This is the submitted version of the article “4D Investigation of new Aluminum Alloy for Additive Manufacturing”, published in Microsc. Microanal. 28 (Suppl 1) 2022, 2022, © Microscopy Society of America 2022, doi:10.1017/S1431927622001970. Published online by Cambridge University Press.

4D Investigation of new Aluminum Alloy for Additive Manufacturing

Katrin Bugelnig[1*], Christoph Wielenberg[2], Bechir Chehab[3], Ravi Shahani[3], Jan Haubrich[1], Camille Pauzon[4], Guilhem Martin[4], Pierre Lhuissier[4], Julie Villanova[5] and Guillermo Requena[1,6]

[1.] Institute for Materials Research, German Aerospace Center (DLR), Cologne, Germany
[2.] Premium AEROTEC GmbH, Varel, Germany
[3] Constellium Technology Center, Voreppe, France.
[4.] Laboratoire SIMaP, Université Grenoble Alpes - Grenoble, France.
[5.] European Synchrotron Radiation Facility (ESRF) – Grenoble, France.
[6.] RWTH Aachen University – Aachen, Germany.
* Corresponding author: katrin.bugelnig@dlr.de

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]. Among the AM techniques, Laser Powder Bed Fusion (LPBF) stands out as it is used for the fabrication of near-net-designed metallic components with complex geometry and higher material efficiency, typically replacing multiple conventional components with savings in material, tooling and assembly costs.
There have been major efforts around the globe to process aluminum alloys by LPBF for a wide range of applications across aerospace, defense, transportation and industrial sectors [2]. However, the so-called legacy aluminum alloys adopted for LPBF typically require solution treatment, quenching and ageing to reach full mechanical properties, but quenching can create a distortion risk in the complex geometries targeted by LPBF. Moreover, these legacy aluminum alloys contain volatile magnesium and in some cases zinc, creating issues during the LPBF process. Considering these circumstances, Aheadd® CP1, a new Al-Fe-Zr alloy specifically customized to exploit the physical conditions of laser-based additive manufacturing, has been developed by Constellium. The alloy is designed to exploit LPBF’s rapid solidification nature, resulting in stable microstructures with attractive excellent performances.

In this work, the microstructural evolution is investigated three-dimensionally as a function of processing conditions and heat treatment at 400 °C by means of in-situ synchrotron nano-tomography (s-XCT). The experiments were performed at the ID16B beamline of the European Synchrotron Radiation facility (ESRF) in Grenoble, France, with a beam energy of 17.5 keV and a PCO Edge 4.1 camera. A small cone/needle shaped sample (ø ~ 120 µm) was heat treated at 400 °C. Two vertically overlapping holotomography (HT) scans at highest resolution (voxel-size = 40^3 nm^3) were taken at room temperature in the as-built condition (400 °C/0h), after 1h, 4h and 7h at 400 °C with total scan times of about 23 minutes. During the holding time at 400 °C, multiresolution scans were conducted every 10 minutes using voxel sizes of $(40\ nm)^3$, $(100\ nm)^3$ and $(342\ nm)^3$, as shown in the temperature profile in Figure 1(a). Figure 1(b-e) shows raw tomographic slices of the same sample at the same position in as

built condition, after 1h, 4h and 7h of heat treatment at 400 °C. Image segmentation of the acquired in situ datasets was supported by a deep learning approach using convolutional neural networks [4].
Preliminary observations reveal a very low porosity with pore diameters < 4 µm. Moreover, a morphological evolution during the heat treatment at 400 °C of Fe-rich intermetallics located in the intergranular regions could be clearly observed. The evolution of shape, size, distribution of these phases will be studied in relation to the processing and heat treatment conditions as well as their spatial distribution in the melt pool.

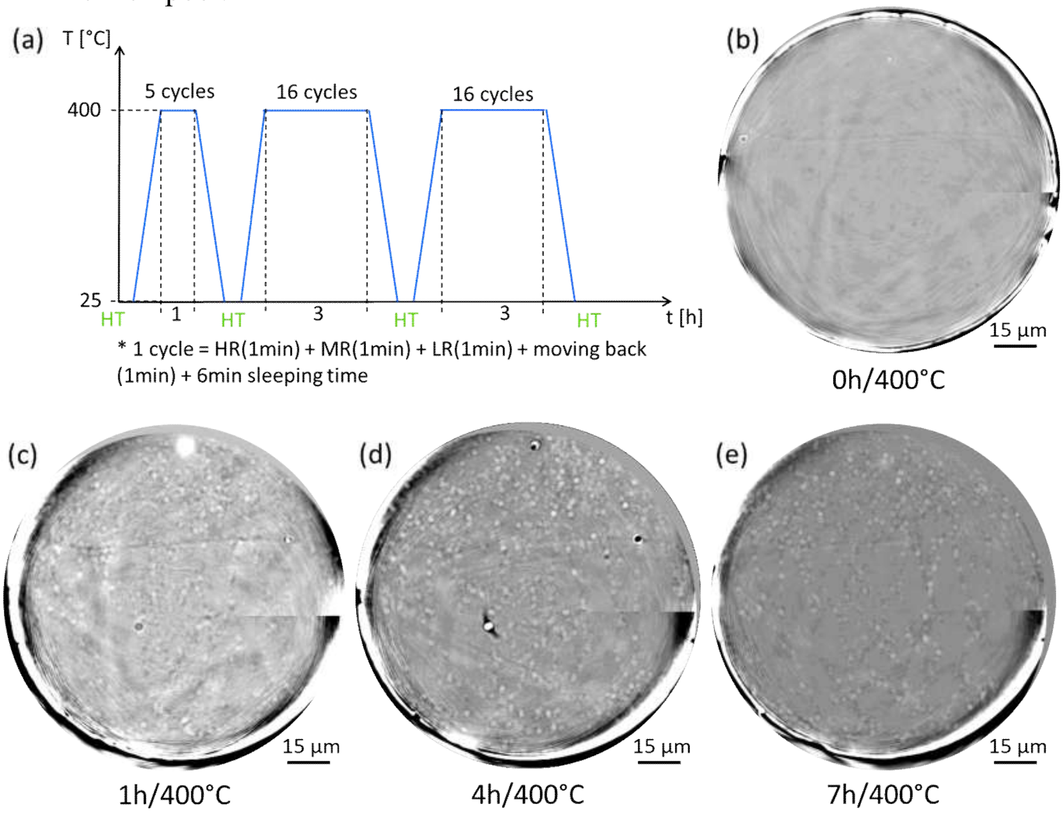

Figure 1. (a) Temperature profile of interrupted in-situ heat treatments and 2D reconstructed slices of the investigated alloy in (b) as-built condition and after (c) 1h/400 °C, (d) 400 °C/4h, (e) 400 °C/7h; sample-to-detector distance = 34.52 mm, voxel size = $(40\ \mathrm{nm})^3$.

References:

[1] T. Nesma et al., Progress in Materials Science 106 (2019), 100578, doi: 10.1016/j.pmatsci.2019.100578
[2] A. Aversa et al., Materials 12 (2019), 1007; doi:10.3390/ma12071007.
[3] Innovation | Constellium, https://www.constellium.com/markets-applications/aerospace/innovation (accessed February 23rd, 2022).
[4] T. Strohmann et al., Scientific Reports 9 (2019), 19611, doi: 10.1038/s41598-019-56008-7
[5] The authors acknowledge the ESRF for the provision of synchrotron radiation facilities in the framework of the proposal MA-4928.