ROLE OF ZIRCONIUM ON THE OXIDATION RESISTANCE OF NICKEL ALUMINIDE COATINGS

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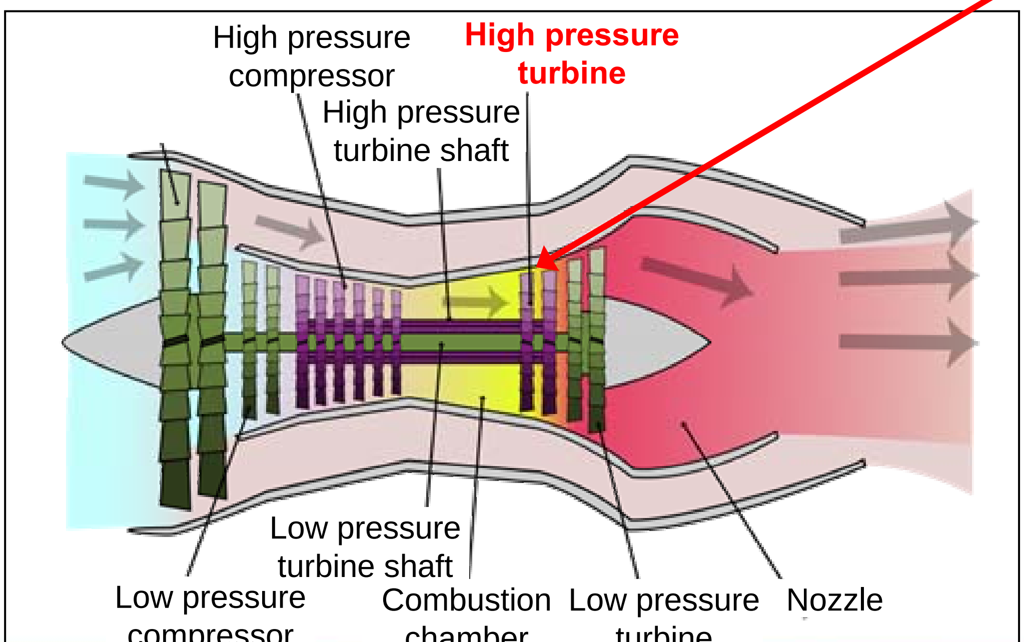
Aeronautical turbine blades

Rafale military plane

Engine schematic diagram

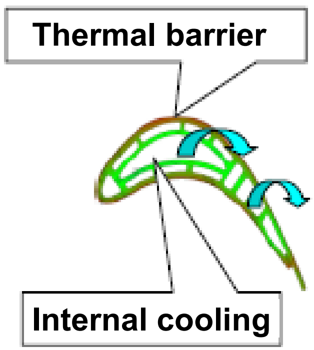


Turbine blade

Aeronautical turbine blades are located at the combustion chamber exit. They are then exposed to the hot combustion gases. The temperature can reach about 1600°C.

