Introduction

Titanium aluminides together with other structural intermetallics have gained a lot of interest due to their properties offering a potential weight reduction and increased performance of high temperature components. In this context, additive manufacturing (AM) has become an interesting novel processing technology creating new requirements on the materials regarding processability, segregation tendency and microstructural control. To understand, screen, develop and select novel and optimized alloys for AM, a systematic approach based on rapid solidification experiments combined with finite element and thermodynamic modeling was established and applied for TiAl alloys.

γ-Titanium aluminides

- α⁺γ microstructure
- low density ~3.9 g/cm³
- high specific strength
- good creep resistance
- good oxidation resistance up to 750°C
- higher Tₚ_max than conventional Ti alloys
- low ductility at RT

Additive manufacturing principle

- part model → model slicing → layer-by-layer deposition → final part

Characteristics of metal-based AM:
- localized heat input by lasers or e-beams
- high heating and cooling rates ~10⁻¹⁰ K·s⁻¹
- multiple reheating and cooling cycles by the heat input of subsequently deposited layers

Rapid solidification of TiAl alloys

1. Experimental rapid solidification
   - arc melting of small alloy amounts
   - formation of spherical specimens
   - the smaller, the higher the cooling rate

2. Microstructural characterization
   - optical and electron microscopy
   - XRD phase identification
   - EDX compositional analysis

3. Finite element modeling
   - calculation of temperature change at different points in the specimen during cooling
   - extraction of cooling rates and dependency on specimen radius
   - verification by in situ high speed camera measurements during solidification

Study and prediction of transformation behavior

Influence of cooling rate and composition in binary Ti-Al

- correlation between solidification path and observed microstructure
- explanation for extension of β-solubility towards higher Al contents
- complete suppression of γ-formation if Al < 46 at.%

Influence of Nb alloying

- extension of β-solubility regime
- formation of a coarse α/α⁺ structure for Al < 47 at.%
- observation of α/α⁺+γₐ microstructure if Nb ≥ 5 at.% and 45 > Al > 47 at.%
- good correlation with calculations for β-solifying alloys with a high tendency to form γₐ

Conclusions & Outlook

- rapid solidification experiments allow to study fundamental alloy behavior at high cooling rates
- cooling rates comparable to beam-based AM can be achieved under controlled conditions
- cooling rate - alloy composition - microstructure maps allow the selection of suitable alloys for AM
- thermodynamic modeling can predict the phase transformation behavior of Ti-Al and Ti-Al-Nb alloys upon rapid solidification
- alloy screening, development and selection can be facilitated by the use of thermodynamic information

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