Structural Materials for LFRs
2019-10-16

Corrosion And Mechanical Testing Of A Low Alloyed AFA For Liquid Lead Applications

Peter Dömstedt, Peter Szakálos

KTH Royal institute of Technology, Surface & Corrosion Science

peterdom@kth.se

Marta Serrano Garcia, Rebeca Hernandez

CIEMAT, Centre for Energy, Environment and Technology

PROJECTS

GEMMA
H2020 programe

GEMMA
Generation IV Materials Maturity

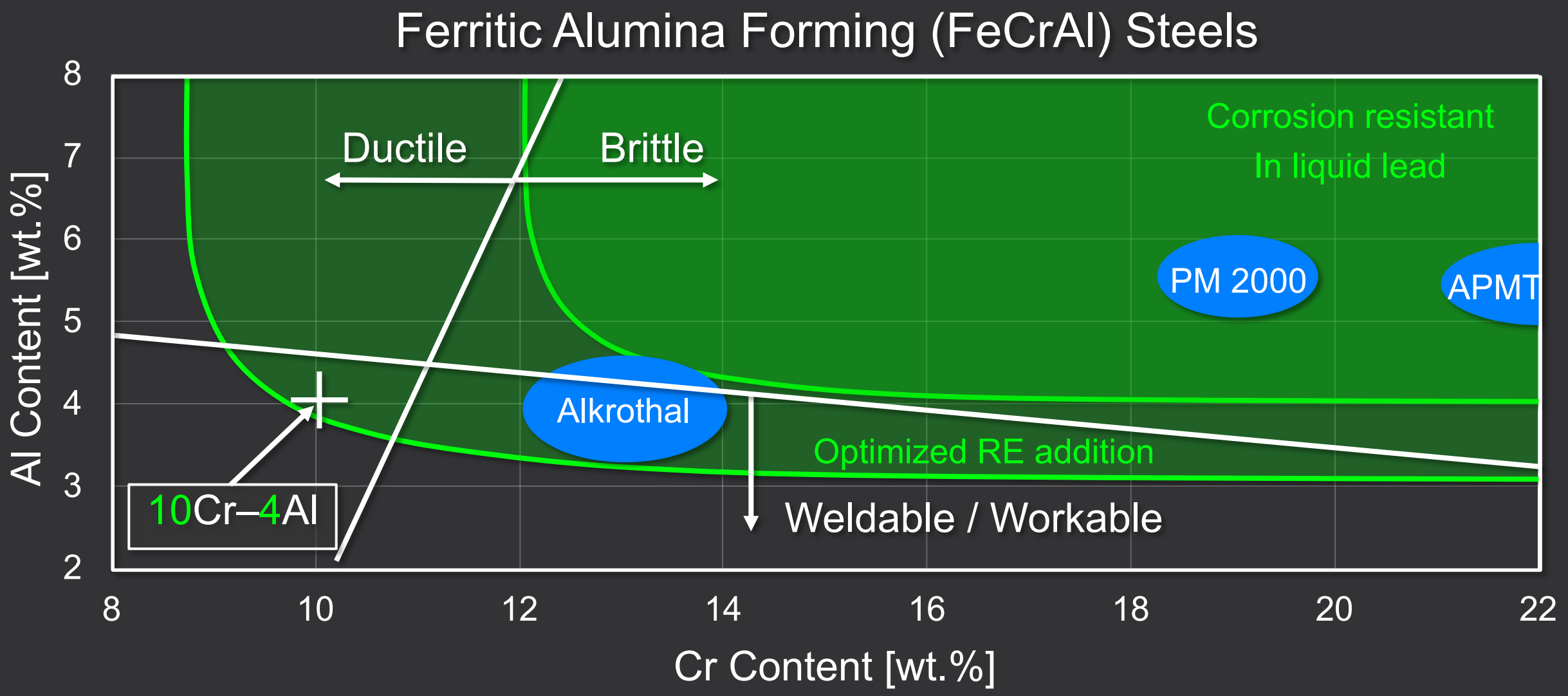
Novels Steels for LFRs
Swedish Research Council (VR)

Vetenskapsrådet

Objectives

- *Material development for LFRs*
- *Lead temperatures up to 700 ℃*

MATERIAL BACKGROUND

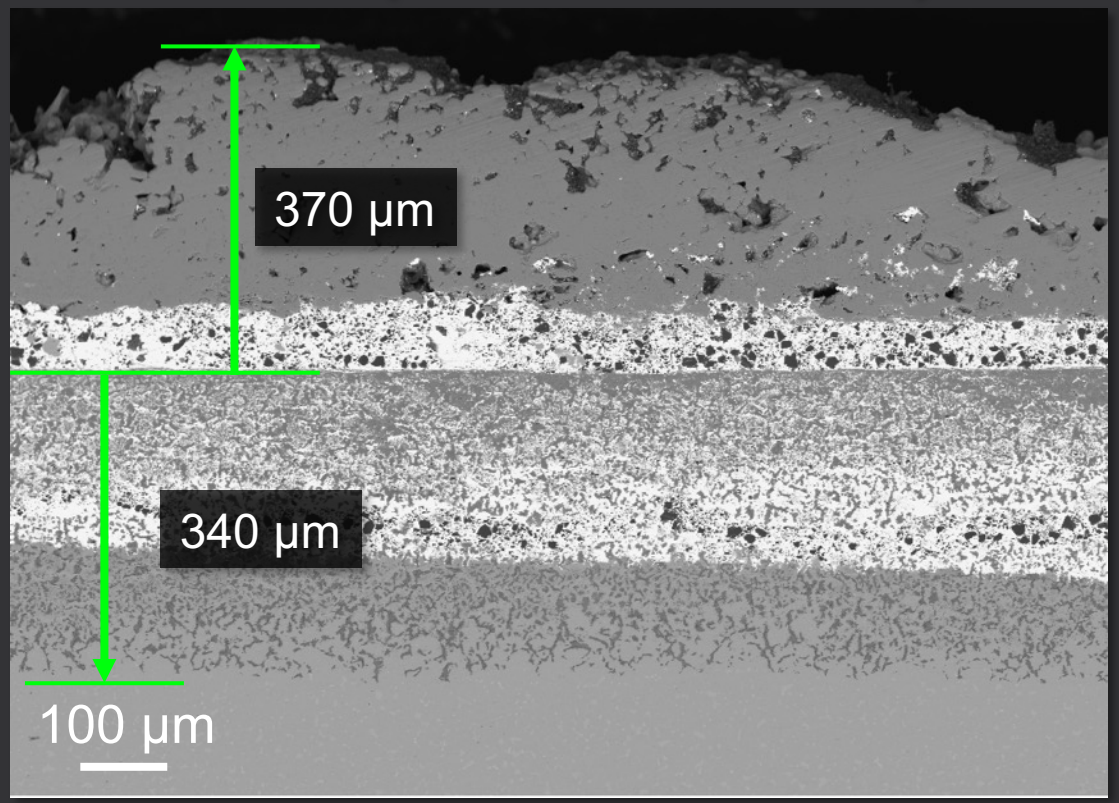


MATERIAL BACKGROUND

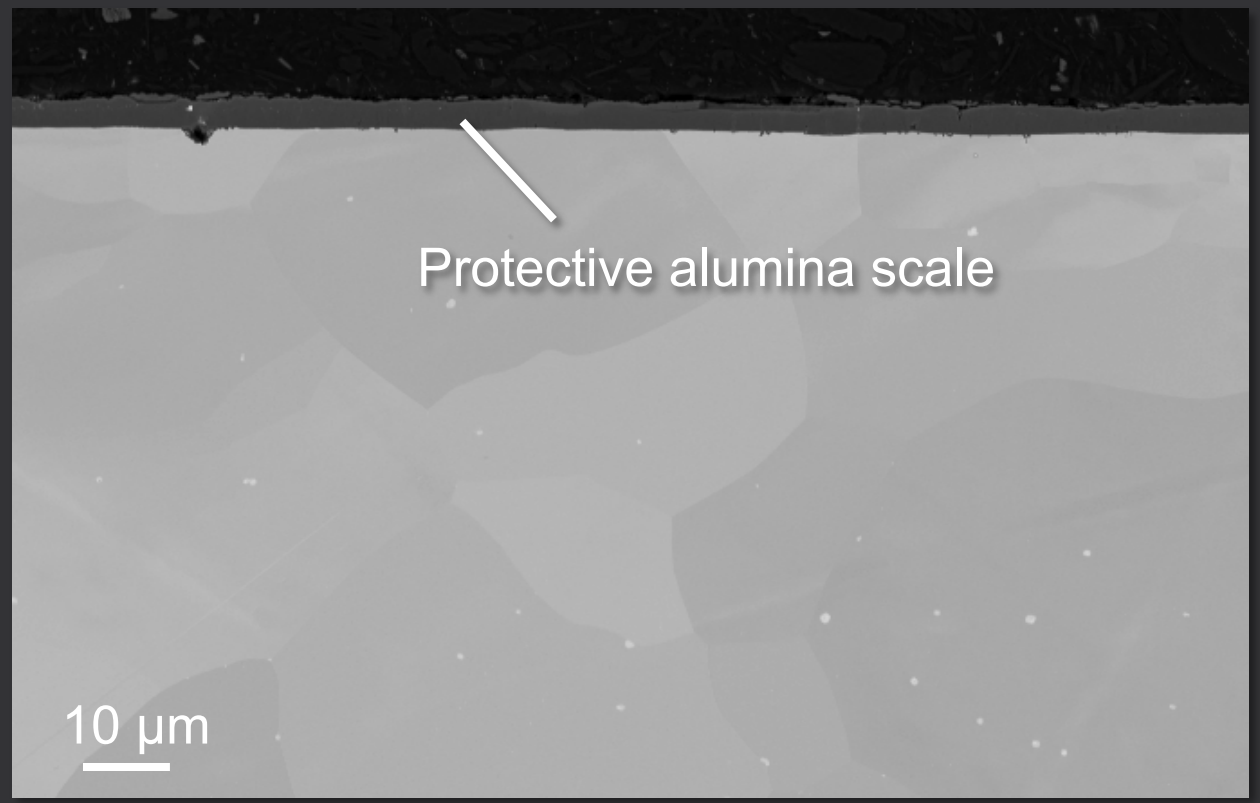
Fe-10Cr-4Al – 800°C Lead Corrosion

10^{-5} wt. % O
1760 hours

316L (10Ni-17Cr-2Mo)



