Characterization of a cast Al alloy by synchrotron tomography

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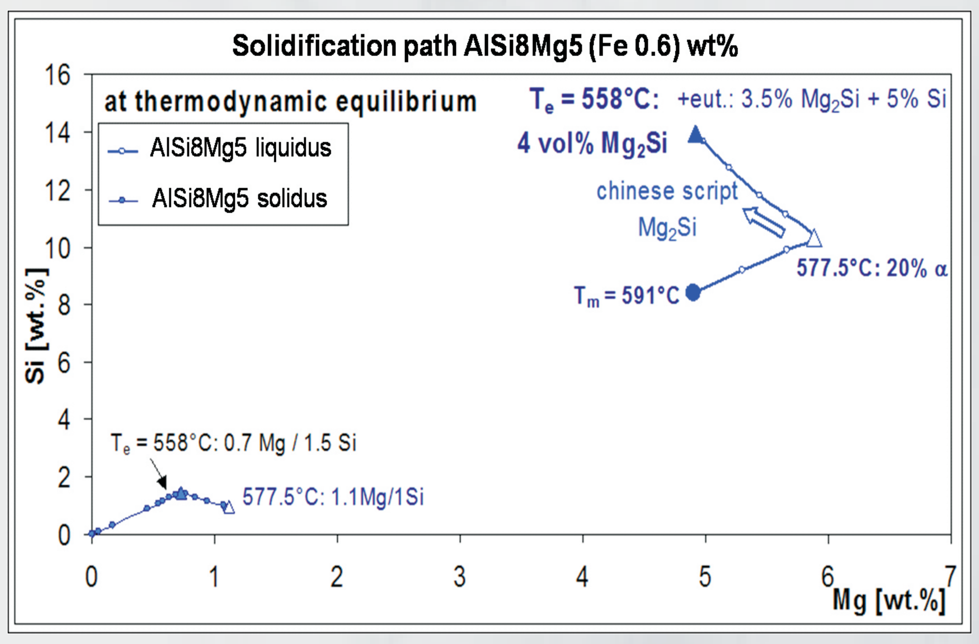
Material:

The studied material is an AlSiMg alloy with 8 wt% Si and 5 wt% Mg content. These alloys are gaining importance for future elevated temperature strength applications. The solidification path of the investigated alloy is presented in Figure 1 according to Thermocalc™ [1]. The aim of this study is the 3D morphological characterization of the contained phases by synchrotron tomography.



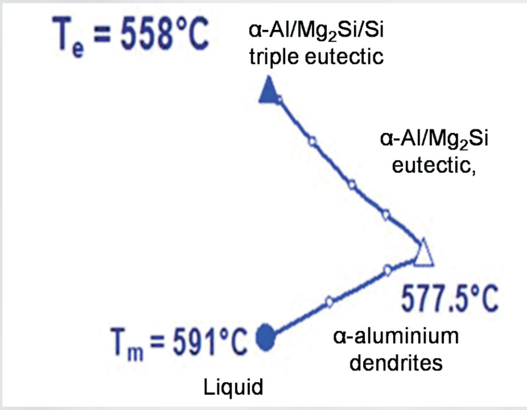


Figure1. Solidification path of the investigated AlSi8Mg5 alloy, computed with Thermocalc™. The solid solution is indicated in the Al-corner.

Experimental

The tomographic measurements were carried out at the ID19 beamline of the European Synchrotron Radiation Facility [3]. The coherence of the X-ray beam allows, performing phase contrast measurements with a voxel size of $(0.3\ \mu m)^3$ [4]. The applied beam energy at the measurement was 20.5 keV and the sample-detector distance 15 mm (Figure 2). The three dimensional volumes were reconstructed from 1500 projections of 0.5 s exposure time each while rotating the sample by 180°.

