4D microstructure evolution in titanium alloys for additive manufacturing

Bugelnig K.[1], Barriobero-Vila P.[1], Breitbarth E.[1], Strohmann T.[1], Silva K.[2], Gussone J.[1], Haubrich J.[1], Villanova J.[3], Schell N.[4], Stark A.[4], Requena G.[1,5]

[1]German Aerospace Center (DLR)
[2]University of Puerto Rico at Mayagüez
[3]European Synchrotron Radiation Facility (ESRF)
[4]Helmholtz-Zentrum Hereon
[5]RWTH Aachen University

Laser-based metal additive manufacturing (AM) permits layer-by-layer fabrication of near net-shaped metallic components with complex geometries not achievable using the design constraints of traditional manufacturing [1]. The goal of our study is to address the loss of microstructure control provoked by epitaxial growth during AM of titanium alloys. In order to overcome this drawback, a new alloy concept which adds the solute α-stabilizer La to commercially pure titanium (CP Ti) is being exploited to alter the regular Burgers-related $\beta \rightarrow \alpha$ transformation [2].

The studied material was obtained by selective laser melting (SLM) of a powder blend of CP Ti-2wt.% La using a SLM 280HL machine. In situ synchrotron tomography (sXCT) was performed at the ID16B-nano-analysis beamline of the European Synchrotron Radiation facility (ESRF) to investigate the microstructure evolution during thermal treatment of the SLM as-built Ti-2wt% La alloy. To this purpose, sXCT scans were taken each ~14 min during a thermal treatment at 900°C/5h. The energy, total scan time and voxel size used are 29.6 keV, 4 min and $(60\ nm)^3$, respectively. Image segmentation of the acquired in situ data was done with the help of a deep learning approach using convolutional neural networks [3].
Complementary to tomography investigations, in situ high energy synchrotron X-ray diffraction (HXRD) was carried out at the P07-HEMS beamline of PETRA III/Deutsches Elektronen-Synchrotron (DESY) using a modified dilatometer Bähr 805 A/D with an inductive furnace for subsequent heat treatments [2].

Results indicate that the Ti-La system shows a promising phase transformation path to produce equiaxed microstructures for SLM materials. The transfer of this transformation path to other alloy systems is a promising approach to create equiaxed microstructures without the need for deformation/ forming steps. In situ sXCT reveals the growth kinetics of individual α equiaxed grains in an α and β matrix during thermal treatment. This data also shows a good correlation to complementary data obtained by in situ HXRD.

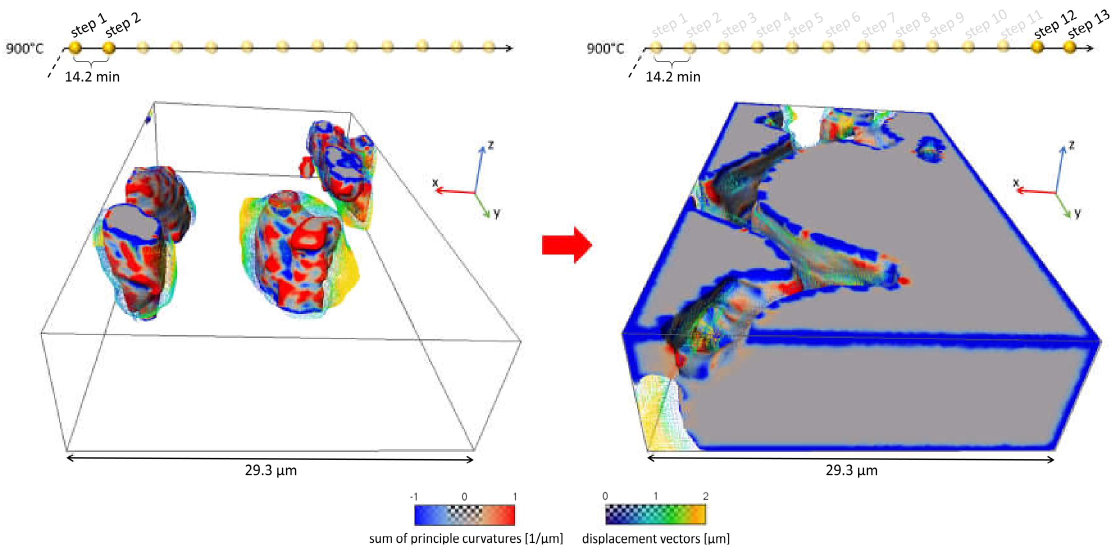

Figure 1. 3D visualization of local velocity and local curvature of the grain boundary displayed for the first (left) and last (right) steps investigated during heat treatment of Ti-2La at 900°C.

References:

[1] B. Dutta et al., ISBN: 9780128047835
[2] P. Barriobero-Vila et al., DOI: 10.1038/s41467-018-05819-9
[3] T. Strohmann et al., DOI: 10.1038/s41598-019-56008-7

Acknowledgements
The ESRF and DESY is acknowledged for the provision of synchrotron radiation facilities in the framework of the proposal MA-4354 and I-20191042, respectively.