Fe-10Cr-4Al + RE



MATERIAL BACKGROUND

Alumina Forming Austenitic (**AFA**) steels

Low alloyed **AFA**

14Cr - 16Ni - 2.5Al - 2.5Mn - 0.9Nb

Properties:

- LME resistant
- Higher creep strength
- Not as corrosion resistant in Pb

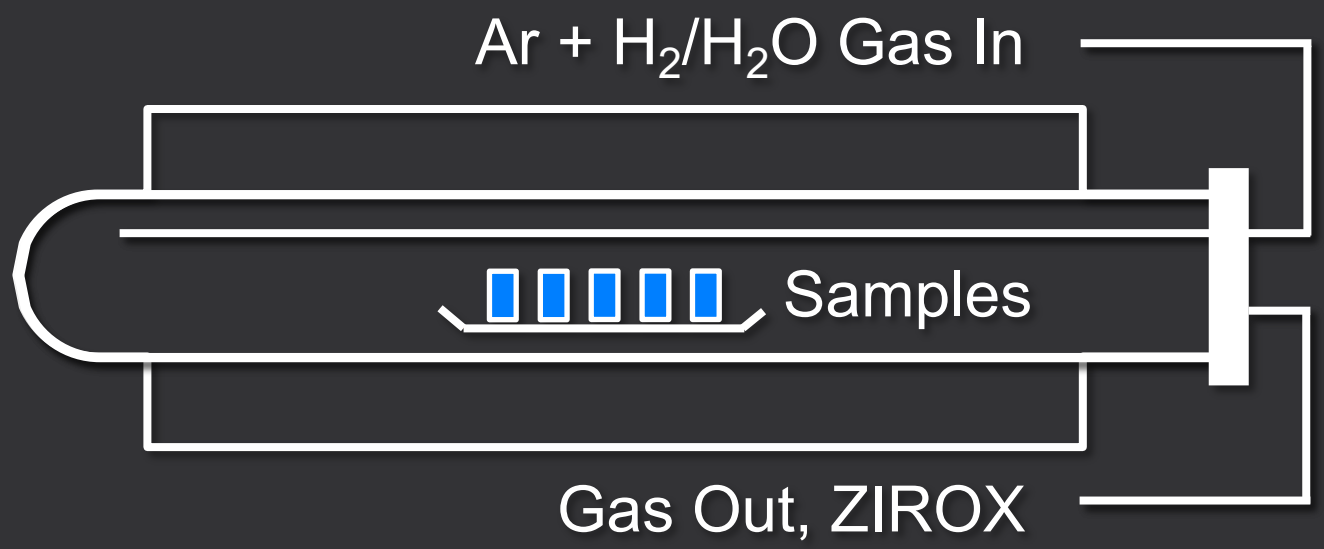
Criterion:

- Aging resistant ~550°C
- Hot ductility
- Minimize irradiation swelling
- Optimize corrosion properties