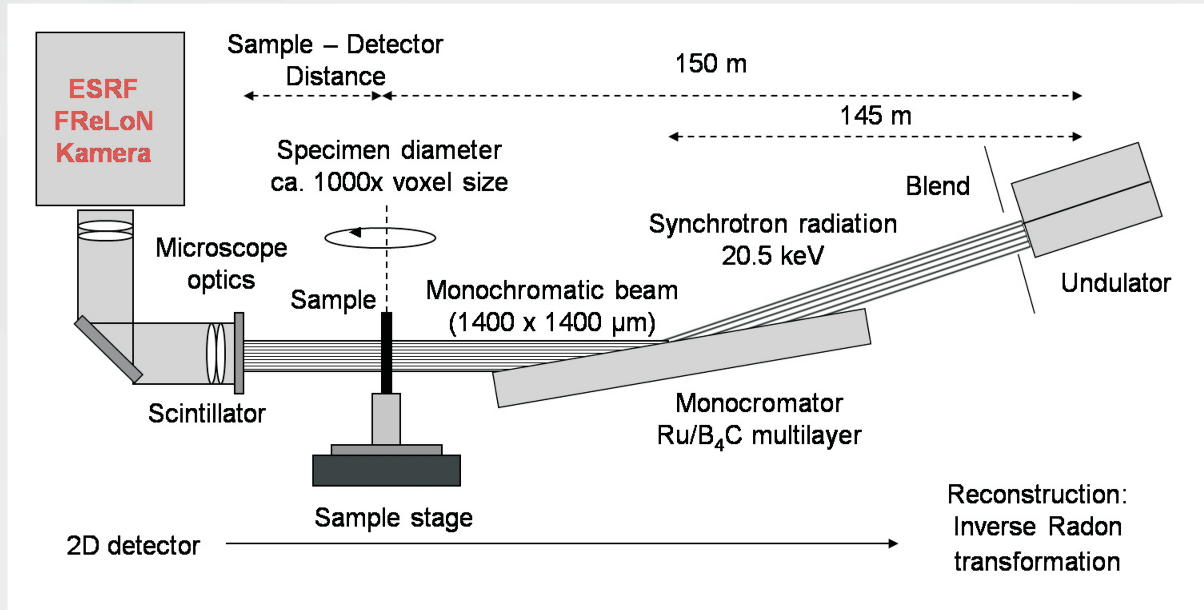


Figure 2. Set up for synchrotron tomography. Phase contrast is achieved by adjusting the sample-detector distance.

Solidification along the eutectic valley

The 3D reconstructions show the complex shape of Mg_2Si, so-called Chinese script particles, shown in Figure 5. A central node can be observed, while several arms emanate. Such nodes could be demonstrated also by FIB-SEM tomography [7]. Although particles seem to be separated on the 2D slices (Figure 3), 3D reconstruction demonstrates clearly the coral like connectivity of these particles (Figure 4).

Prior to the final solidification, iron rich aluminides segregate from the remaining melt enriched by the Fe and Mn impurity content. Relatively big AlFeSi particles extend in two-dimensional planar like shapes, shown in Figure 5.

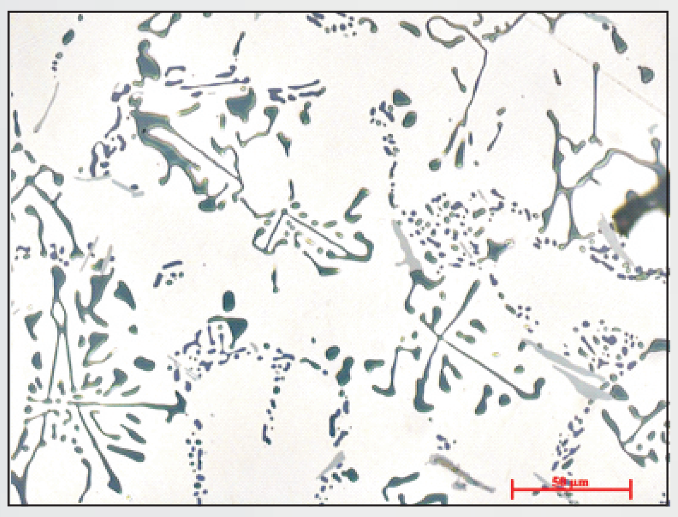


Figure 3. Metallographic picture of the investigated alloy

Characterization of the triple eutectic

The distinction of the small particles of the triple eutectic from the "Chinese script" can be based on the size distribution shown in Figure 6.