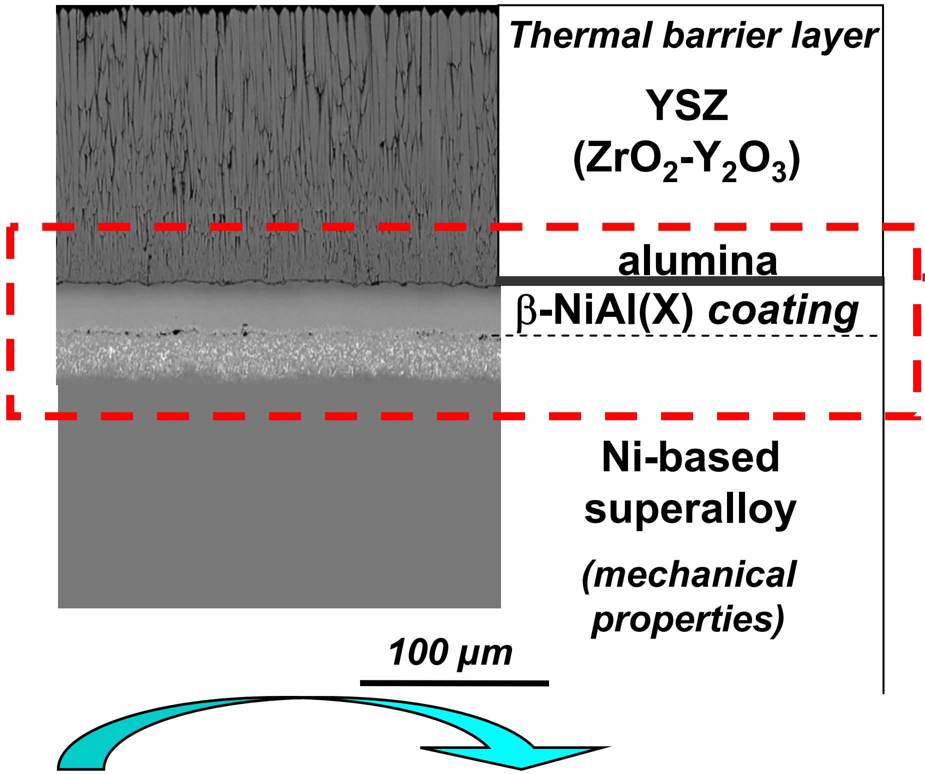
Thermal barrier systems

Turbine blade cross section



Thermal Barrier system

1150 - 1200 °C



600 - 700°C
Internal cooling

1100°C

Key point:
adhesion of thermally grown alumina on top of the NiAl coating

NiAl(X) coatings

Influence of adding elements on the oxide adhesion

3 types of NiAl coating

- unmodified NiAl
- Pt-modified NiAl: great improvement of alumina adhesion, system in production, high processing costs
- Zr-doped NiAl: Zr as a reactive element is said to improve alumina adhesion on NiAl and NiCrAl bulk materials *
  NiAl(Zr) has to be investigated as a coating. One-step elaborating process.

Studied system

Ni-based superalloy: AM1 (<u>Ni</u>, Cr, Co, Mo, W, Al, Ti, Ta)