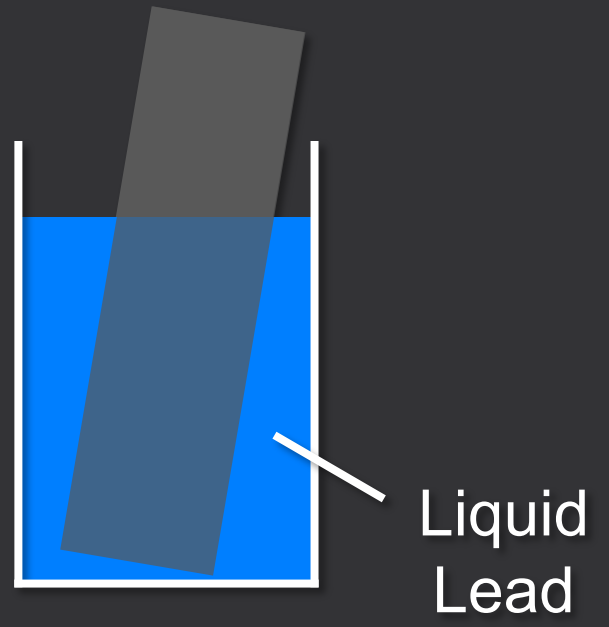
EXPERIMENTAL SETUP

Liquid Lead Corrosion Facility

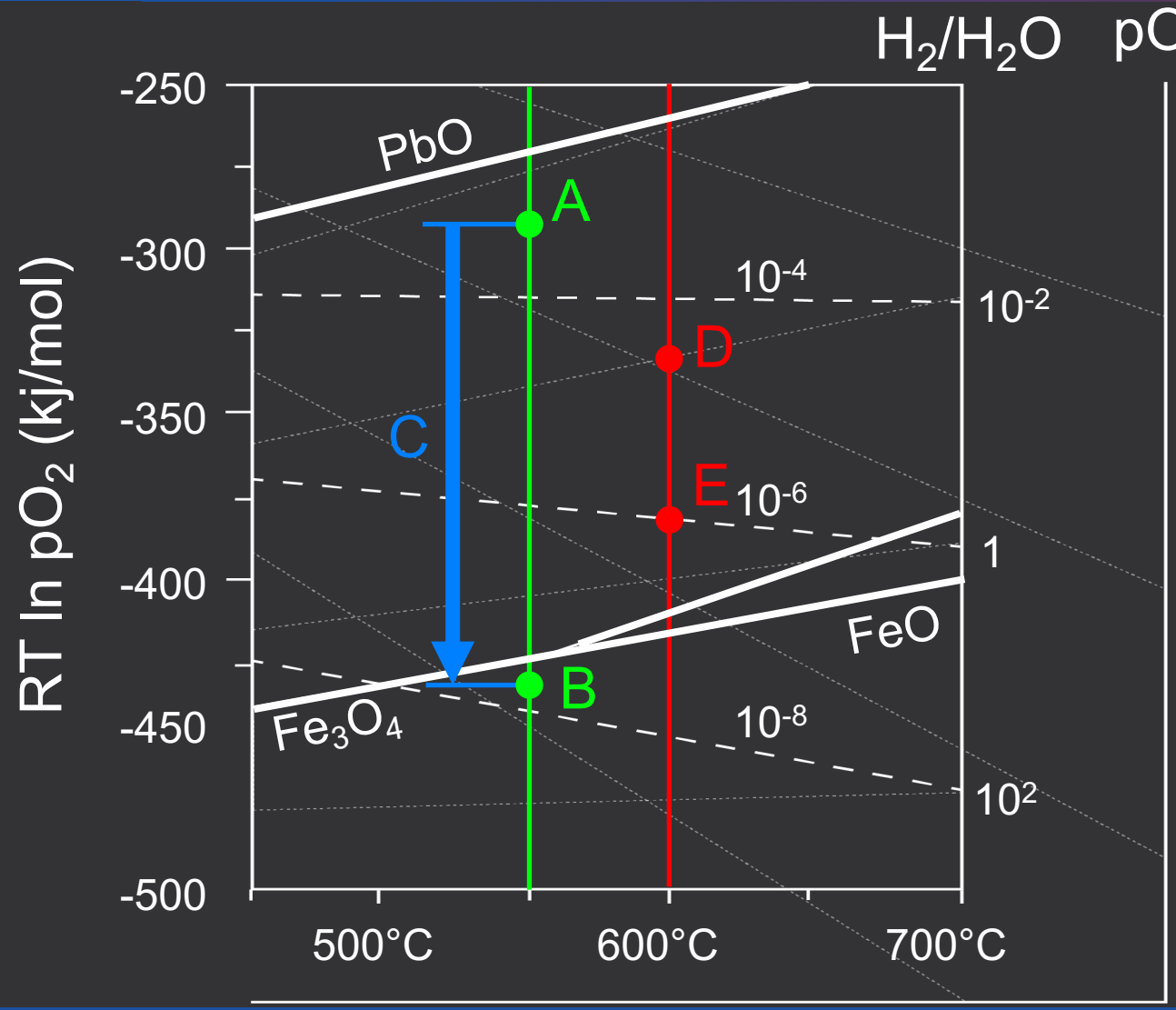
COSTA Tube Furnace



Samples



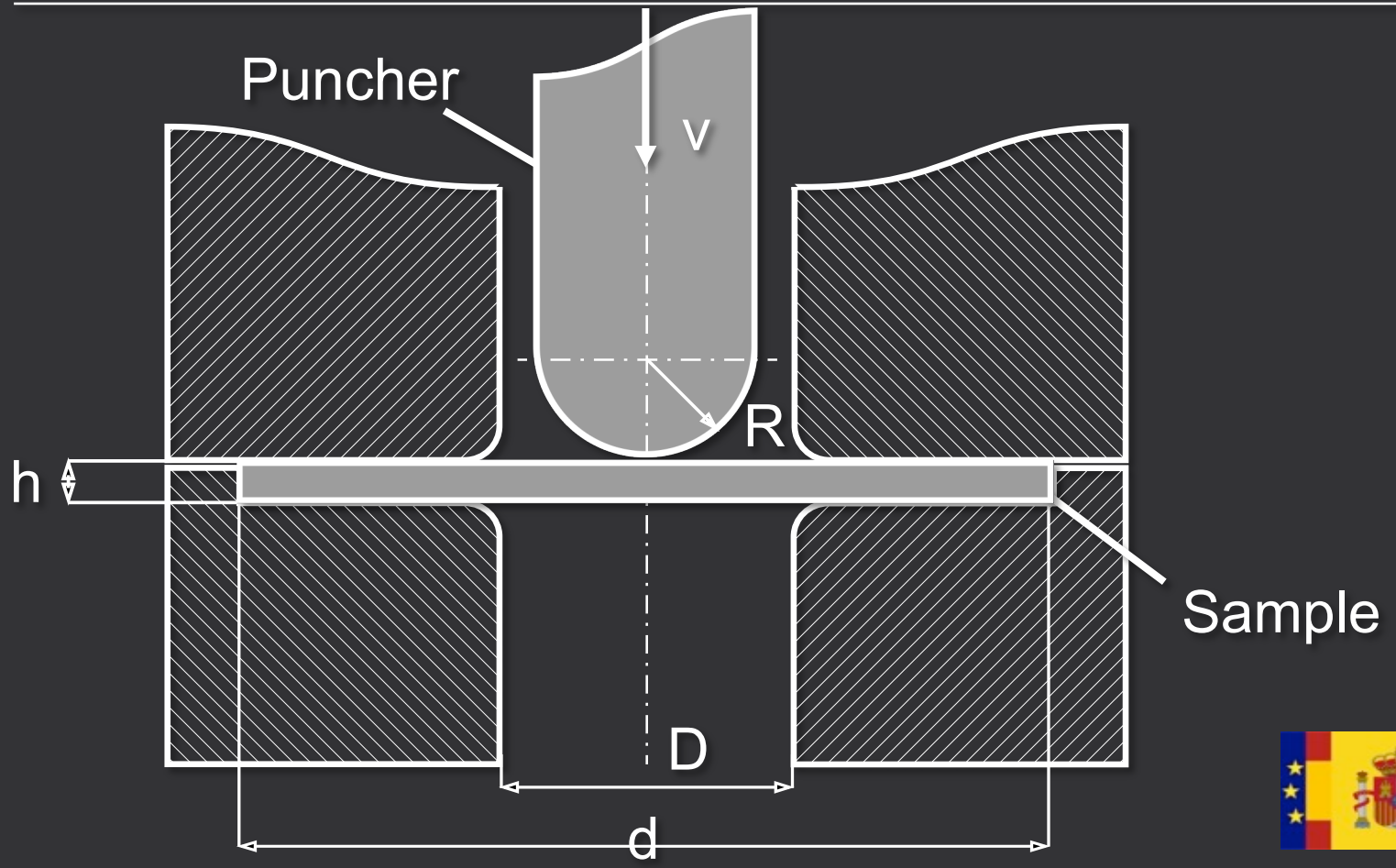
EXPERIMENTAL SETUP



Experiment	H_2/H_2O	wt. % O	hours
A	10^{-4}	10^{-4}	680
B	7	10^{-8}	552
C	-	-	680 + 552
D	0.01	10^{-5}	1272
E	0.3	10^{-6}	1080

EXPERIMENTAL SETUP

Small Punch Rig for High Temperatures - CIEMAT



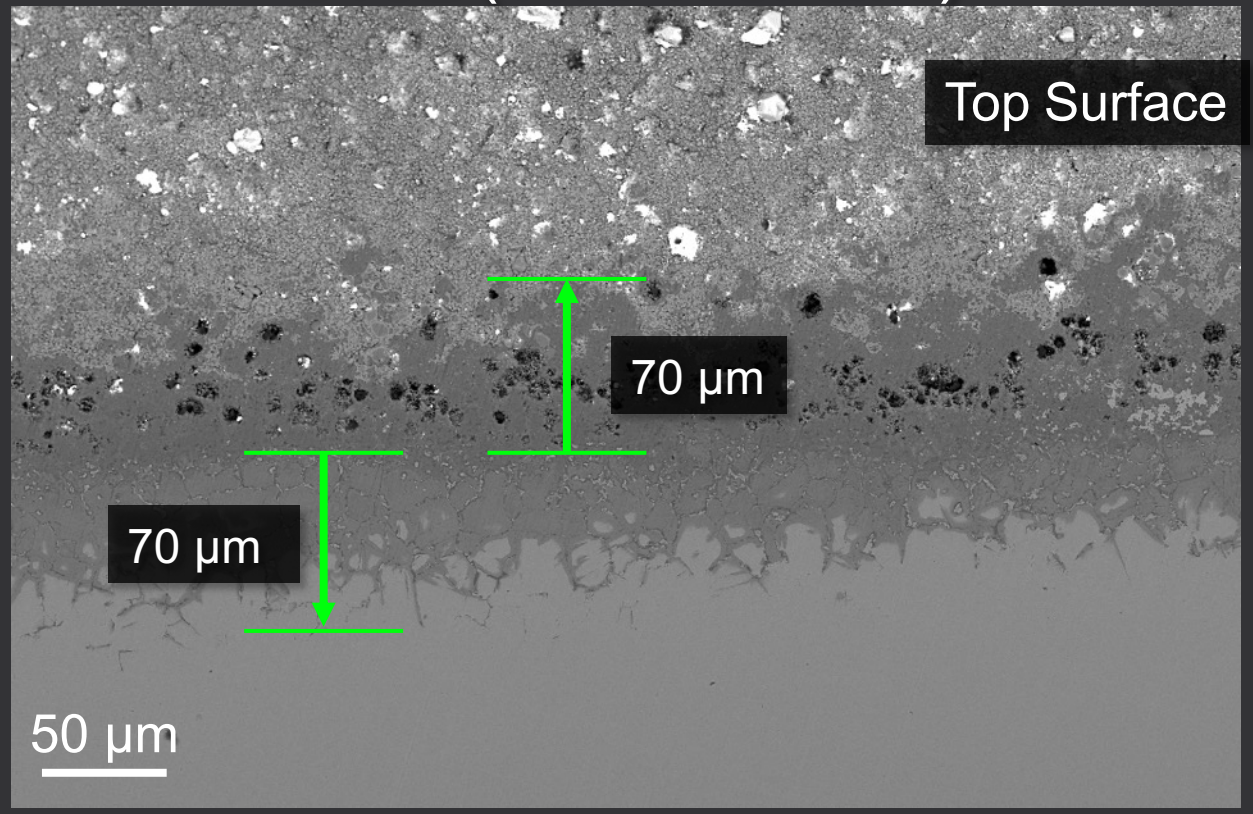
SP parameters	
D	4 mm
d	6/8 mm
h	0.5 mm
R	1.25 mm
v	0.30 mm/min

RESULTS

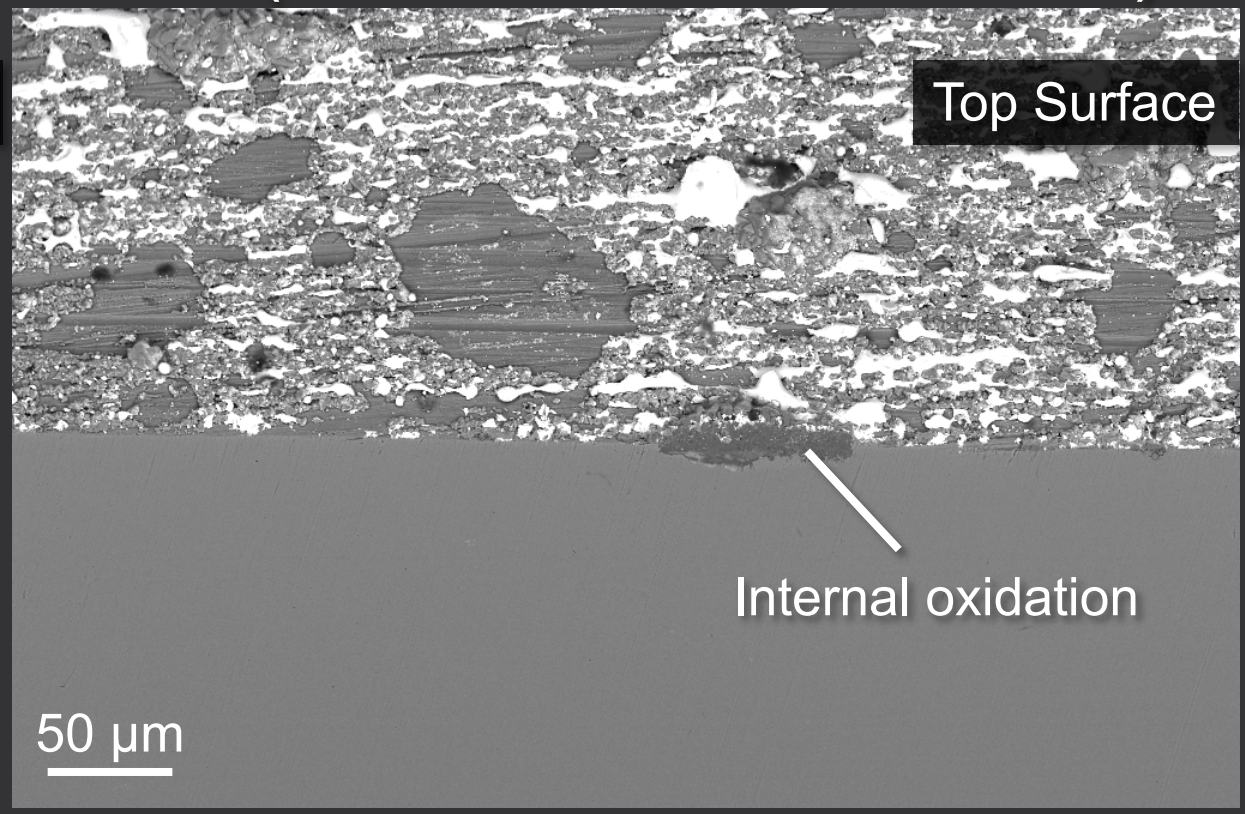
Experiment A - 550°C (*high pO_2*)