In order to define the spatial distribution of the small Si and Mg_2Si particles, a cluster analysis is presented. The reachability diagram, shown in Figure 7, obtained by calculating the shortest neighbouring distances among the particles [8], allows to determine several Si clusters, separated by the embedding phases.

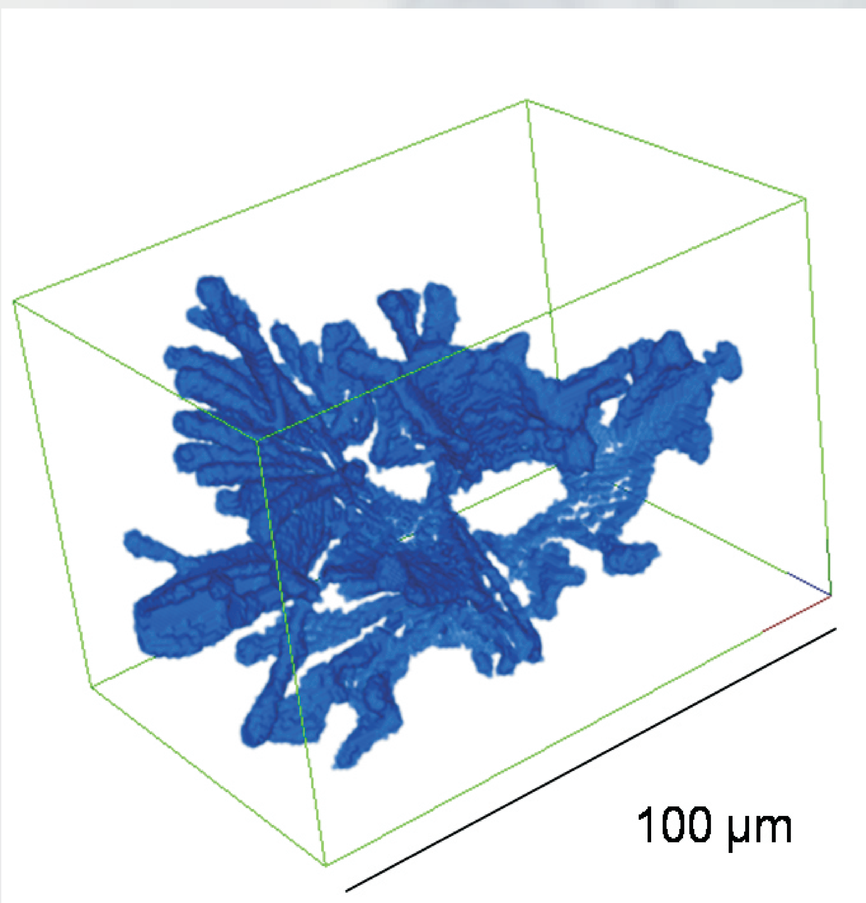


Figure 4. Segmented Mg_2Si coral, solidified along the eutectic valley.