oxidation protective <u>coating</u>: Zr-doped NiAl

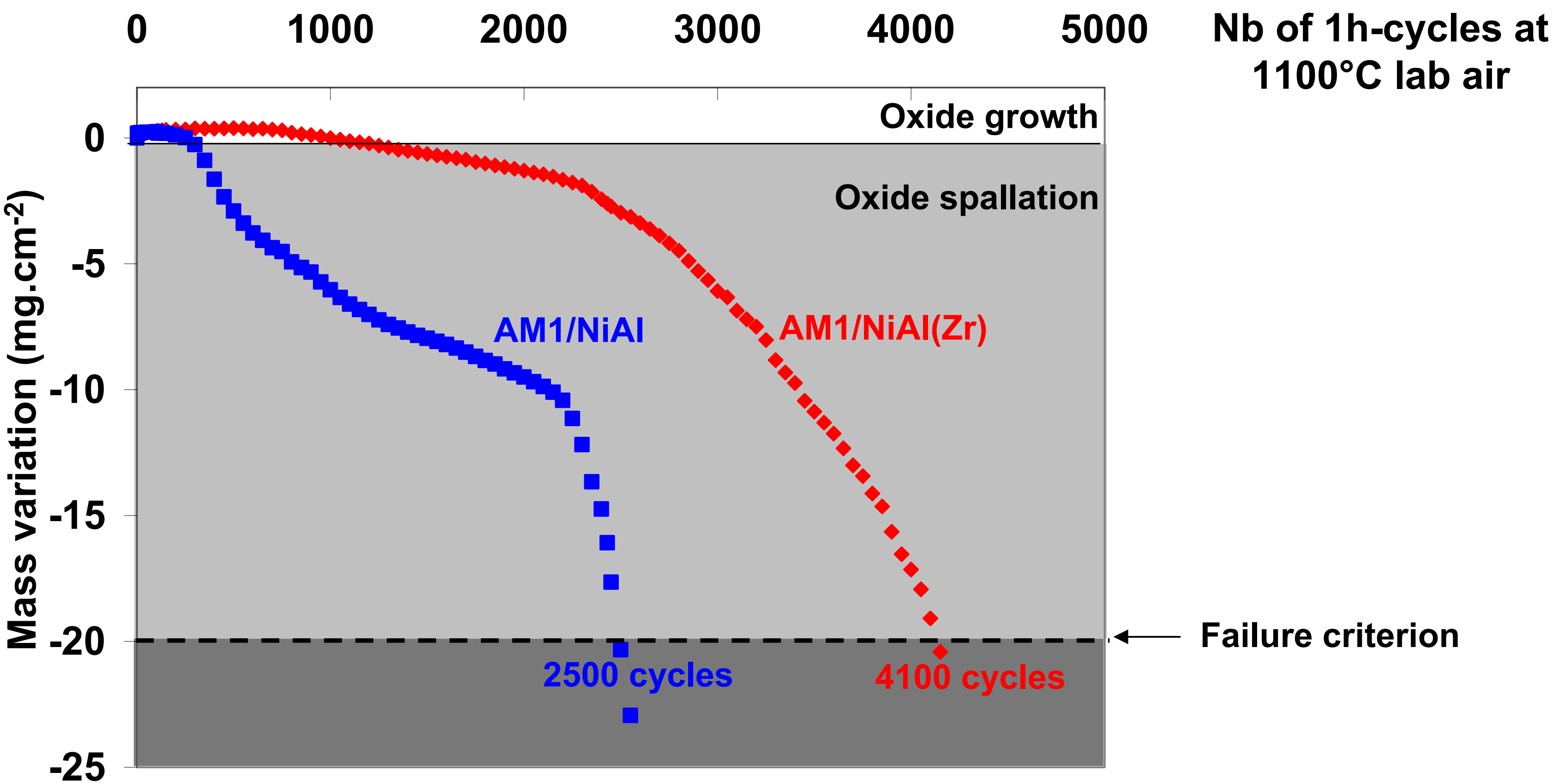
No thermal insulating topcoat

<u>What is the role of Zr on the oxidation resistance of the NiAl coating?</u>

* Smialek, 1987 ; Pint *et al.*, 1996

AM1/NiAl(Zr) efficiency

Cyclic oxidation tests



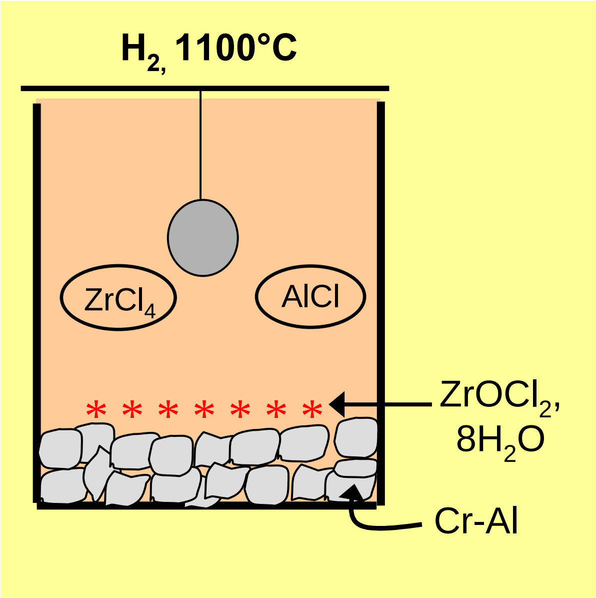
AM1/NiAl(Zr): better oxidation resistance than AM1/NiAl. WHY ?

as efficient as the industrial system

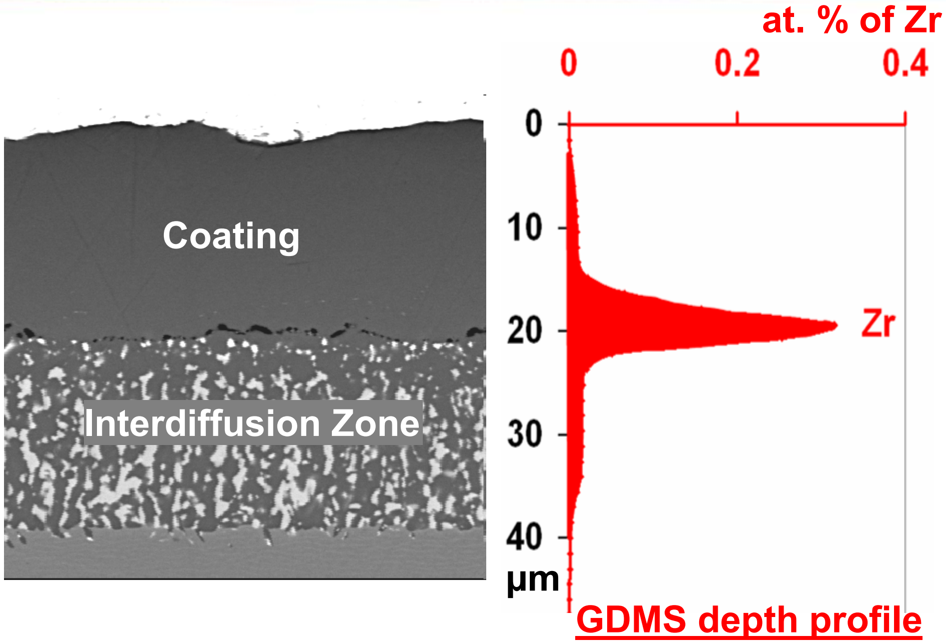
AM1/NiAl(Zr) characterization

Process

Deposition process*



Vapor Phase co-deposition of Al and Zr on AM1 Ni-based superalloy



NiAl(Zr) coating:

β-NiAl phase (XRD)

Al: 36 at. % (EPMA)

