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Oxidation-Induced Embrittlement of Titanium Aluminides and its Prevention by a Three-Step Coating Concept

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Motivation

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- Innovative materials required for aircraft combustion engines as well as stationary gas turbines
- Weight reduction can lead to diminished fuel consumption, CO_2 and NO_x emission and noise
- 3rd generation TiAl have already destined for new generation jet engines (Fig. 1a) [1]
- TiAl suffers from insufficient oxidation resistance at T > 750°C constraining its broad application (Fig. 1b)
- Enabling higher service temperatures requires an oxidation resistant coating concept

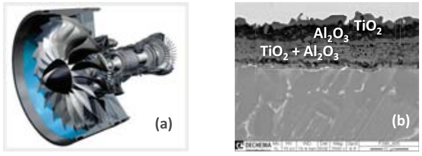

Fig. 1: New generation Geared Turbofan^{TM} (a), Oxidized (100h, 900°C, air) TNM-B1 alloy (b)

Strategy

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1st step: Al-rich γ-TiAl layer deposition
- 1st approach: Out-of-pack cementation process (PC)
- 2nd approach: Magnetron sputtering process (MS)

2nd step: Al_2O_3 formation via F-treatment (F)
- PTFE-Spray application and pre-oxidation
- Activation of the so-called halogen effect

3rd step: Thermal barrier coating (TBC) deposition
- Yttria stabilized zirconia (7YSZ) as TBC material
- Columnar growth during EB-PVD

Results - 1st step

3

- Successful deposition of an Al-rich TiAl layer for both approaches
- PC: Single γ-TiAl layer [2], MS: γ-TiAl and $TiAl_2$

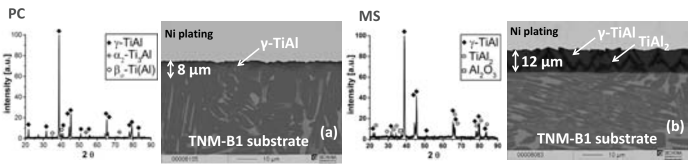

Fig. 2: BSE images of pack cemented (a) and magnetron sputtered (b) samples with corresponding XRD pattern

Results – 2nd step

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- Selective oxidation of Al leads to a dense, slow growing Al_2O_3 layer [3]
- Small oxygen uptake during the first hours of pre-oxidation at 900°C

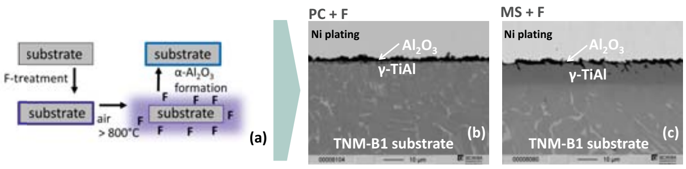

Fig. 3: Scheme of the fluorine treatment (a), BSE images of the samples after fluorine treatment and pre-oxidation for 24h at 900°C (b)-(c)

Results – 3rd step

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- EB-PVD leads to columnar growth of the TBC (150 – 200 µm) [4]
- Increases service temperature by approximately 150°C

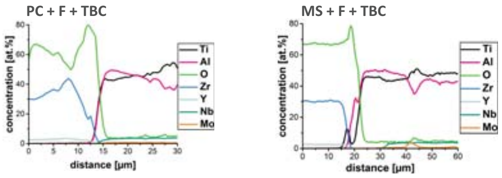

Fig. 4: EPMA linescans of the three-step coated samples before high-temperature exposure

High-temperature exposure (100h, 900°C, air)

- Dense, Al_2O_3–rich oxide scale after isothermal high-T exposure
- Successively increase in strain/stress values after each coating step

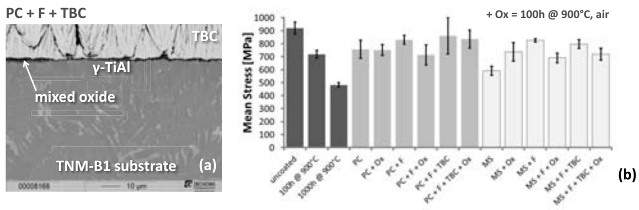

Fig. 5: BSE image of a three-step coated sample after exposure at 900°C for 100h (a), Mean stress results for four-point bending tests at RT (b)

Conclusion

6

- Enhanced oxidation resistance due to Al_2O_3 formation and 7YSZ deposition
- Pre-oxidation as critical step in terms of oxygen inward diffusion
- Improved stress/strain values compared to the uncoated samples after isothermal high-temperature exposure

Literature

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[1] S. Mayer et. al., Advanced Engineering Materials (2017), 19, No. 4
[2] J. Grüters, M. C. Galetz, Intermetallics 60 (2015) 19-27
[3] R. Pflumm, A. Donchev, M. Schütze, Intermetallics 53 (2014) 45-55
[4] S. Friedle, N. Laska et. al., Corrosion Science 92 (2015), 280-286

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