10^{-4} wt. % O
680 hours

316L (*10Ni-17Cr-2Mo*)



AFA (*16Ni-14Cr-2.5Al-2.5Mn-0.9Nb*)

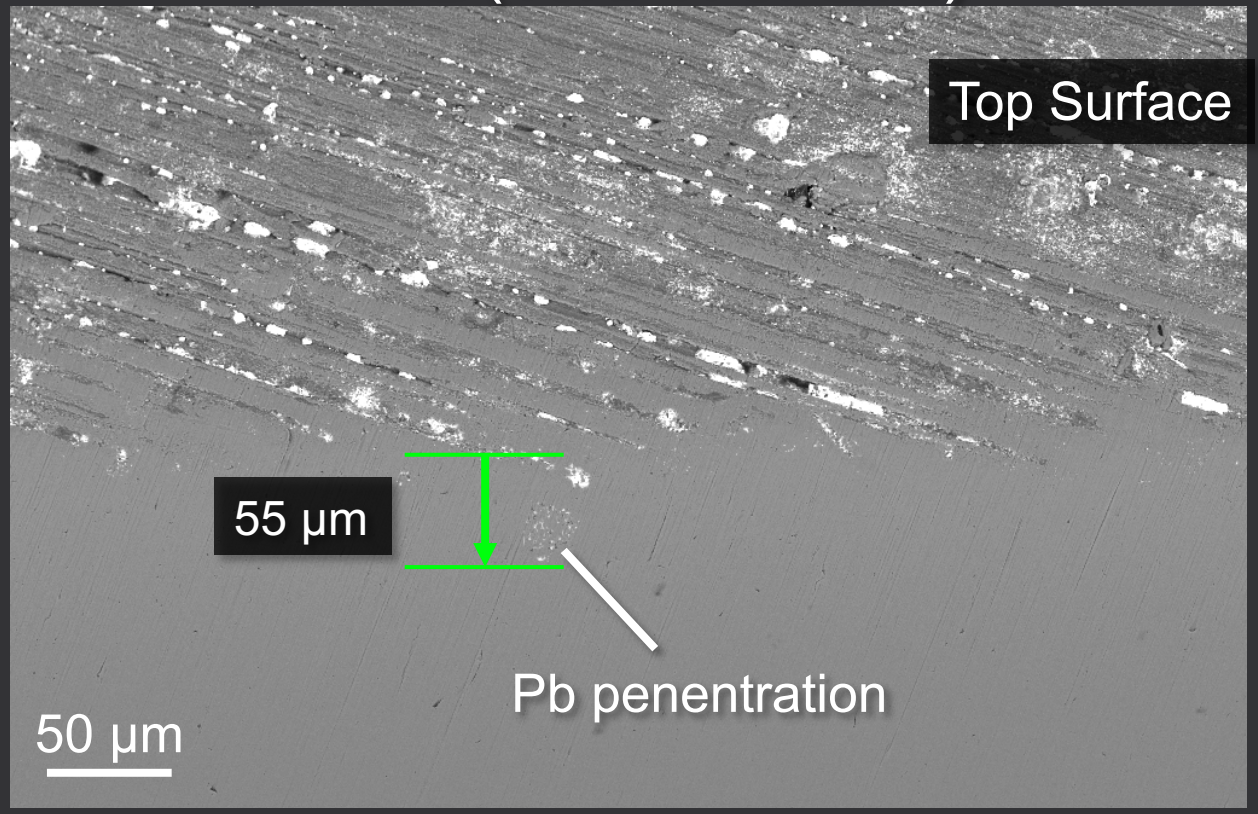


RESULTS

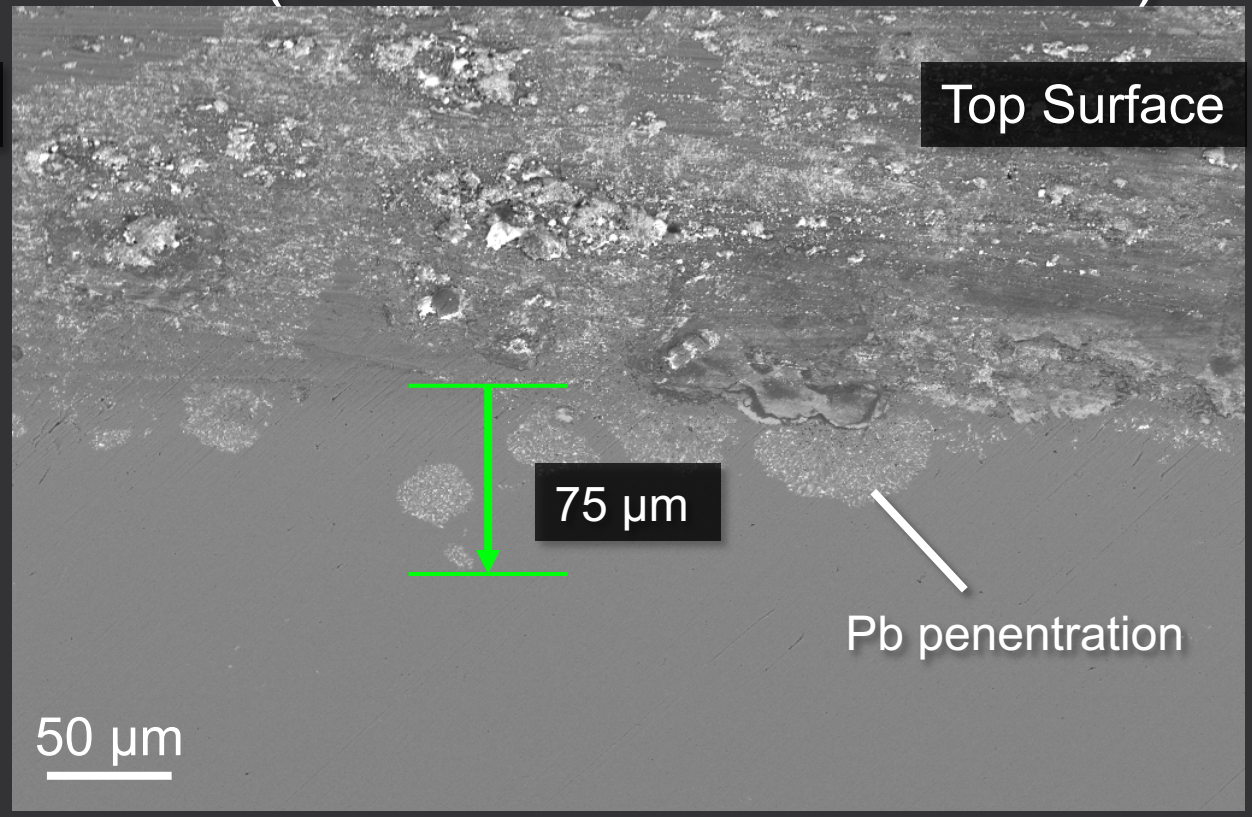
Experiment B - 550°C (*low pO_2*)

10^{-8} wt. % O
552 hours

316L (*10Ni-17Cr-2Mo*)



AFA (*16Ni-14Cr-2.5Al-2.5Mn-0.9Nb*)