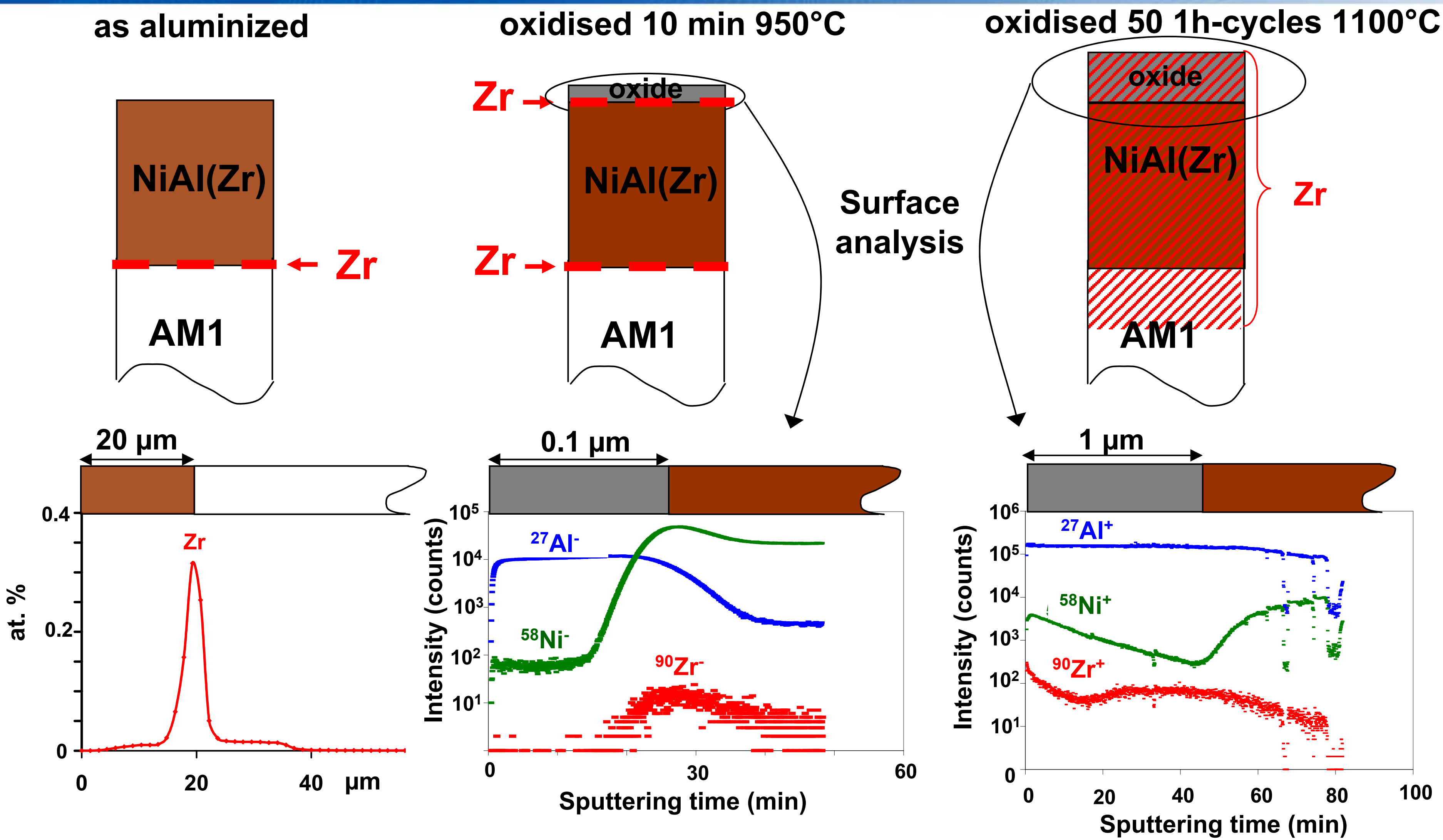
Zr: 300 at. ppm (GDMS) ~ 20 µm from the surface

* **M.-P. Bacos, P. Josso, and S. Navéos, Patent FR2853329 B1 (2006).**

EPMA: Electron Probe Micro Analysis
GDMS: Glow Discharge Mass Spectrometry

AM1/NiAl(Zr) characterization

Zr distribution in oxidising conditions



GDMS depth profile

ToF-SIMS depth profile

ToF-SIMS depth profile

AM1/NiAl(Zr) characterization

→ **Zr diffuses quickly trough the coating towards the metal/oxide interface.**

→ **After longer oxidation, Zr is present in all the layers of the sample.**

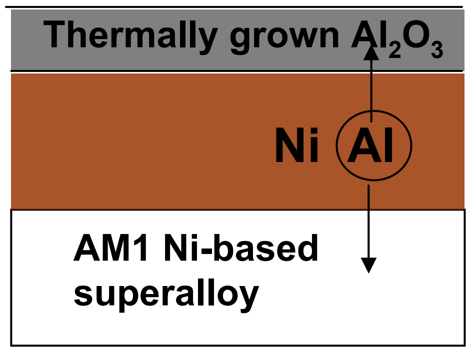
How does Zr improve the oxidation resistance of NiAl?

