DECHEMA FORSCHUNGSINSTITUT

High Temperature Materials

Influence of Different Coating Techniques on a γ-TiAl alloy

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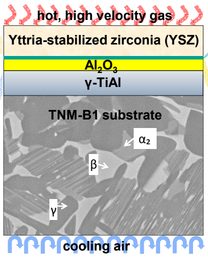
Introduction

γ-TiAl-based alloys represent an important class of new light weight high temperature materials with less than half the weight of nickel-base alloys. They provide an unique set of physical and mechanical properties that can lead to substantial payoffs in industrial applications, where high specific strength and stiffness are required. In high temperature applications such as turbine blades intermetallic TiAl-alloys can enhance the performance and operating efficiency [1]. Presently two-phase TiAl-alloys are already applied, for example in the low-pressure region of the GEnx-1B engine. However the impact of oxidation and oxygen-induced embrittlement at higher temperatures (> 700°C) must be decreased. This project develops a new coating concept on the next generation γ-TiAl alloy TNM-B1 (Ti-43.5Al-4Nb-1Mo-0.1B [at.%]). This alloy consists of three phases - α_2-Ti_3Al, γ-TiAl, and β_0-Ti – providing a higher malleability. γ-TiAl has the lowest oxygen solubility of these phases. Hence, γ-TiAl-based coatings are fabricated on TNM-B1 substrates by pack-cementation and magnetron sputtering. In order to improve the oxidation resistance of γ-TiAl, the halogen effect is used in addition, which promotes the formation of a protective Al_2O_3 layer at high temperatures. Furthermore the effect of the bond coat on the morphology of the thermal barrier coating is shown.

Coating System

Thermal barrier coating (TBC):
Low thermal conductivity

Bond coat (BC):
Al reservoir to form and maintain the alumina layer

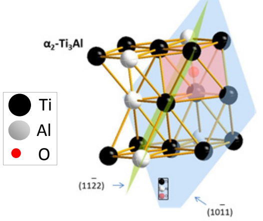


Halogen-containing polymer
Improving selective Al oxidation

Thermally grown oxide (TGO):
Thermally grown oxide
Oxidation protection
Diffusion barrier

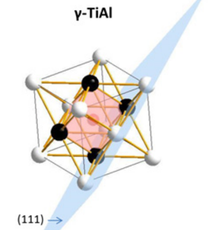
Oxygen Solubility of TiAl Phases

α_2-Ti_3Al phase: 10 – 20 at.% [3]



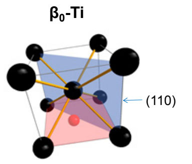
$D0_{19}$ structure of α_2-phase

γ-TiAl phase: 1 – 3 at.% [3]



$L1_0$ structure of γ-phase

β_0-Ti phase: ~8 at.% [4]



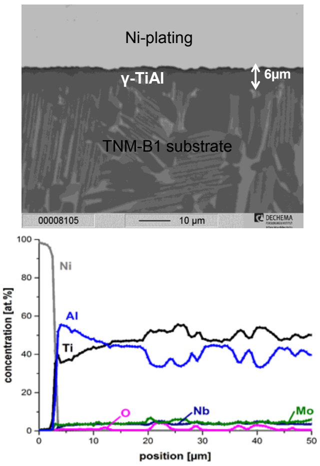
A2 structure of β_0-phase

- Octahedral cavities are possible sites for oxygen interstitials
- Interstitial sites of
  α_2-Ti_3Al, β-Ti : Ti_4Al_2, Ti_6
  γ-TiAl: Ti_4Al_2, Ti_2Al_4
- Ti_6 cavities of α_2 and β_0 convenient for interstitials

generate γ-TiAl surface layer to inhibit O incorporation and prevent mechanical property degradation

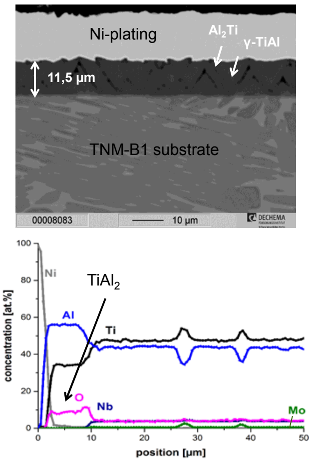
Coating deposition

Pack cementation



- γ-TiAl diffusion coating
- Remaining refractory metals in γ-TiAl (Nb: 3,2 at.%, Mo: 0,9 at.%)

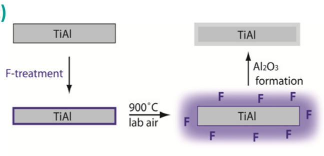
Magnetron sputtering



- Mixed γ-TiAl/$TiAl_2$ sputter layer
- No side elements
- High oxygen solubility of $TiAl_2$ (up to 12at.%)

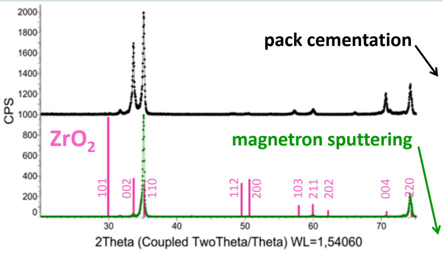
2nd step: fluorine treatment (halogen effect)

- Selective oxidation → enables protective Al_2O_3 oxide scale formation during oxidation
- Enhanced oxidation protection of Al_2O_3 because of its very low permeability for O, N, H, and metal ions



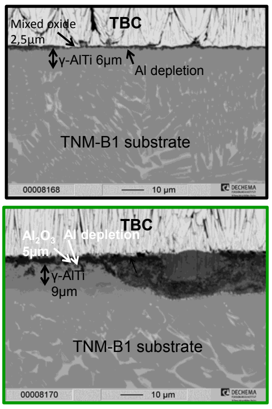
flourine treatment process

Influence of Bond Coat on Thermal Barrier Coating



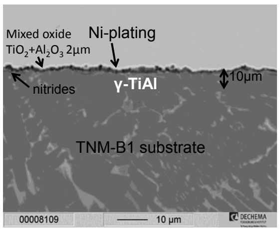
XRD pattern of thermal barrier coatings deposited on different BC layers

after 100h @ 900°C, air

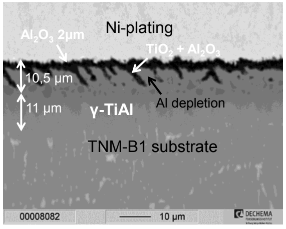


- TBC deposition via electron beam physical vapor deposition at 1000°C
- Bond coat structure determines TBC orientation

Oxidation Mechanism of Coatings



100h @ 900°C, air



- Remaining Al reservoir below thin oxide scale
- Increase of O-concentration in β-phase up to 10 at.%
- In the case of thin γ-TiAl layer: locally high oxidative attack and consumption of whole γ-TiAl layer
  → increase of γ-TiAl layer thickness

- Higher oxidative attack of former $TiAl_2$ phase boundaries due to higher oxygen solubility → oxide growth into the substrate and TiO_2 forms
- Al diffuses into the substrate: γ-TiAl
- Increase of O-concentration in β-phase up to 10 at.%

Outlook

- Investigation of O incorporation in β-phase by GDOES
- Effect of coating deposition steps and TBC orientation on mechanical properties

Project Partners

A DLR

B TECHNISCHE UNIVERSITÄT DRESDEN

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References

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