DECHEMA FORSCHUNGSINSTITUT

High Temperature Materials

Lifetime Model for NiAl Diffusion-Coatings

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Motivation

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- NiAl Diffusion-Coatings → oxidation protection of thin-walled components in turbine engines.
- Service conditions including the superposition of thermal and mechanical strains lead to microstructural changes due to outward and inward Al-flux (Fig. 1).
- The mechanical impact of the coating is either neglected or not thoroughly investigated.
- Precise determination of the lifetime → reduction of maintenance costs → the requirement of a modelling tool to simulate the alteration of the microstructure and load bearing capacity

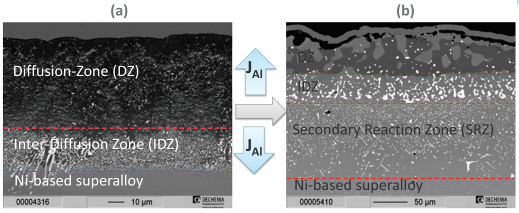

Fig.1. BSE-images (a) prior to, (b) after exposure at 1100°C

Microstructural Degradation

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- Thermocyclic exposure → Al-depletion → formation of the γ'-phase (Fig. 2)
- Higher exposure temperatures → Accelerated Al-depletion (Fig. 3a)
- Interdiffusion with the substrate → Parabolic growth of the SRZ (Fig. 3b)
- Model parameters → Al-concentration, zone thickness and phase fractions

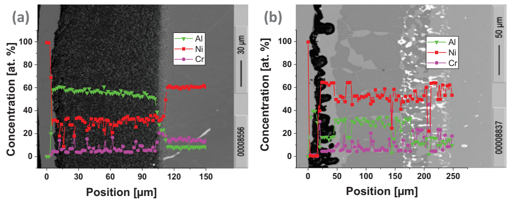

Fig.2. BSE-images and EPMA line-scans of coatings (a) prior to, (b) after thermocyclic exposure at 1100°C for 500 h

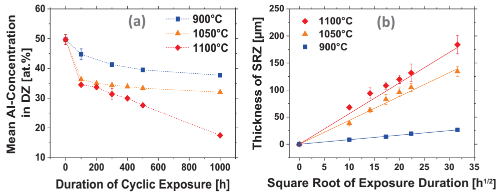

Fig.3. Mean Al-concentration in (a) DZ, (b) thickness of SRZ as f(t) at different T

Mechanical Properties

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- Fracture strain increases with decreasing Al in the NiAl phase (Fig.4b)
- High T exposure → SRZ growth → loss of mechanical superiority of the substrate (Fig. 5)
- Model parameters → Fracture strain, Young's modulus, creep strength (1% creep strain in 100 h)

Al-depletion → Increase in fracture strain

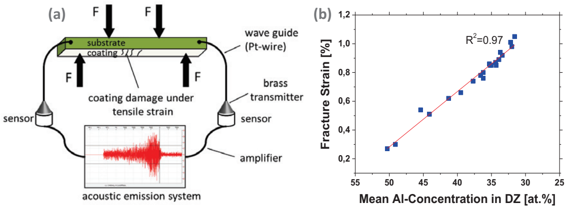

Fig.4. (a) Four-point flexural test setup with in-situ acoustic emission measurement, (b) Fracture strain as a function of mean Al-concentration [1].

Al-depletion → Loss of creep strength due to SRZ growth

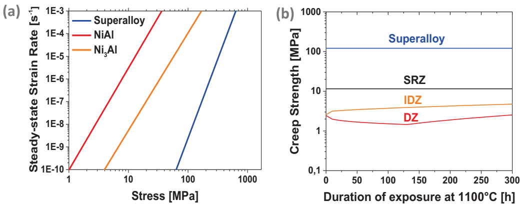

Fig.5. (a) Creep strain rate of NiAl, Ni_3Al and substrate at 1100°C via power law using literature data from [2,3], (b) Creep strength of coating zones and substrate

Computational Results

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- Surface recession and the alteration of the coating thickness can be simulated as f(T,t) (Fig. 6a).
- Determination of chemical lifetime (Fig. 6b) (lifetime criterion: absence of the B2-NiAl phase) as f(T)
- Higher exposure temperatures → accelerated enhancement of elastic load bearing capacity and reduction of creep strength (Fig. 7a and Fig.7c)
- The simulation can be used to tailor the aluminization process (Fig. 7b).
- Mechanical impact of the coating → especially important for thin-walled components (Fig. 7d)

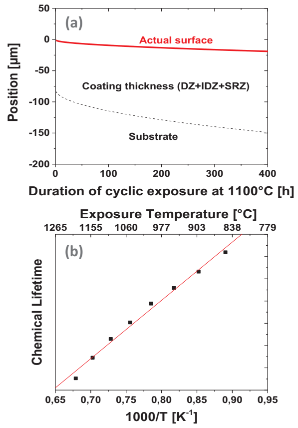

Fig.6. Alteration of (a) the zone thickness, (b) chemical lifetime as f(T)

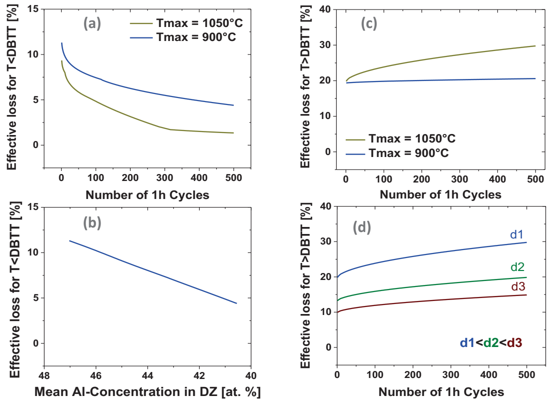

Fig.7. Effective loss for T<DBTT (a) 1 mm component at different T, (b) for different Al-concentrations, for T>DBTT (c) at different T (d) for varying component thickness during exposure at 1050°C

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