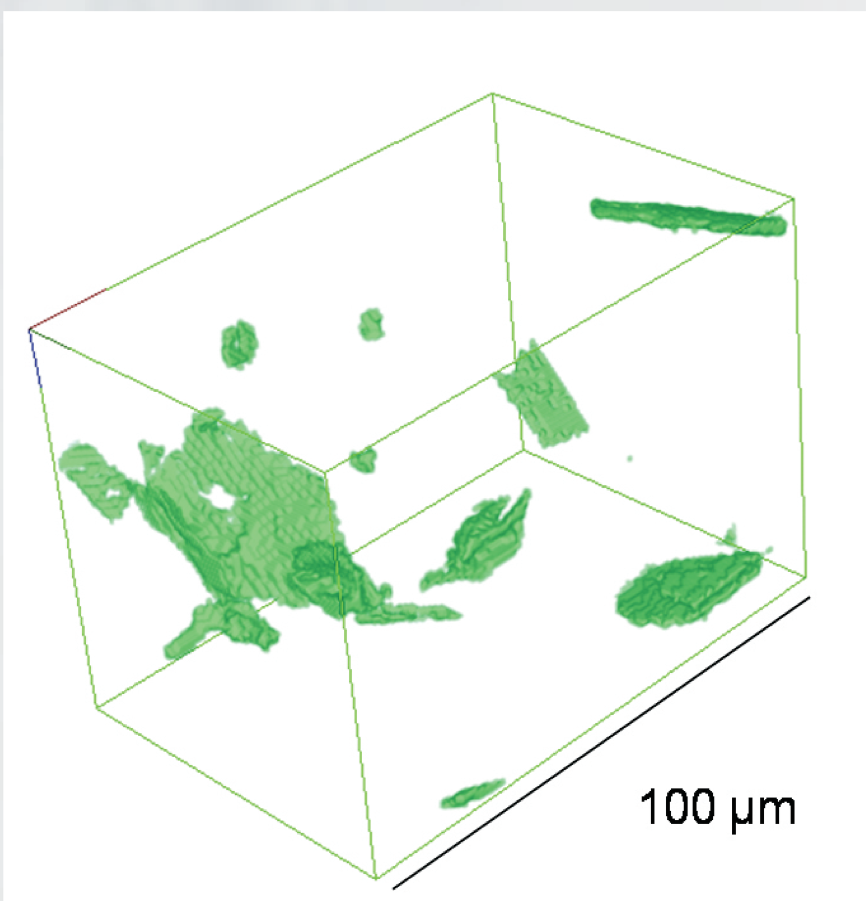
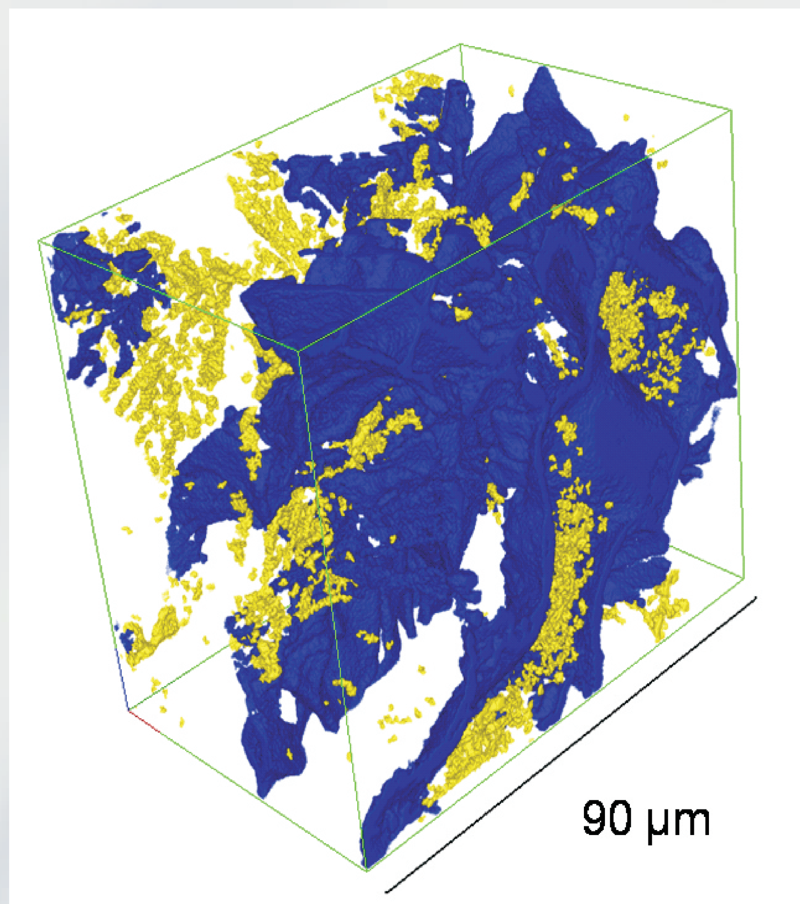


