1.9.16. MICROFOCUS COMPUTED X-RAY TOMOGRAPHY OF SEGREGATIONS IN HIGH STRENGTH ALUMINIUM ALLOYS

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Introduction. High strength aluminium alloys are widely used in aerospace vehicles because of their high specific strength, good hot workability, resistance to corrosion, toughness and fatigue durability. The as – cast microstructure, of the pre-material for rolling, casting and forging, consists basically of α-Al dendrites and interdendritic eutectic regions due to segregations.

On the basis of selected examples of AlCuMg and AlZnMgCu alloys, the possibilities and limits of high – resolution cone – beam microfocus X-ray computed tomography with a transmission target (µXCT) yielding a minimum voxel size of $(1\ \mu m)^3$ will be presented. Alignements and the formation of the dendritic structure are shown in 3D. Thereby important additional information and a better understanding of the casting process can be achieved.

Furthermore we show a method for the discrimination of different types of segregations, which both appear higher – absorbing in comparison to the Al – matrix. The microstructures have been observed by metallographic techniques in order to verify the results.

Results. Figure 1 shows the result of a CT – measurement with a voxel size of $(1.1\ \mu m)^3$ of a chill cast slab of an AlCu4Mg1 – alloy using a cone – beam nanotom 180 F device. The higher – absorbing interdendrititc Al-Al_2Cu – eutectic appears brighter than the Al – dendrites. In addition to the phases some micropores with diameters between

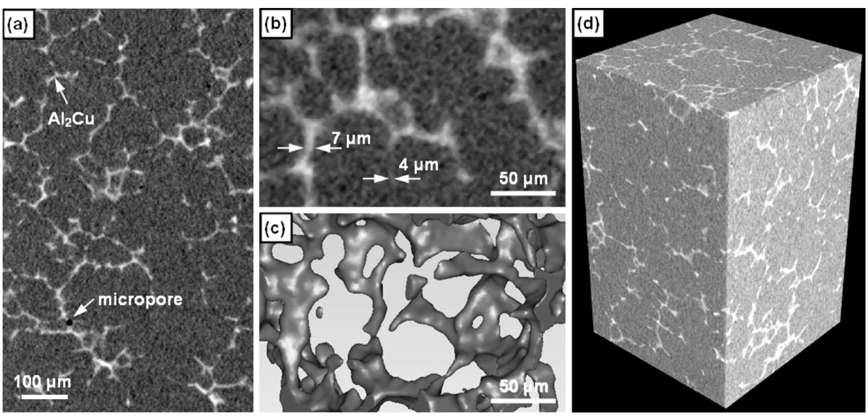

Fig. 1. High – resolution µXCT and segmentations of eutectic Al-Al_2Cu regions in AlCu4Mg1:
(a) – cross section with bright interdendritic eutectic and a micropore;
(b) – enlarged cross section and measured thickness of interdendritic space;
(c) – connectivity of the segmented eutectic regions;
(d) – $550 \times 550 \times 850\ \mu m^3$ cuboid with 3 cross sections

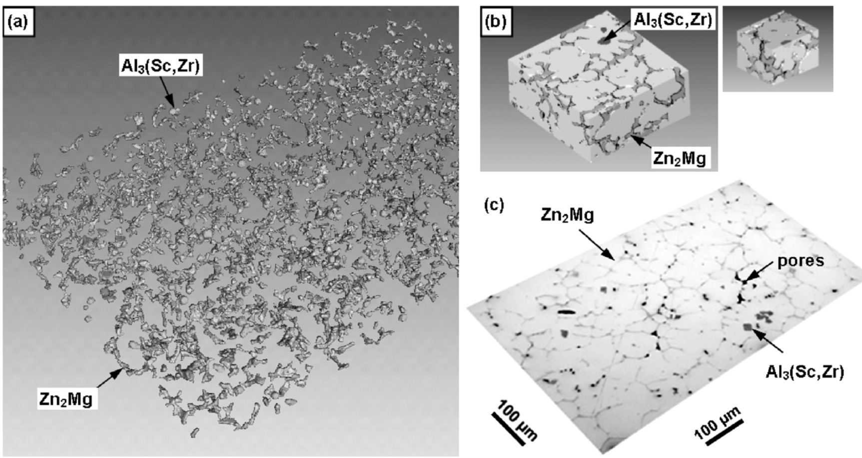

Fig. 2. Discrimination between Al_3(Sc, Zr) – particles from interdendritic Zn_2Mg- and Cu-rich regions in an AlZn6.4Mg2.2Cu1.7 alloy and metallographic verification at the same scale:
3D views of (a) segmented interdendritic segregations (gold) and Al_3(Sc, Zr) particles (blue) and (b) with µ-Al dendrites (white), (c) perspectively blurred light – optical – microscope image

4 – 13 µm could be found. It is possible to segment the highly absorbing interdendritic regions and to measure their thickness down to a width of ~4 µm. The structure of the complementary α-Al dendrites with a diameter between 50 – 100 µm can be identified in fig. 1c and fig. 1d.

The µXCT – measurement with a voxel size of $(1.5\ \mu m)^3$ of a chill cast AlZnMgCu – alloy is discussed as a second example. The alloy contains Sc and Zr, which form mainly secondary Al_3(Sc, Zr) dispersoids inhibiting grain growth. In addition to these particles, interdendritic segregations rich in highly absorbing elements like Zn and Cu appear. Both, the eutectic region and the Al_3(Sc, Zr) – particles are similarly absorbing more X-rays than the α-Al dendrites. Discrimination between eutectic and particles via a grey value – threshold is not possible. Since the Al_3(Sc, Zr) – particles have a globular and in some cases an cuboidal shape, it is feasible to separate them from the eutectic by means of a shape factor, i.e. the three-dimensional sphericity. Figure 2a shows the interdentritic, Zn_2Mg rich regions of small sphericity values and in between almost spherical Al_3(Sc, Zr) particles in a volume of $1{,}09\times0{,}73\times0{,}14\ mm^3$. In fig. 2b, one can see, that the Al_3(Sc, Zr) – particles are located centrally in the dendrites indicating that the Al_3(Sc, Zr) – particles act as seed crystals for the α-Al dendrites limited by the surrounding eutectic region. Metalo-graphic techniques were used in order to verify the results as can be seen in fig. 2c.

Summary.

– Apart from the detection of shrinkage pores and cracks, it is possible to quantify the eutectic segregations and primary Al_3(Sc, Zr) – particles in as – cast Zn and/or Cu containing high strength aluminium alloys by high – resolution µXCT in 3D.

– The morphology and distribution of the interdendritic eutectic replicates the dendritic solification structure, where the orientation and width of the individual dendrite arms can be measured. Conclusions on the speed and direction of the solidification process can be drawn from those results at different positions in the slab.

– The distribution and the extension of the interdendritic segregations can be determined in different positions of a casting with high accuracy within a relatively big volume (in comparison to 2D metallographic techniques).

– The ability of the discrimination between Al_3(Sc, Zr) – particles bigger than 7 µm and the interdendritic segregations of elements heavier than Al allows to estimate the amount of primary Al_3(Sc, Zr) – particles. The metallurgist can decide, how many primary Al_3(Sc, Zr) are needed and can adjust the appropriate amount of these alloying elements.