3D characterization of beta-phases in AZ91D by synchrotron-radiation based microtomography

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Light metals such as magnesium alloys gained an increasing interest in transportation and air & space industries during the past years. Especially the need of reducing weight to increase the payload, to minimize fuel consumption and the emission of the green house gas CO2 lead to a growing number of applications made out of magnesium alloys [1-9]. Besides the development of alloys that can be used at service temperatures in the range of 150 °C or even more the corrosion properties are of major importance [10]. Especially the corrosion resistance is a limitation to magnesium alloys in transportation and air & space industries.

In contrast to known applications, new research areas focusing on magnesium alloys as biodegradable implants will use an adjusted corrosion behavior to produce a temporary implant material [11]. The mechanical behavior and corrosion resistance of magnesium alloys is determined by its metallurgical factors. The metallurgical factors can influence the corrosion behaviour of any particular magnesium part and is dependent on the combined effects of its chemical composition and its microstructure [12, 13]. High purity (HP) magnesium alloys have been developed in the past to overcome the poor corrosion behavior of commercial magnesium alloys. The content of Fe, Cu and Ni was significantly reduced to a few ppm of these elements in modern magnesium alloys. The modern HP alloys like AZ91D show similar corrosion properties as Cu containing aluminium alloys or mild steels. Besides the influence of impurities like Fe, Cu and Ni, especially the beta-phase ($Mg_{17}Al_{12}$) in magnesium-aluminium alloys are known to influence the mechanical and corrosive properties of the alloy depending on their shape and spatial distribution [10, 12, 13]. Annealing or solution treating at temperatures near 430°C will cause all or part of the beta-phases to dissolve [12, 13].

Synchrotron-radiation based micro-computed tomography (SRμCT) allows the 3D reconstruction of a specimen from a set of 2D projections using the backprojection of filtered projection algorithm. The SRμCT were performed at beamline BW2 at Hamburger Synchrotronstrahlungslabor HASYLAB at Deutsches Elektronen Synchrotron DESY (Hamburg, Germany).

The specimens were imaged by microtomography in absorption mode utilizing synchrotron radiation at beamline BW2 using 16 keV photon energy. Exposed to the parallel synchrotron X-ray beam, the sample was precisely rotated 0.25° stepwise to 180°, and after every fourth step the reference image (projection) was recorded to eliminate intensity inhomogeneities and variations of the X-ray beam.

The results of the microtomography using synchrotron-radiation (SRμCT) showed the 3D orientation of the beta-phases, micro-pores and high density areas of aluminium-manganese particles. The typical microstructure of $Mg_{17}Al_{12}$ precipitates in the form of secondary, lamellar structures can be observed threedimensionally (Fig. 1).

This study showed that SRμCT is an advantageous method for the characterization of the microstructure in magnesium-aluminium alloys. It was successfully demonstrated that Synchrotron-radiation based microtomography (SRμCT) is a three-dimensional, non-destructive method to visualize the microstructure of magnesium alloys. The microstructural changes in magnesium alloy AZ91D according to the processing route were successfully visualized three-dimensionally using SRμCT. SRμCT is able to visualize any network of phases at grain boundary as well as the size and distribution of pores. Therefore, SRμCT gives valuable additional information to explain materials behavior especially in cases where phases on grain boundaries determine properties as it is in the case of corrosion or creep behavior for magnesium alloys.

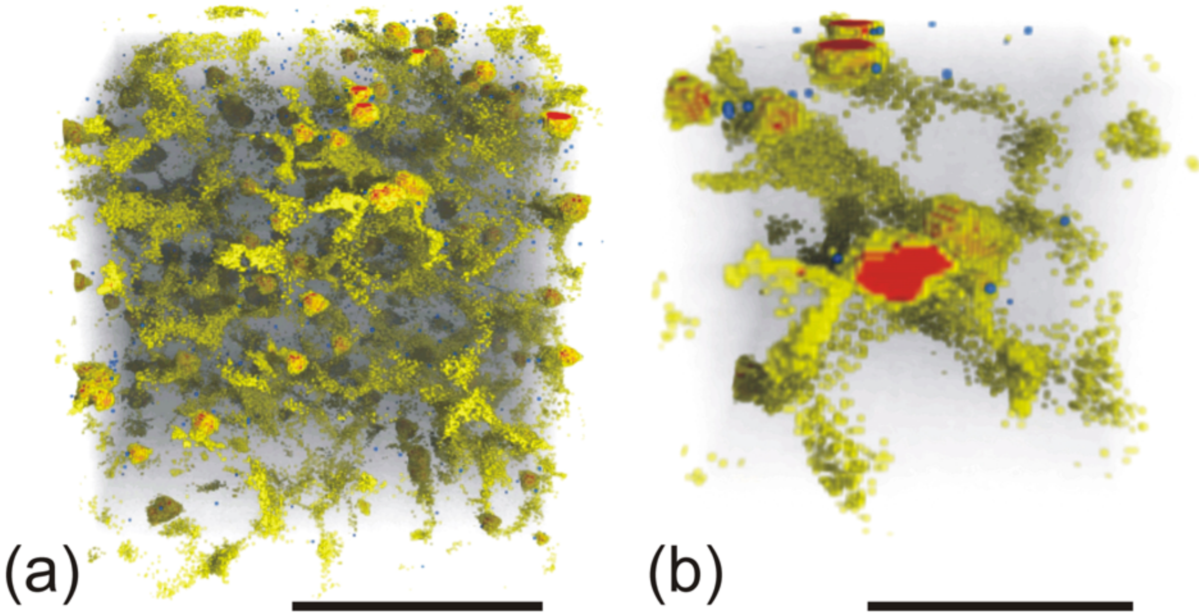

Figure 1: Left 3D reconstruction (a) shows 3D-segmented beta-phases (yellow), pores (blue) and Al-Mn-phases (red) in an as-cast AZ91D. Scale bar = 150 µm. Right 3D reconstruction (b) shows a 3D-magnification of figure 1a, demonstrating the lamellar character of the beta-phases enclosing the Al-Mn-phases in a kind of network. Scale bar = 50 µm.

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