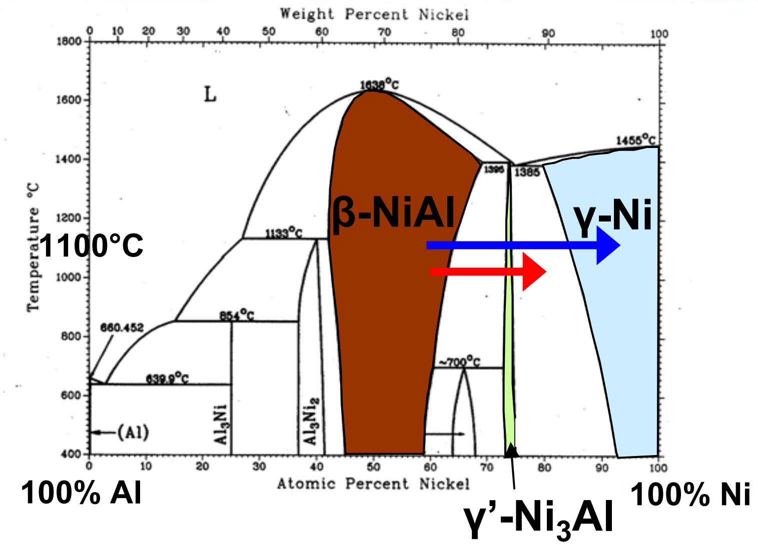
Comparison between the AM1/NiAl and the AM1/NiAl(Zr) systems:

1. **β-NiAl ageing**
2. **oxide growth**

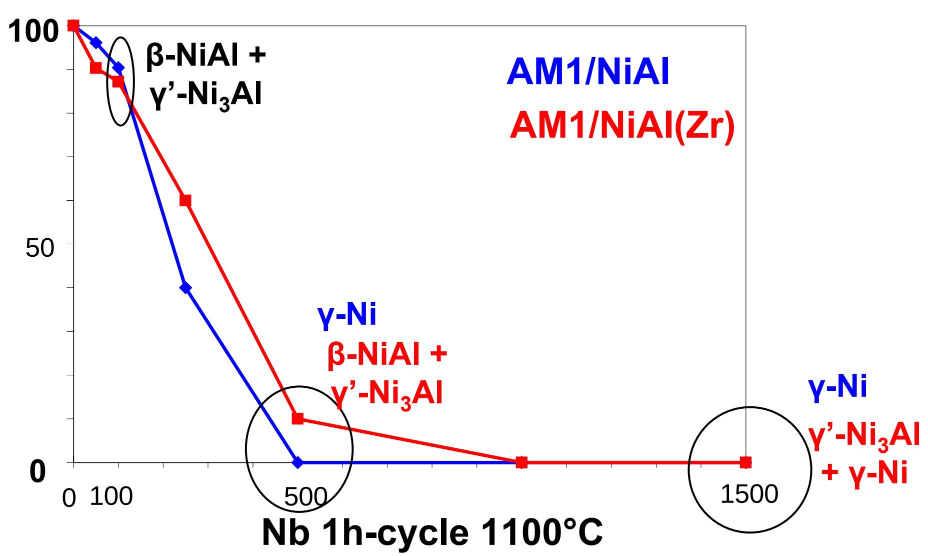
1. β-NiAl ageing

1h-cyclic oxidation tests





β-NiAl fraction (%)