Figure 5. Segmented AlFeSi particles, adjacent to the Mg_2Si in Fig. 4.



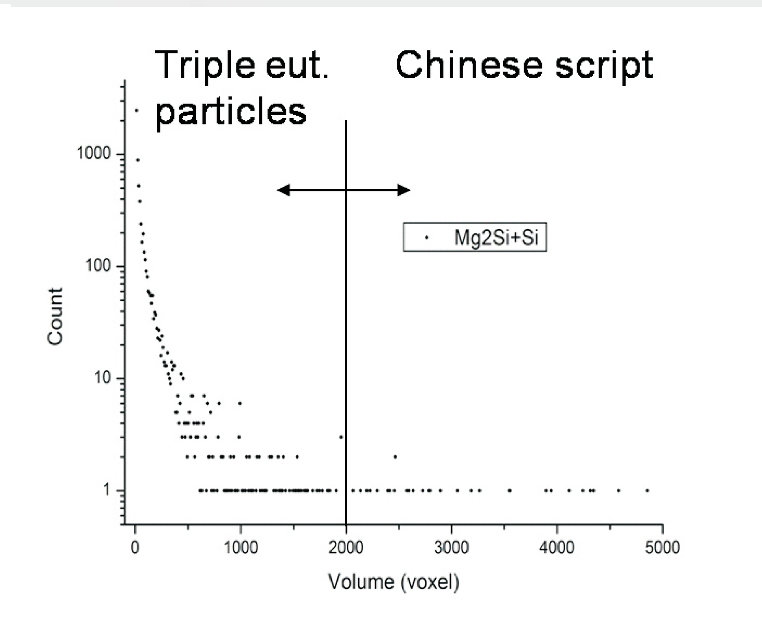


Figure 6. Segmentation of the phase contrast images of the chinese script Mg_2Si (blue) and the triple eutectic Si, Mg_2Si particles (yellow).

