Environmental Protection of a beta-Stabilized γ-TiAl Alloy by a Combination of the Halogen Effect with Thermal Barrier Coatings

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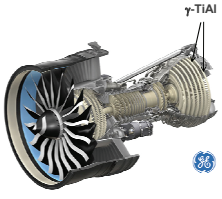
Novel TBC-Concept on γ-TiAl

γ-TiAl alloys

- Ti-(42–49)Al-(0.1–10)X [in at.%]
  X = Cr, Nb, W, V, Ta, Si, B, C
- Low density: ~4 g/cm³ *vs.* ~8 g/cm³ for Ni-based superalloys
- Good mechanical properties at HT
- High specific strengths and moduli

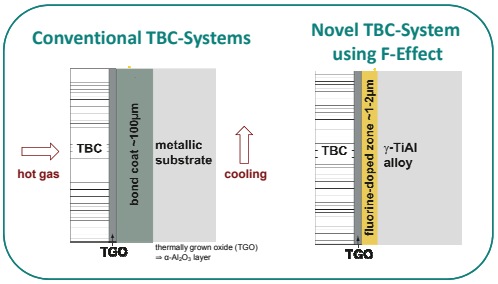
→ **Attractive materials for aeroengines**



GEnx-engine: γ-TiAl blades in low-pressure turbine

Disadvantage: Oxidation resistance limited to ca. 800°C

→ **Environmental protection is required**



Disadvantages of conventional bond coats (BC) on γ-TiAl:

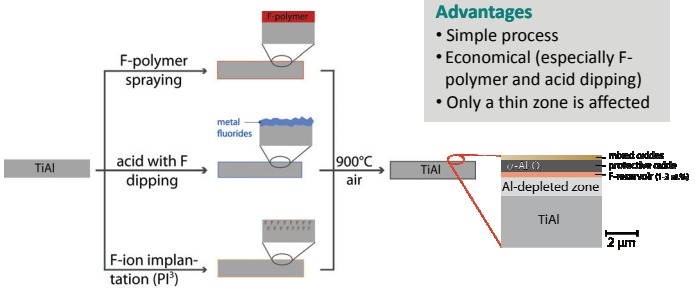
- Formation of brittle intermetallic phases
- Interdiffusion between BC and substrate
- Insufficient oxidation resistance at long-term exposure

Goal: Utilization of halogen effect (fluorine)

- Promotes formation of thermally-grown oxide (TGO) of α-Al_2O_3
- Enhances oxidation protection up to 1050°C

Fluorine Treatments

Simple fluorination methods allow treatment of even complex geometries. Pre-oxidation at around 900°C promotes the formation of a protective α-alumina layer [1].

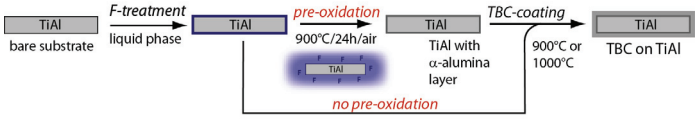


Advantages

- Simple process
- Economical (especially F-polymer and acid dipping)
- Only a thin zone is affected

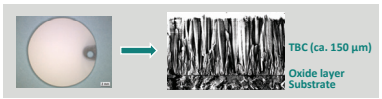
Production of the TBC-System

Thermal barrier coatings of YPSZ were applied via Electron-Beam Physical Vapor Deposition (EB-PVD) at 900°C and 1000°C with and without the implementation of a pre-oxidation step. The TiAl alloy TNM-B1 Ti-43.5Al-4Nb-1Mo-0.1B was studied.



As-deposited samples
Show excellent adherence of TBC on TiAl-substrate, independent of

- Fluorination methods
- Pre-oxidation step
- Deposition temperature (Successful application of 1000°C TBC on TiAl alloy first time)

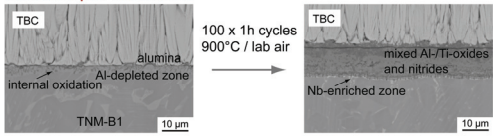


Influence of the Pre-Oxidation Treatment

Samples without a pre-existing dense alumina layer fail in cyclic tests. Reason is the removal of volatile fluorine species in the vacuum atmosphere of the EB-PVD process.