NiAl: The whole coating is γ phase as soon as 500 oxidation cycles

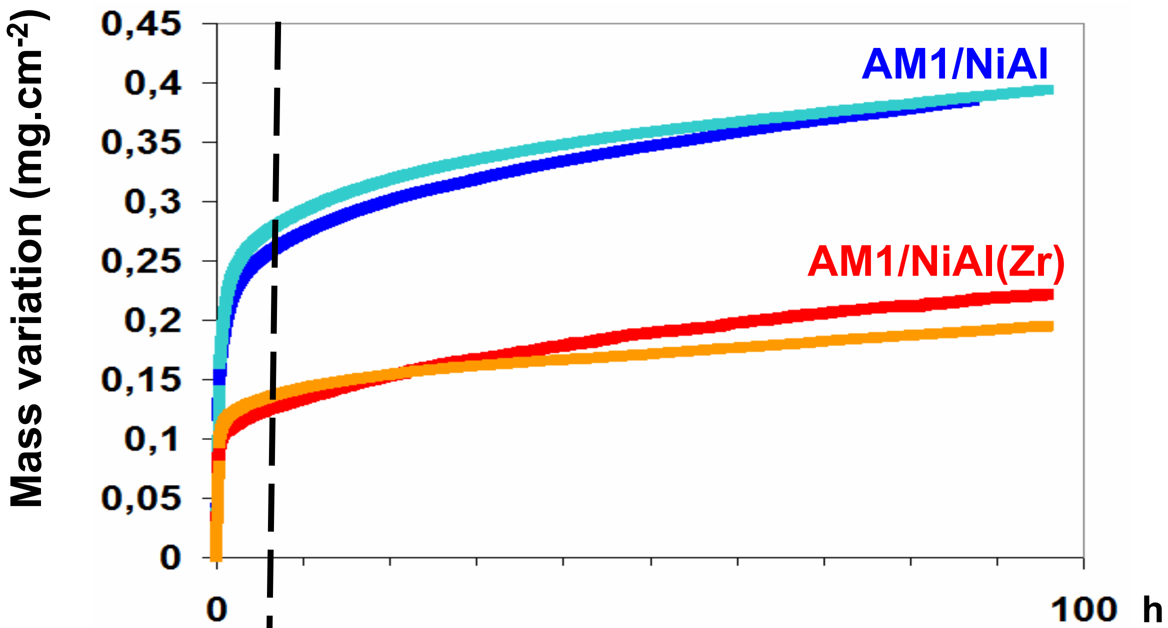
NiAl(Zr): β-phase is still present after 500 oxidation cycles the coating is γ/γ' after 1000 and 1500 oxidation cycles

Zr delays the coating ageing

2. Oxide growth

Isothermal 1100°C oxidation tests

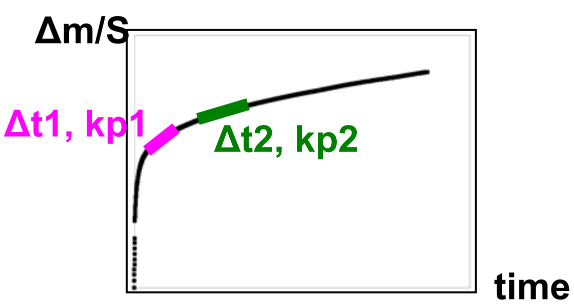
96 h 1100°C, synthetic air, followed by TGA



