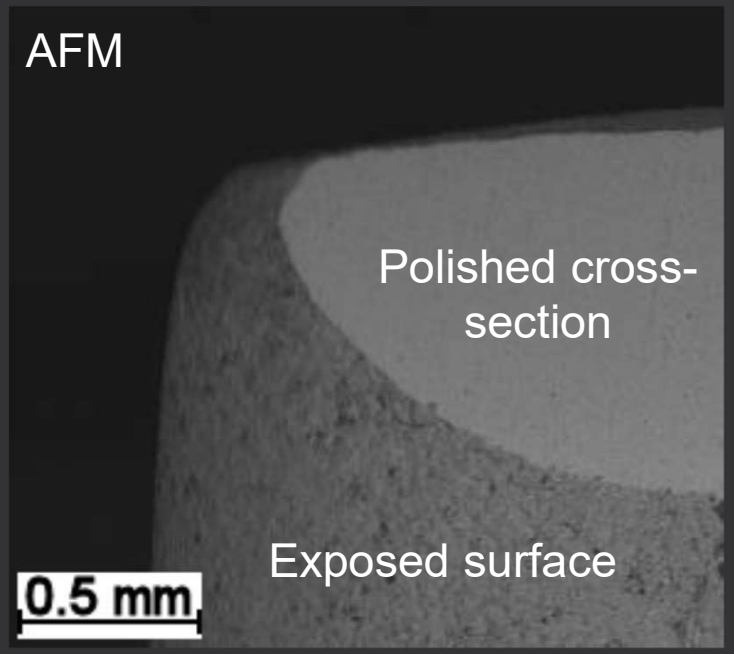
ALUMINA FORMING MARTENSITES (AFM)

Excellent corrosion properties < 650°C in steam

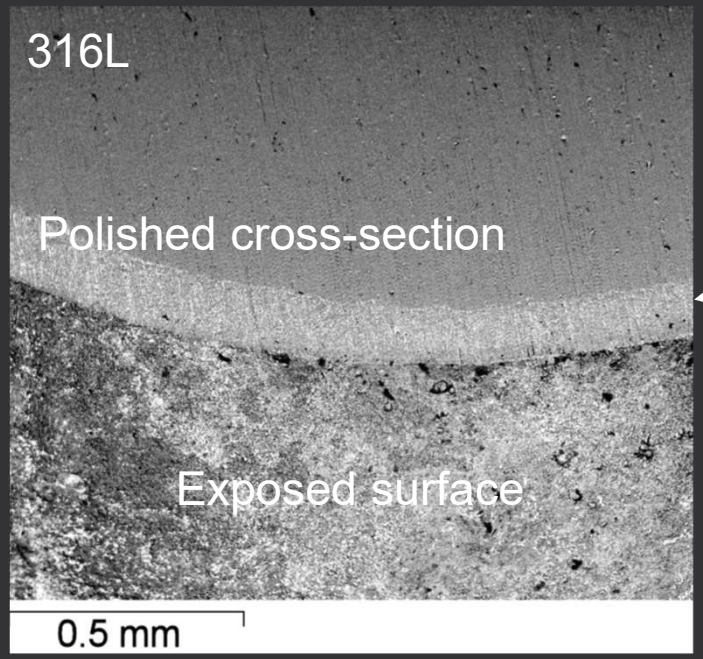


ALUMINA FORMING MARTENSITES (AFM)

Erosion Corrosion in Pb @ 480°C, 340h ~7m/s, ~ zero oxygen (5%H_2)



No weight loss and no visible erosion corrosion



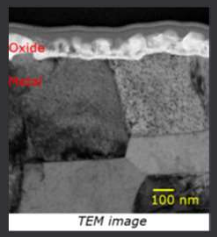
Lead penetration

Severe erosion corrosion, weight loss <u>and</u> lead penetration

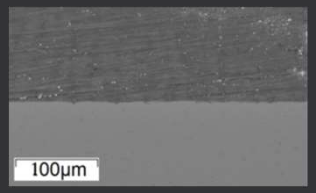
CONCLUSIONS

Future LFR´s will be constructed of alumina forming alloys:

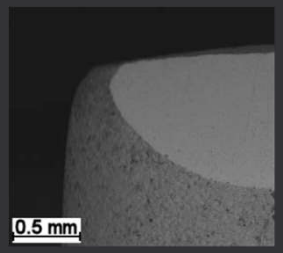
Fe10Cr4Al: Excellent corrosion protection (self-healing) up to 800°C in Pb



AFA: Good mechanical strength and good corrosion properties up to 700°C in Pb



AFM: Excellent erosion and corrosion resistance up to at least 600 °C



Thank you for your attention!

Any questions?

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