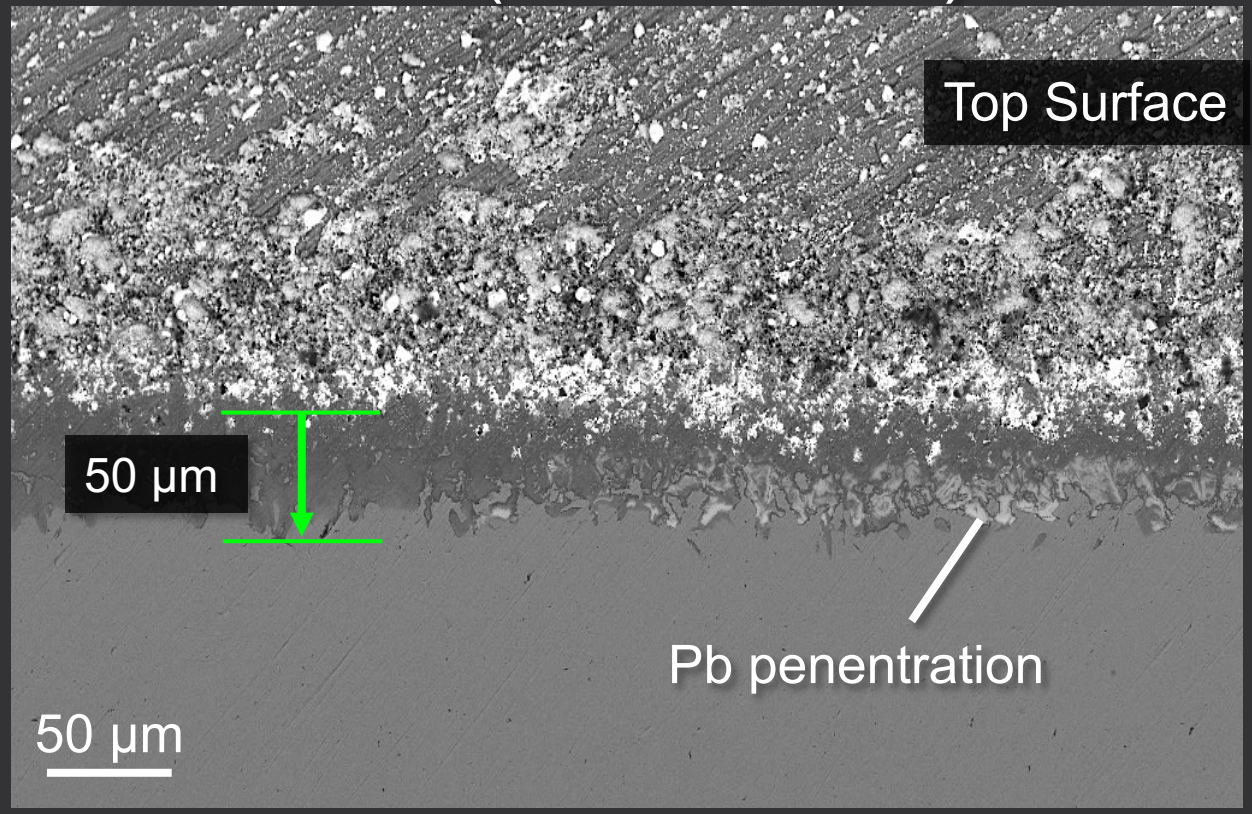


RESULTS

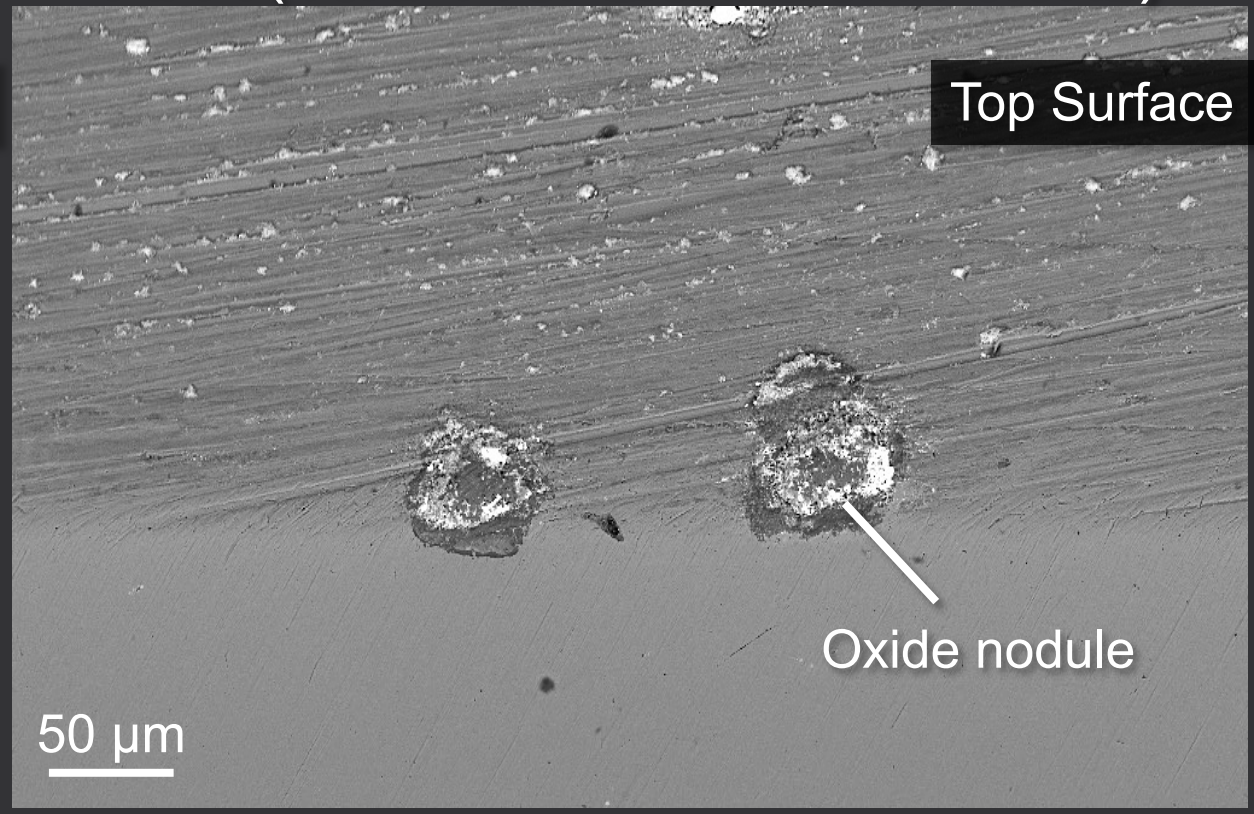
Experiment C - 550°C (*high → low pO_2*)

10^{-4} → 10^{-8} wt. % O
680 + 552 hours

316L (*10Ni-17Cr-2Mo*)



AFA (*16Ni-14Cr-2.5Al-2.5Mn-0.9Nb*)