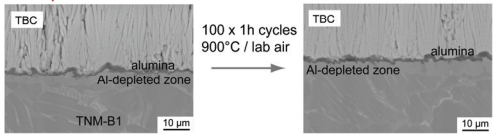
F-treatment: HF	Conditions for cyclic oxidation tests:
TBC-deposition at 1000°C	60 min. at 900°C; 10 min. at T below 30°C

Without pre-oxidation



No oxidation protection. A thick layer of non-protective oxides and nitrides forms similar to untreated material.

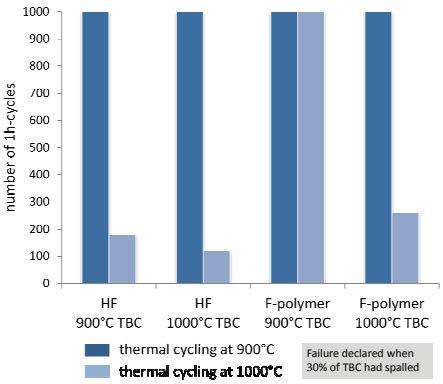
With pre-oxidation



Excellent oxidation protection. The thin and dense Al-oxide layer barely changes its thickness.

Long-Term Exposure Tests

Cyclic Tests at 900°C and 1000°C in Lab Air



Influence of

1. F-treatment

- At 900°C: Oxidation resistance of HF and F-polymer samples extends 1000 x 1h-cycles
- At 1000°C: F-polymer samples perform best

2. TBC-deposition temperature

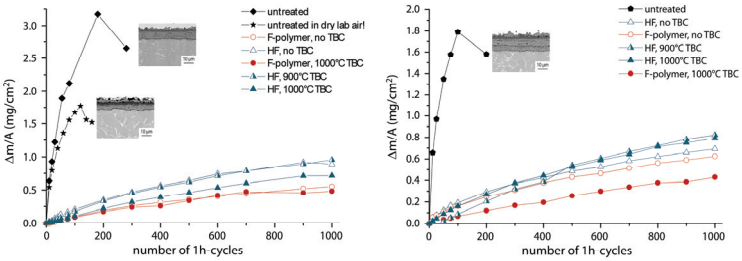
- Comparable lifetimes of TBCs deposited at 900°C and 1000°C at exposure tests at 900°C
- Samples with a 900°C TBC have a longer lifetime during exposure tests at 1000°C

The negative influence of the higher deposition temperature is currently under investigation.

Exposure to Synthetic Air Containing Water-Vapor or Sulfur Dioxide

10 vol.% H_2O in synth. air
60 min. at 900°C; ~25 min. at 40°C

0.5 vol.% SO_2 in synth. air
60 min. at 900°C; ~25 min. at 40°C



TBC-deposition at 1000°C for all samples

Untreated samples show deep attack.
F-polymer samples show significantly thinner Al-depletion zones due to lower surface roughness.
HF samples show thicker Al-depletion zone due to increased surface roughness by etching process. Internal oxidation (alumina) is partially observed.

Outlook

This new TBC-system reveals excellent adherence of TBCs during long-term cyclic tests in aggressive atmospheres, offering a promising alternative to TBC-systems on γ-TiAl with conventional Al-rich bond coats.
Future work focuses on the understanding of the influence of this TBC-system on the mechanical properties of the substrate material.

Literature: [1] A. Donchev, M. Schütze, R. Yankov, A. Kolitsch, W. Möller in *Structural aluminides for elevated temperatures*, ed.: Y.-W. Kim *et al.* TMS (2008), 323-332 [2] S. Friedle, N. Nießen, R. Braun, M. Schütze, Surf. Coat. Technol. 212 (2012), 72-78
Project Partners: R. Braun, N. Laska at DLR (German Aerospace Center) Köln: Application of TBCs, exposure tests ; C. Leyens, A.Straubel at Technische Universität Dresden: Investigation of mechanical properties