The parabola

$t = A + B\ \Delta m/S + 1/\underline{kp}\ (\Delta m/S)^2$

is used to fit the isothermal oxidation curves on selected intervals



Transient regime: fast oxide growth first few hours

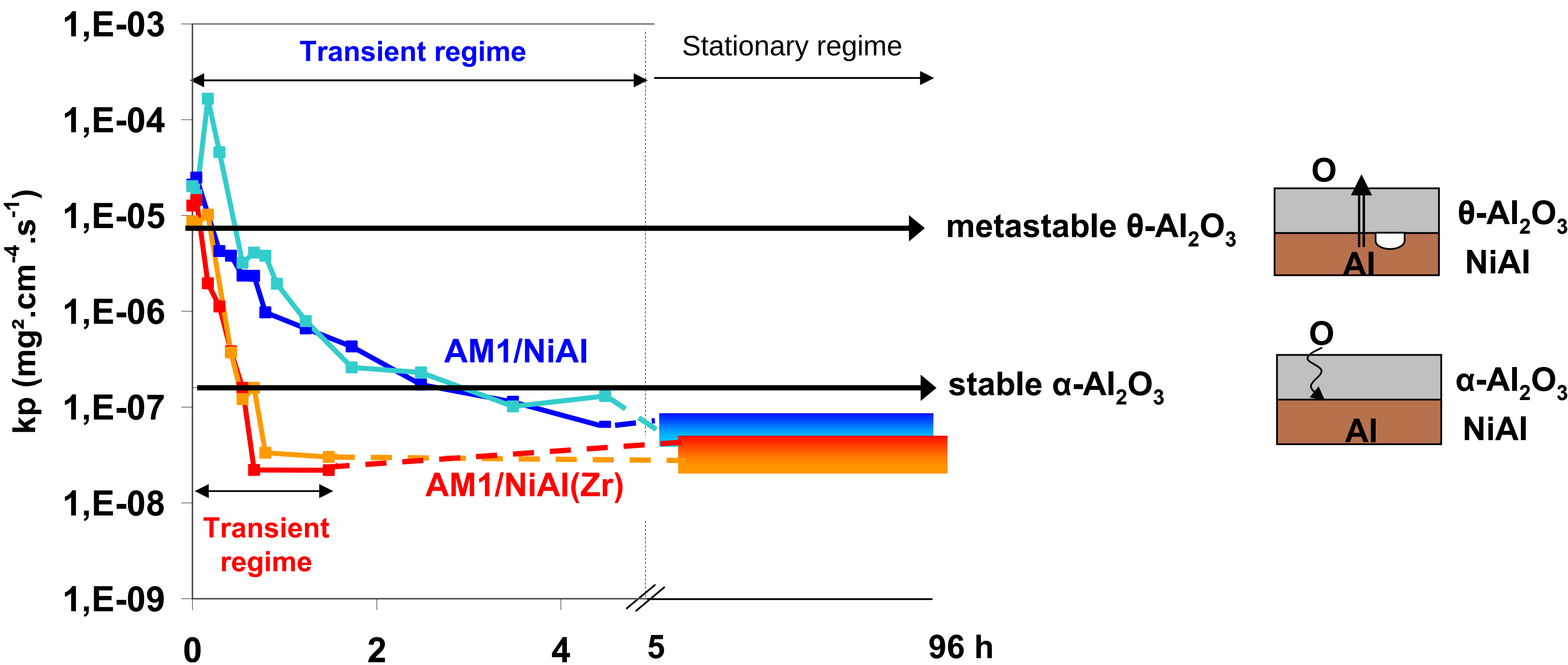
Stationary regime: slow oxide growth

Zr lowers the global mass gain

→ Reduces the oxide thickness

2. Oxide growth

Growth kinetics $t = A + B\, \Delta m/S + 1/kp\, (\Delta m/S)^2$

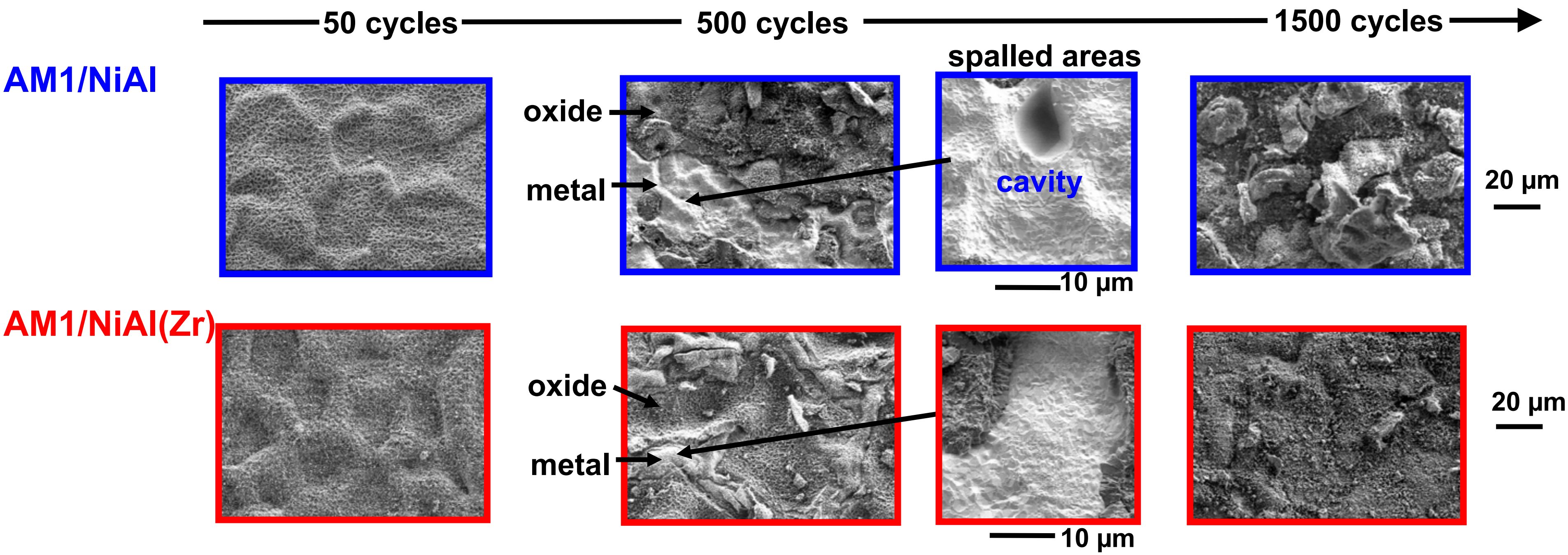


- Zr has no major effect on θ and α growth kinetics.
- Zr reduces the transient regime duration.
- When exposed to oxidation at 1100°C, as Zr reduces the period during wich θ-alumina grows, it reduces the formation of interfacial cavities.