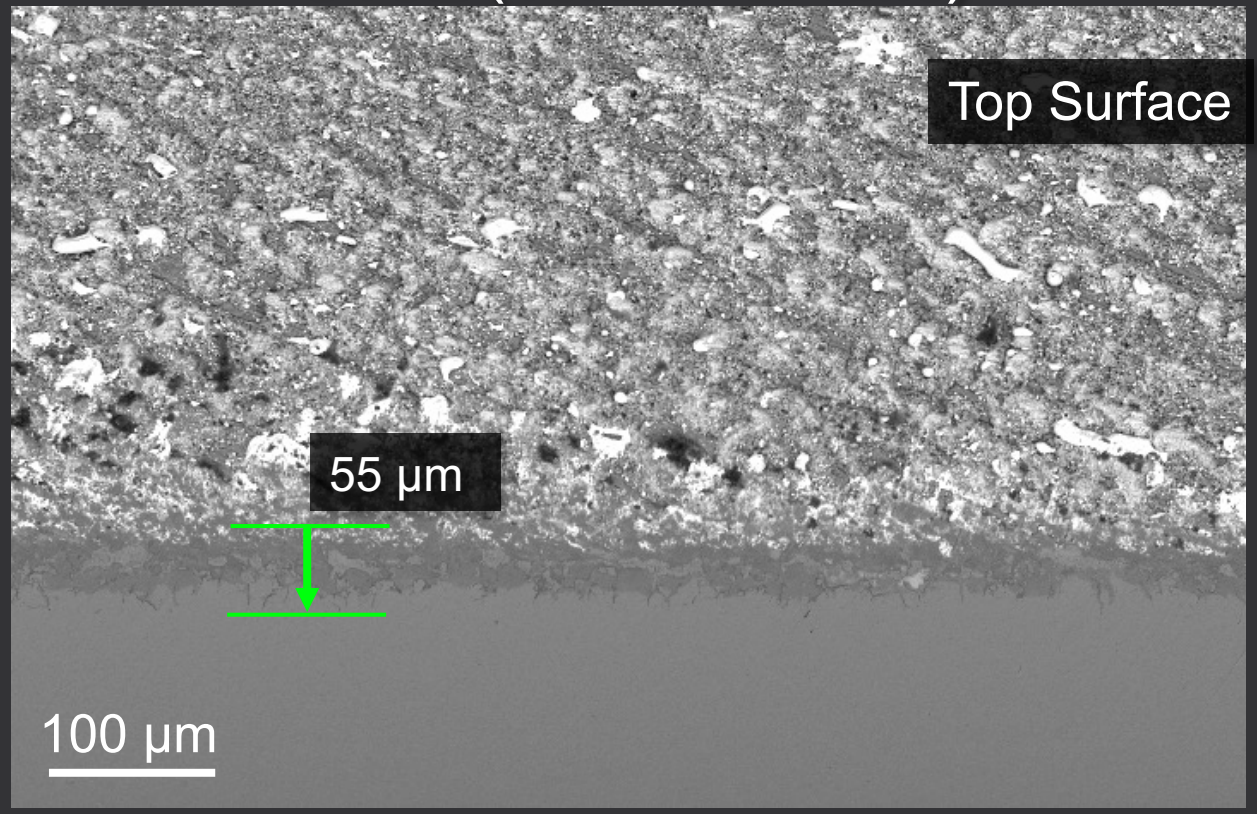


RESULTS

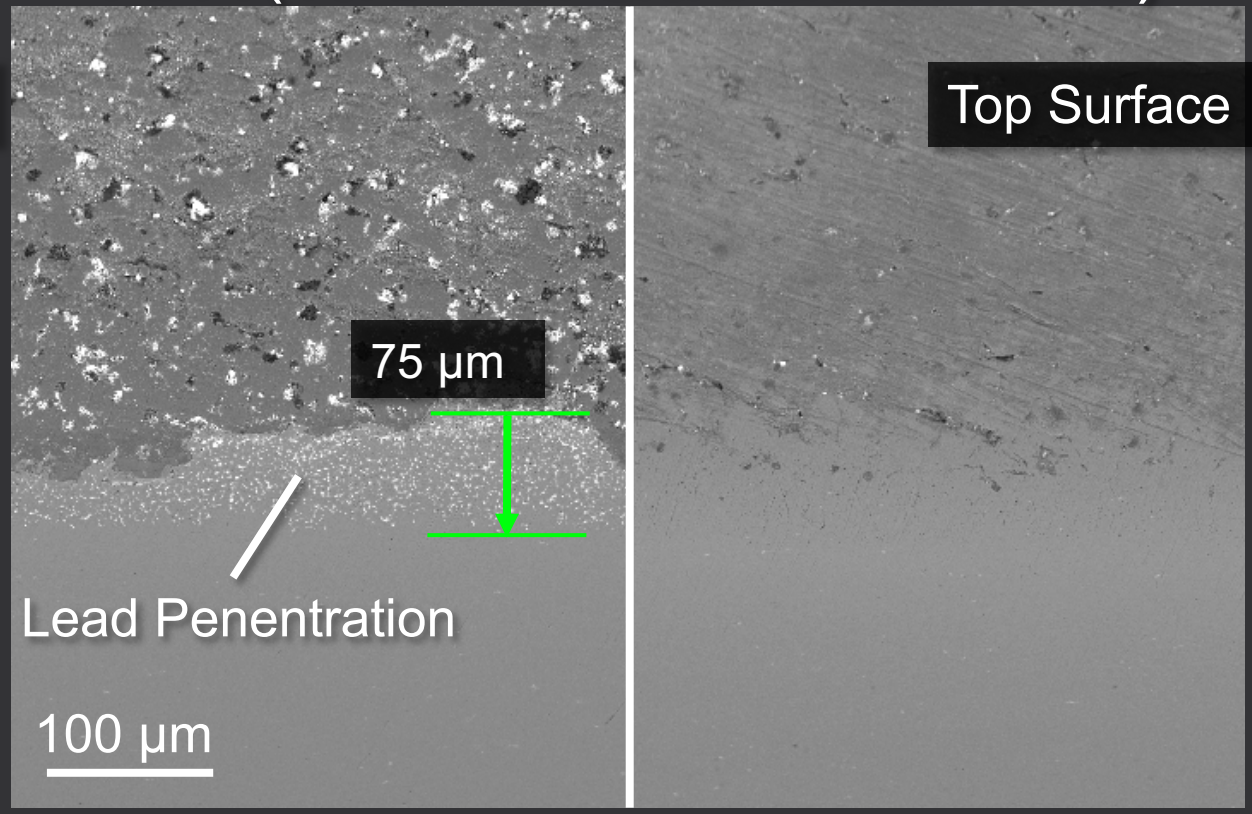
Experiment D - 600°C (*high pO_2*)

10^{-4} wt. % O
1272 hours

316L (*10Ni-17Cr-2Mo*)



AFA (*16Ni-14Cr-2.5Al-2.5Mn-0.9Nb*)

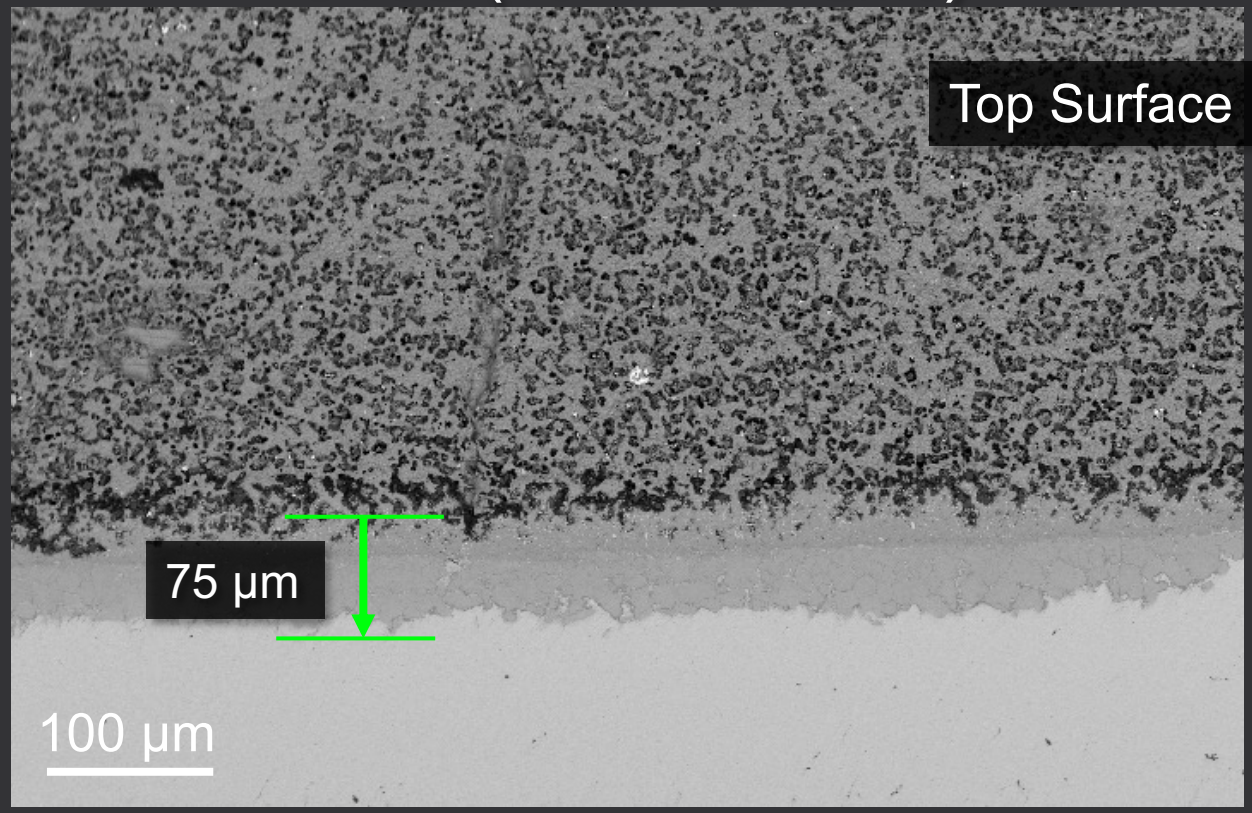


RESULTS

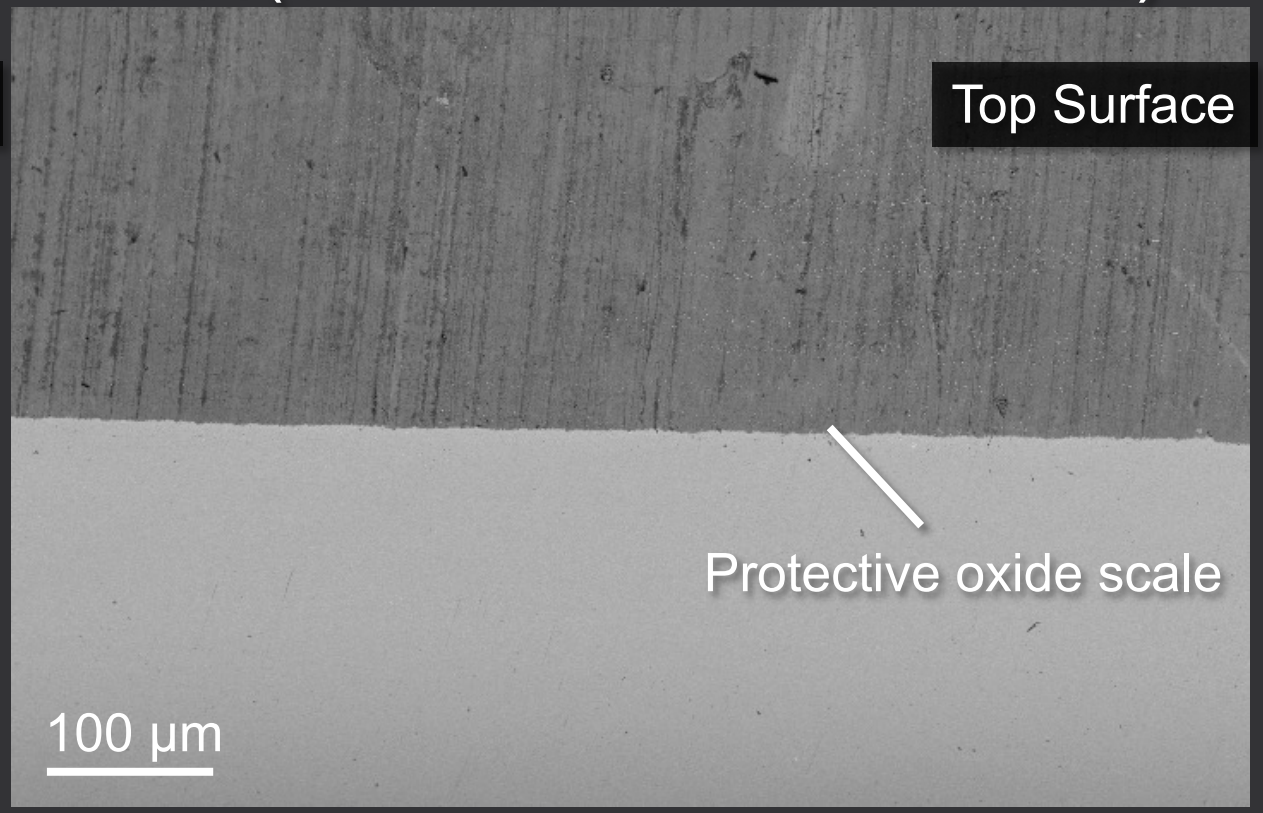
Experiment E - 600°C (*low pO_2*)

10^{-6} wt. % O
1080 hours

316L (*10Ni-17Cr-2Mo*)

