Novel titanium-based sulfur containing bulk metallic glass for PBF-LB/M

Hanna Schönrath
Jan Wegner, Maximilian Frey, Martin A. Schroer, Xueze Jin, María Teresa Pérez-Prado, Ralf Busch, Stefan Kleszczynski
Introduction

Bulk Metallic Glasses – BMGs

- Amorphous arrangement of constituent elements,
  - High strength and elasticity
  - (mostly) Isotropic properties

X-ray diffractogram

[Nunes, 2005]
Fundamentals

Fabrication of BMGs

TTT

Temperature

Melt

SCL

T<sub>I</sub>

casting

PBF-LBM

crystal

T<sub>g</sub>

glass

log (time)

[LMW Saarland; Thorsson 2022; Wegner 2021]
Motivation

Novel Material: Ti-based sulfur containing BMGs

Material: $Ti_{60}Zr_{15}Cu_{17}S_8$

- Can this material be processed by PBF – LB/M?
  - density
  - microstructure

Frey, 2021; Kuball, A., 2018; Kuball, A., 2019
Preliminary study: Laser treatment of cast material

Methods

[amazemet.com]

[slm-solutions.com]
Results

Laser treatment

70 W
2000 mm/s

1000 mm/s

500 mm/s

17.05.2024
Results

Line A – 70 W 2000 mm/s

Amorphous structure within weld track
Results

Atomization

<table>
<thead>
<tr>
<th></th>
<th>At%</th>
<th>Ti</th>
<th>Zr</th>
<th>Cu</th>
<th>S</th>
<th>W</th>
<th>Al</th>
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<tbody>
<tr>
<td>target</td>
<td>60.0</td>
<td>17.0</td>
<td>15.0</td>
<td>8.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1</td>
<td>67.41</td>
<td>13.80</td>
<td>10.39</td>
<td>6.63</td>
<td>1.08</td>
<td>0.70</td>
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<tr>
<td>3</td>
<td>62.85</td>
<td>13.96</td>
<td>15.10</td>
<td>7.51</td>
<td>0</td>
<td>0.59</td>
<td></td>
</tr>
</tbody>
</table>

- Compositional offset
- Oxygen intake:
  * Cast → powder
  * 0.05 wt% → 0.17 wt%

100 µm Spherical, crystalline powder
Results

Laser-material interaction

![Graph showing single track width vs. laser energy density.](image)

- **Single tracks**
- **10 layers:** leveling base, build plate

![Images of laser-melted tracks.](image)

- **80 W**
  - 1600 mm/s
- **120 W**
  - 800 mm/s
Results

Laser-Material interaction

80 W 1600 mm/s

120 W 800 mm/s
Results

Manufacturing of bulk material

80 W
1600 mm/s
30 x 3 x 2 mm beam

Relative density: >99%
Results

SEM & EDX & Analysis of bulk material

Elemental segregations detected, no oxidation
Results

Microstructural analysis – XRD & DSC

DSC: AM part is 50% amorphous
AM of Ti-based sulfur containing BMG

Summary & Outlook

- Laser treatment of cast surface leads to amorphous structure
- Spherical, crystalline powder received by atomization
- Additive manufacturing:
  - High relative density achieved
  - Partially crystalline microstructure
- Challenges:
  - Elemental offset & increased oxygen content
  - Partially crystalline microstructure in bulk material
  - In-process cracking
Thank you for your attention!

Hanna Schönrath
AM of Ti-based sulfur containing BMG

Challenges

- In-process cracking
- Crystalline phase formation
- Atomization:
  - Oxygen
  - Elemental composition
Results

Oxygen and Sulfur

- Oxygen contamination during atomization
- Low oxygen intake during additive manufacturing

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17.05.2024
AM of Ti-based sulfur containing BMG

Outlook

Crack initiation prevention

Elemental composition

Amorphous microstructure
Methods

Analysis

TEM
[thermofisher.com]

SEM
[jeol.com]

Microscopy

Microstructural analysis

XRD
[Rigaku Inc.]

DSC
[perkinelmer.com]