Long-term cyclic oxidations

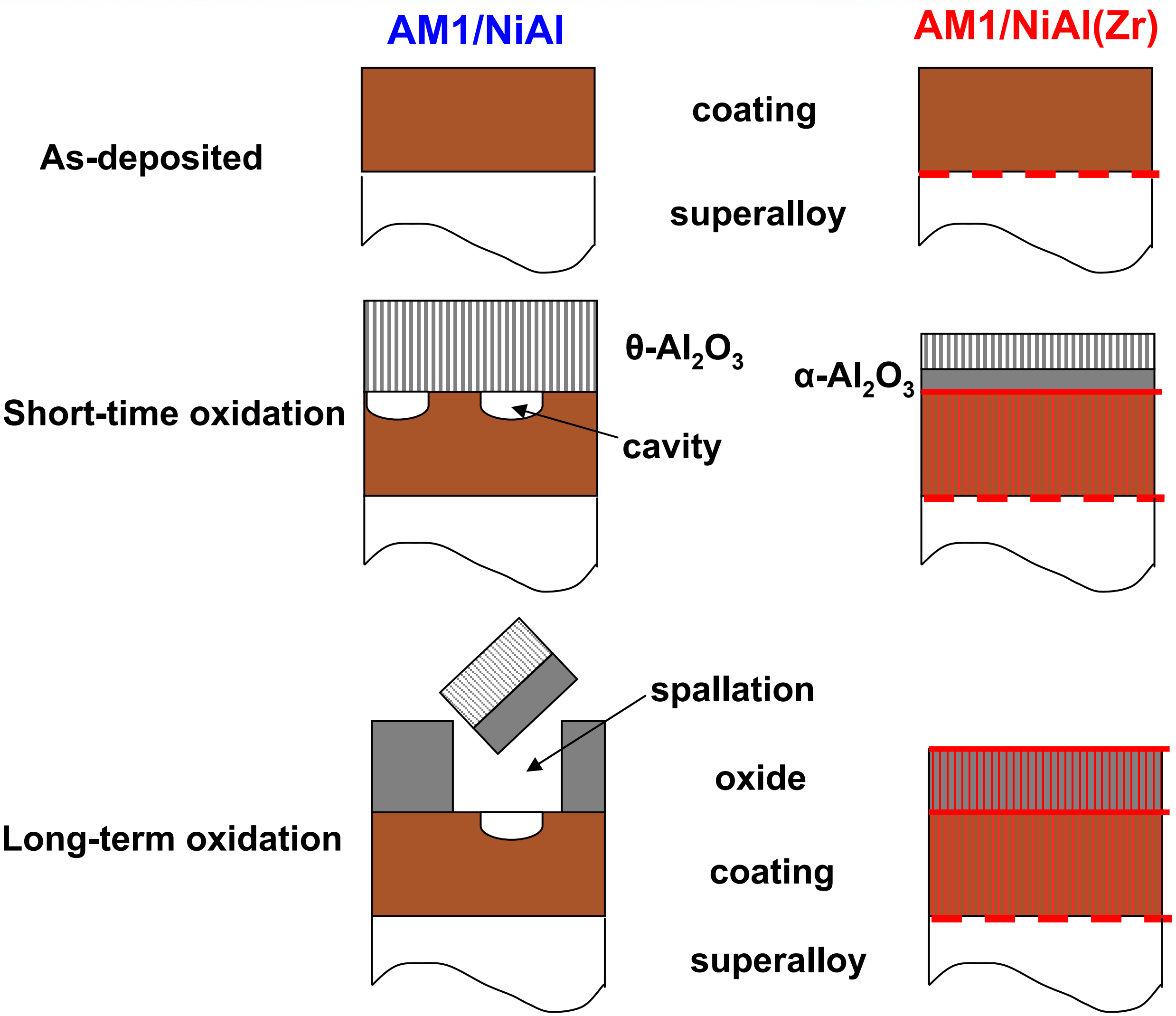
1h-cyclic oxidation tests

Oxidised surfaces



AM1/NiAl(Zr)

- The alumina is more adhesive
- Oxide spallation is delayed, as well as spallations/reoxidations that lead to metal consumption



Zr is located at the superalloy/coating interface

Zr migrates through the coating and favours α-Al$_2$O$_3$

Zr delays the oxide spallation

Conclusions

- Zr reduces the transient regime of oxidation, favouring alpha alumina nucleation

- Zr reduces cavities and delays the oxide spallation

→ Zr increases the system lifetime

NiAl(Zr) promising protective coating, is being investigated as a bond coat in TBC systems

Acknowledgments

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