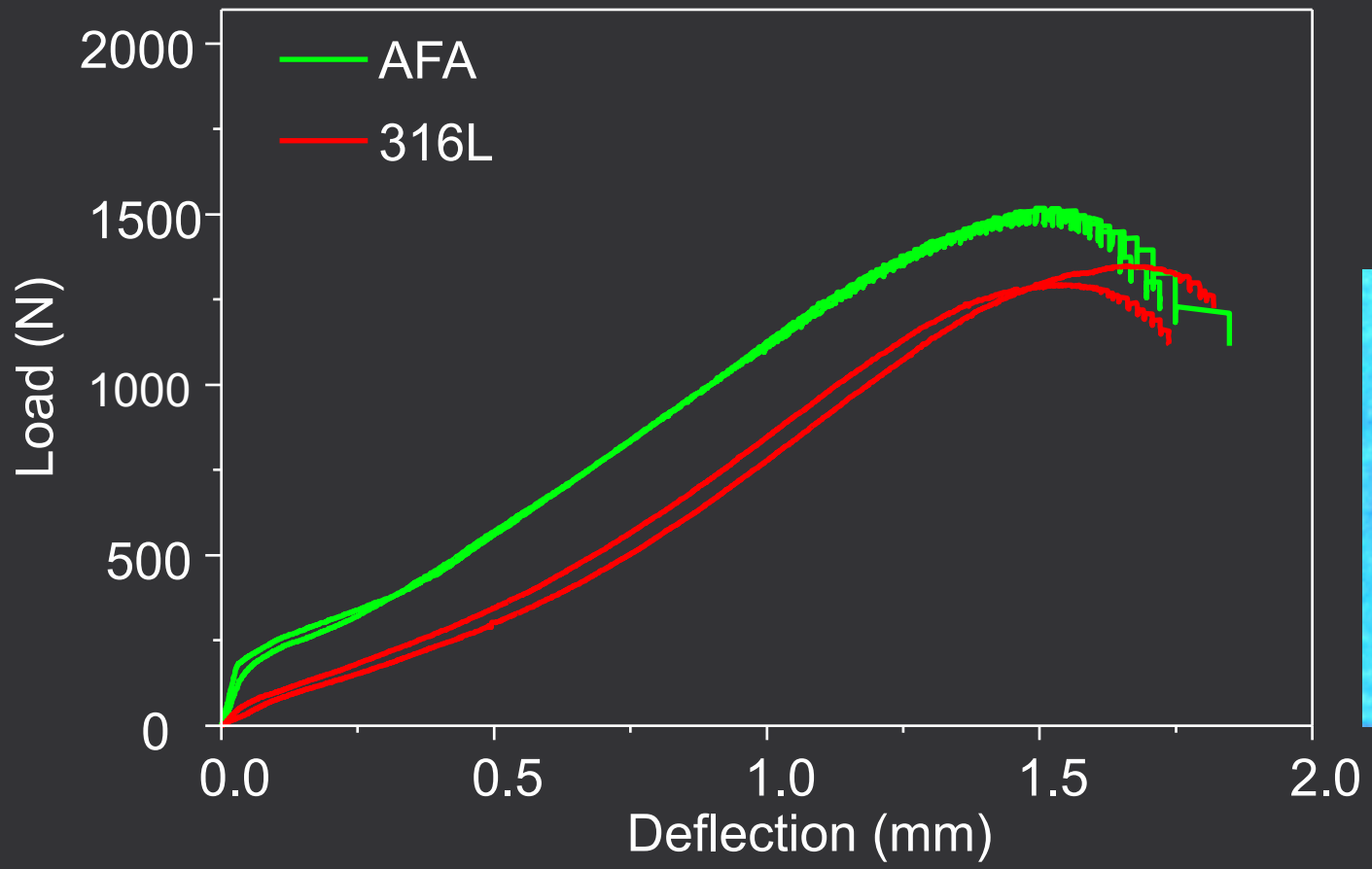


AFA (*16Ni-14Cr-2.5Al-2.5Mn-0.9Nb*)



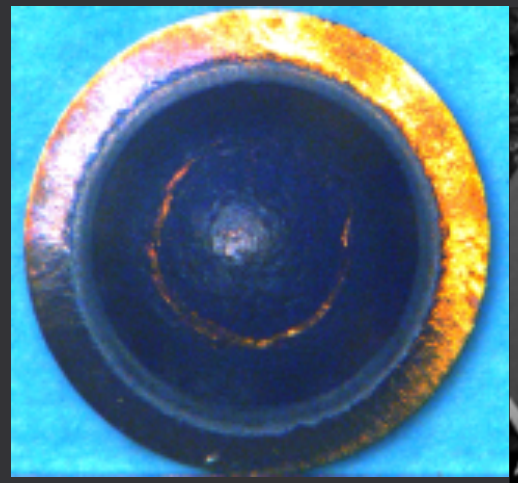
RESULTS

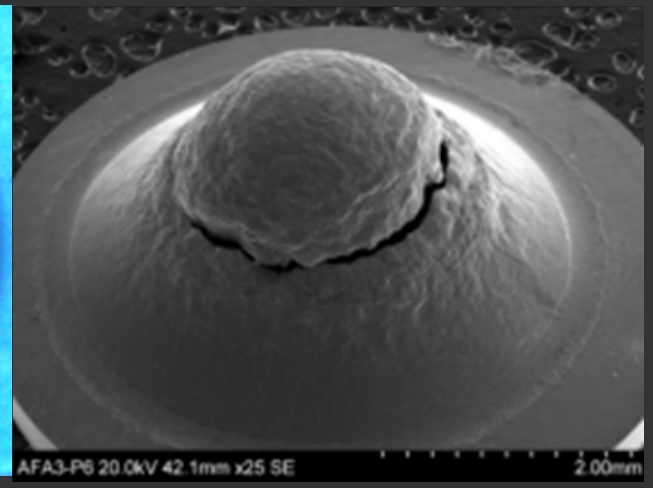
Small Punch Testing – 500°C (CIEMAT)



AFA

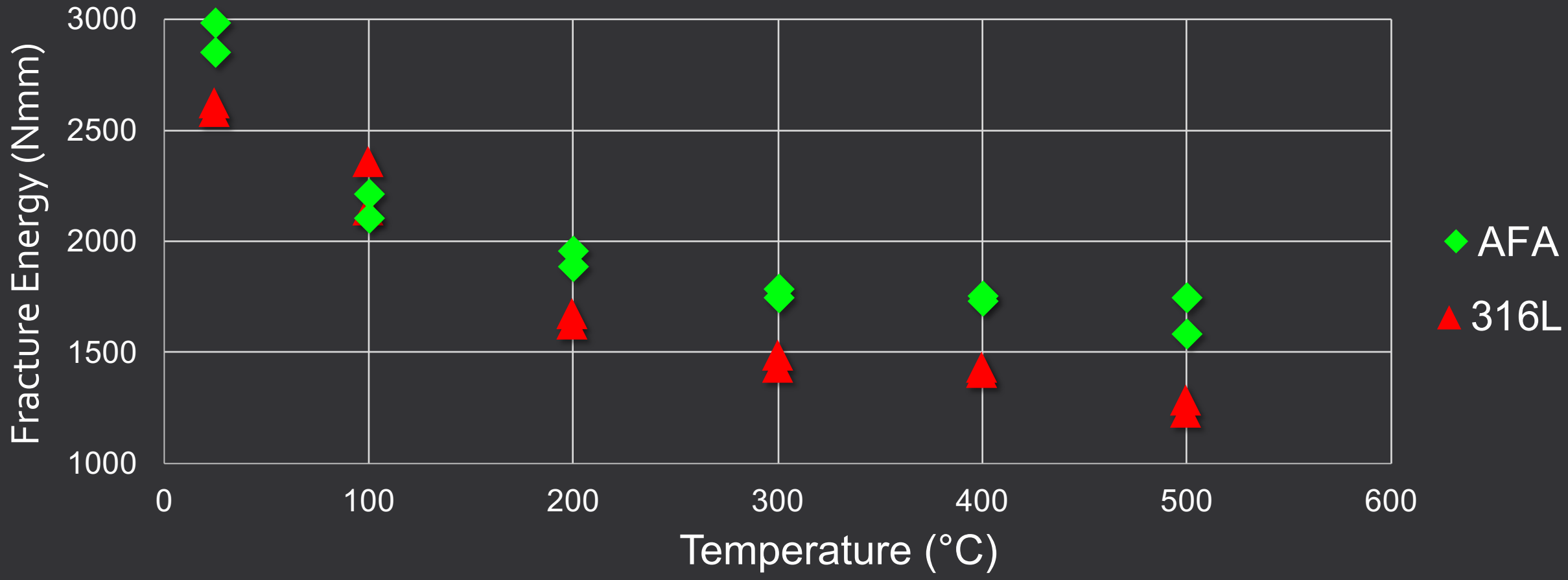
(*16Ni-14Cr-2.5Al-2.5Mn-0.9Nb*)