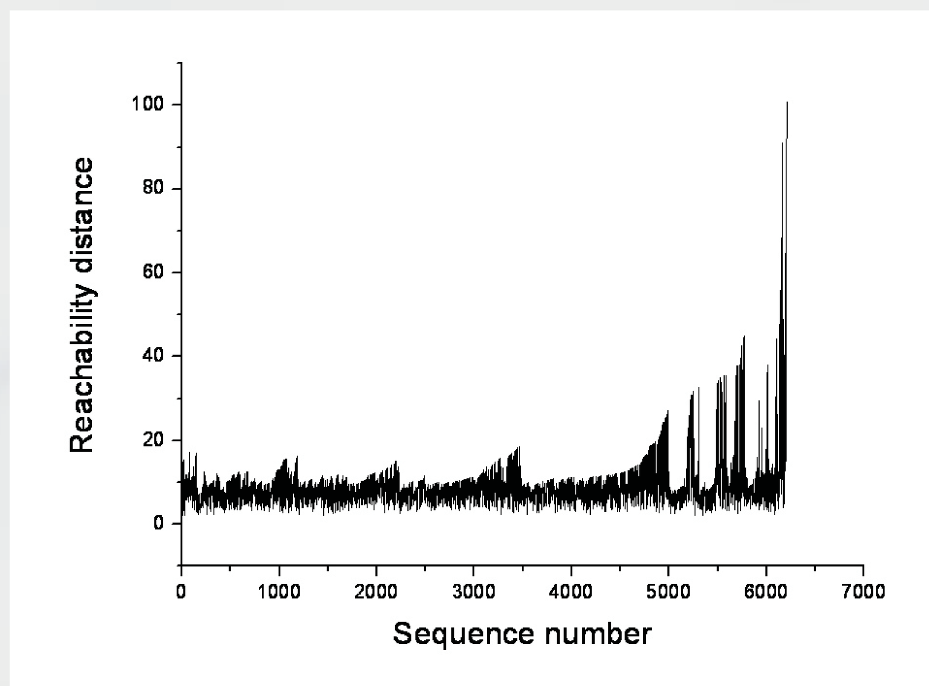


Figure 7. Reachability plot of small Si/Mg_2Si particles revealing clusters, where the large distances are followed by a short one.

Conclusions

X-ray phase contrast measurements reveal the microstructure of the Si and Mg_2Si phases in the Al-Si-Mg alloy with sufficient resolution (particles bigger, than 3 µm).

The plate like AlFeSi particles could be simply segmented by absorption contrast.

The Chinese script Mg_2Si particles have complex coral-like shapes revealed by 3D tomography.

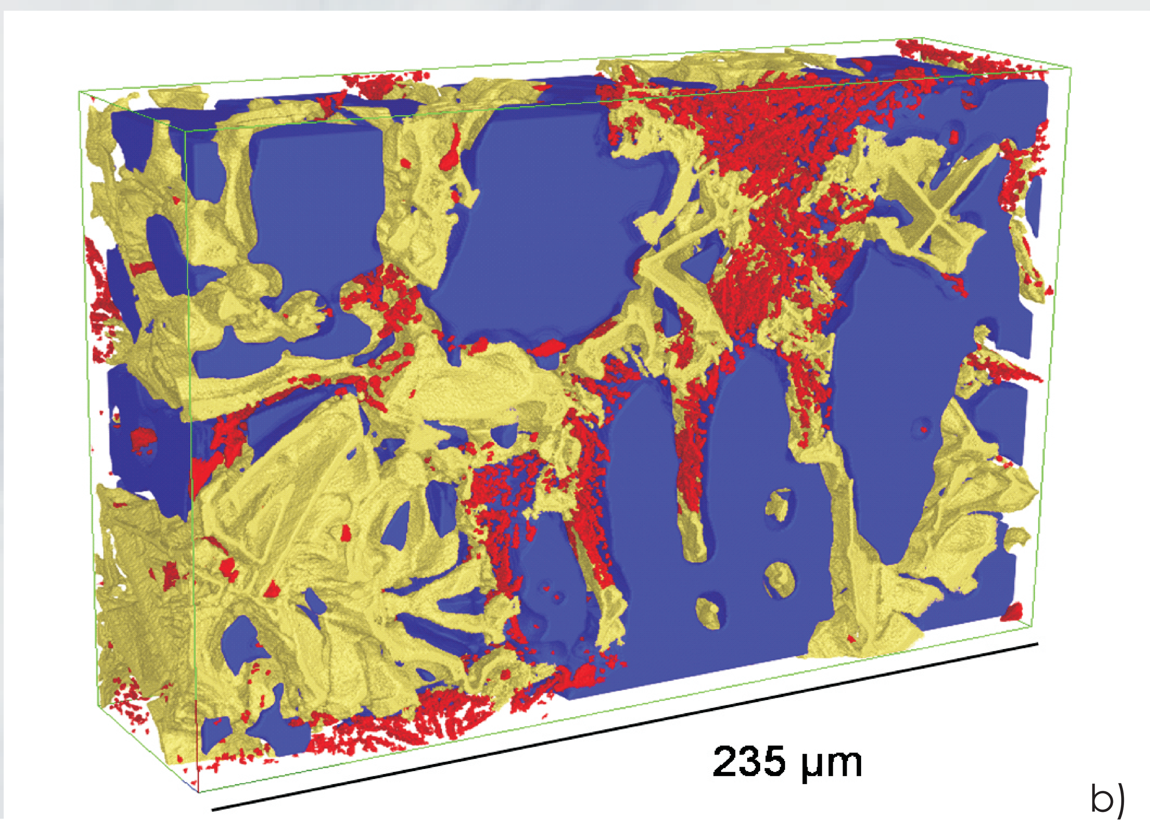
The Si/Mg_2Si particles of the triple eutectic show clustering, corresponding to the inhomogeneous distribution in the interdendritic space.