RESULTS

Small Punch Testing - CIEMAT

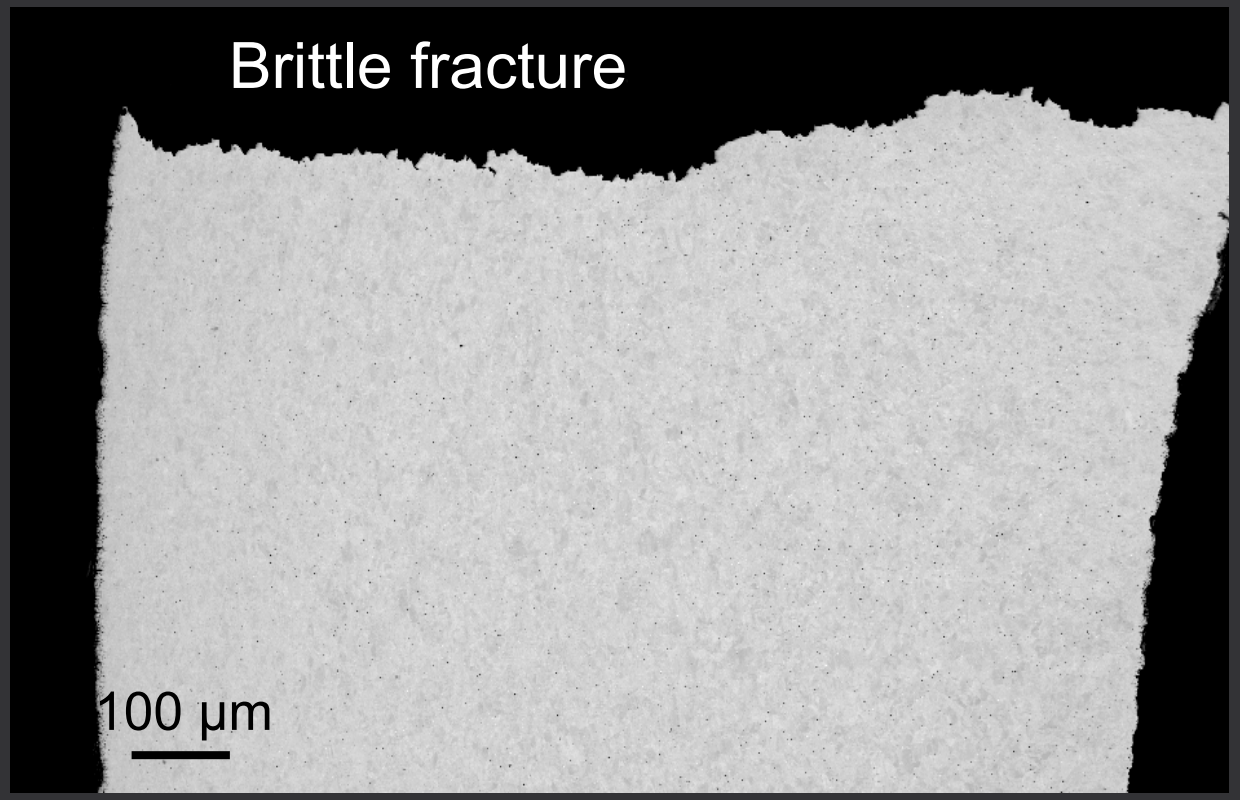


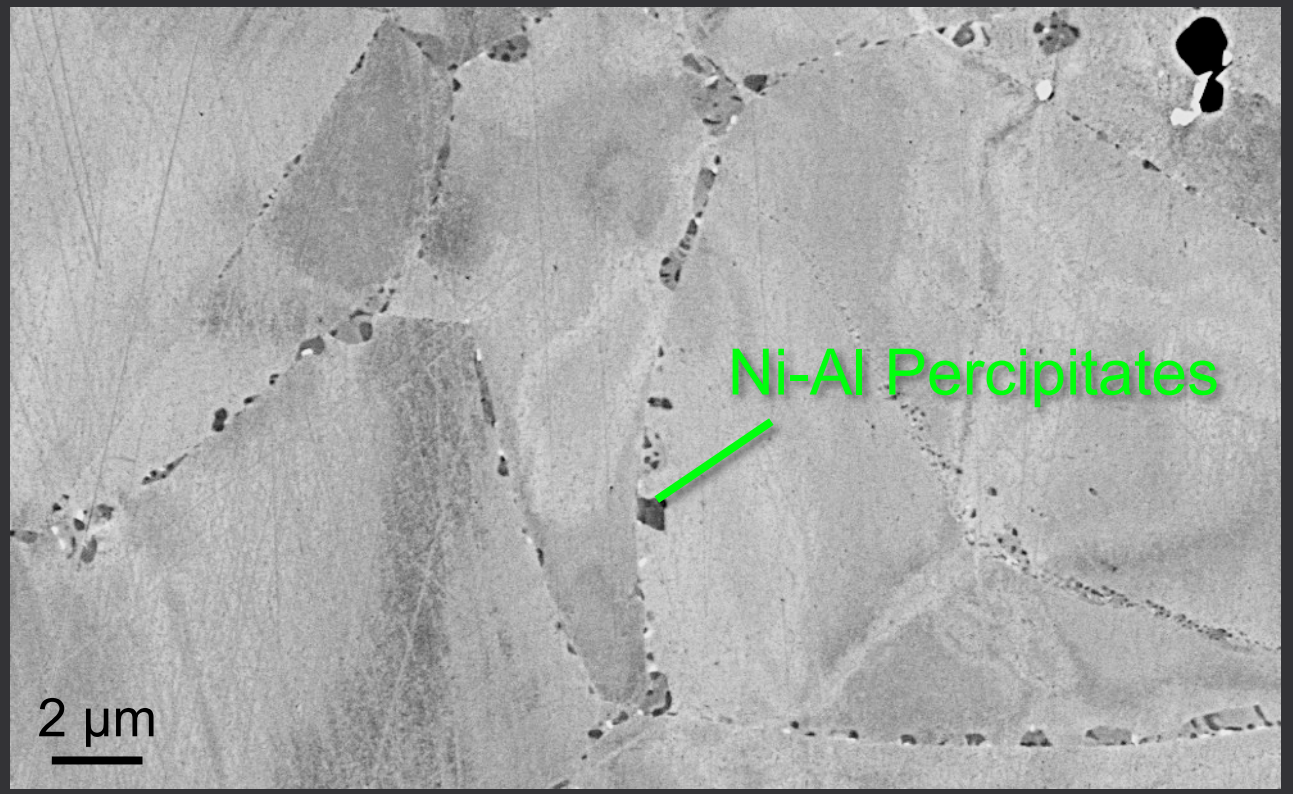
RESULTS

Ageing issues of high alloyed AFA steel

600°C - Air
3600 hours

18Ni-10Cr-2.8Al-Nb – Cold worked ~15%

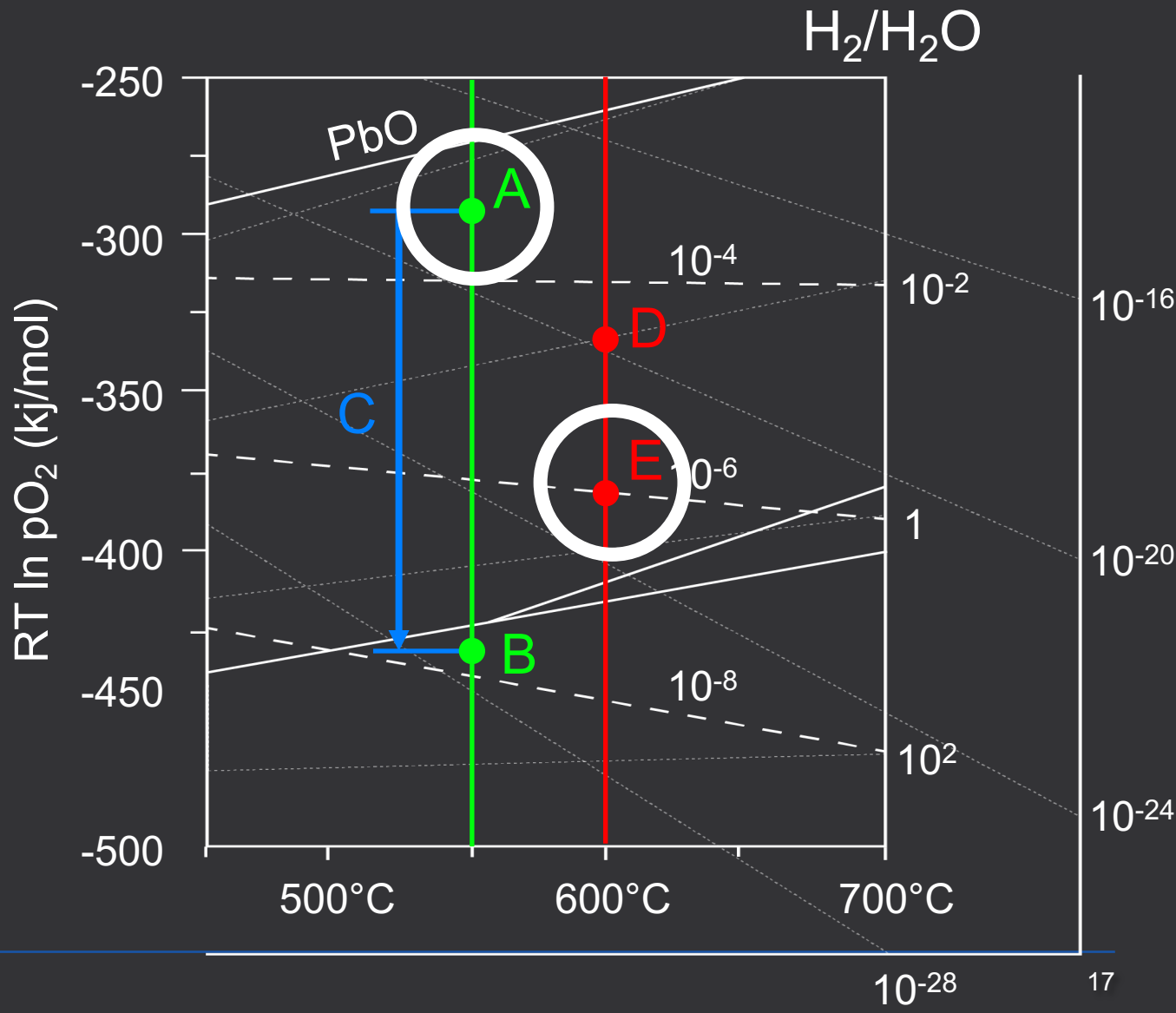




SUMMARY

- **Fe-10Cr-4Al-RE** – Only alloy with excellent performance in liquid lead up to **800°C** (*Submitted to JNM*)
- **Austenites** (**AFA**) needed for **HT** mechanical properties
- Further **RE optimisation** and **testing** of **AFA**s required
- Combination of high **Al** and **Ni** → **Ageing embrittlement**

AFA Performance



Thank you for your attention!

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

Ciemat
División de Materiales de Interés Energético