The extraction of the dendrite structure became possible after the segmentation and characterization of the other phases, and using different image analysis methods.

The characterization of the investigated alloy in three dimensions revealed several so far unknown details of the solidification processes.

3D visulalization of the dendrite structure

Once all the eutectic and intermetallic phases are segmented and characterized, the dendrite structure can be extracted. Since the dendrites are the largest regions containing aluminium, they can be isolated by density mapping (Figure 8).



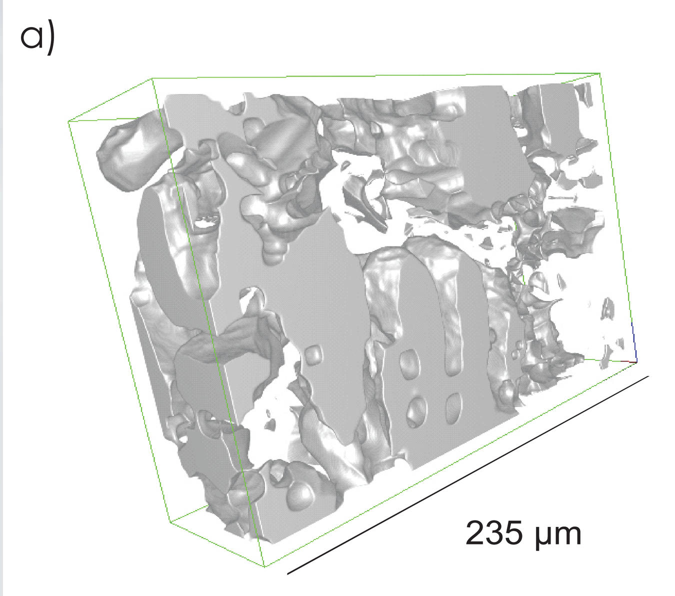


Figure 8. a) α-Al dendrite section, b) Dendrites in 3D, with the fully segmented phases. The aluminium dendrites in blue, Mg_2Si particles in gold, and Si particles in red. The eutectic aluminium is transparent.

Acknowledgements

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References

[1] http://www.thermocalc.com, Version 3.
[2] L. F. Mondolfo, Al alloys: structures and properties, Butterworth-London/Boston 1976.
[3] European Synchrotron Radiation Facility, http://www.esrf.eu
[4] J. Baruchel, J.-Y. Buffiére, E. Maire, P. Merle and G. Peix, X-Ray Tomography in Material Science, HERMES Science Publications, Paris, 2000.
[5] A. Borbély and F. F. Csikor, tomo3D http://metal.elte.hu/~tomo3D
[6] H.P. Degischer, H. Knoblich, E. Maire, L. Salvo, M. Suery, Sbd.Prakt.Metallographie 38 (2006), 67 - 74.
[7] F. Lasagni, A. Lasagni, E. Marks, C. Holzapfel, F. Mücklich, H.P. Degischer, Acta Mat. 55 (2007), 3876-3882.
[8] M. Forina, M. Concepción, C. Oliveros, C. Casolino, M. Casale, Analytica Chimica Acta 515 (2004), 43-53.
[9] H.P. Degischer, F. Lasagni, D. Tolnai in Ind. Computertomografie, ed. J. Kastner, Shaker (2008), 97-101.