Effect of trace elements on the material properties of an aluminium casting alloy

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Introduction

The aim of the project is to determine the fundamentally effects of impurities and individual micro-alloying elements (eg. as vanadium V, titanium Ti, calcium Ca, zirconium Zr, potassium K, phosphorus P and others) or combinations of these trace elements in aluminum alloys and their impact on the quality of aluminum castings.

As a result, limit values and tolerances for individual impurities (trace elements) should be defined and determined. Further on practical study methods should be developed that support on the one hand a reliable series production of high-quality alloys and castings and on the other hand the procurement of aluminum alloys by the foundries.

Examinations

The examinations were performed on the base of a high purity alloy AlSi7Mg0.3 with systematic addition (30ppm, 300ppm, 3000ppm) of micro-alloying elements.

The following examinations were implemented:

Phase calculations by ThermoCalc-Software: The formation of intermetallic phases and their impact on the microstructure were analyzed by virtual additions of trace elements of vanadium V, titanium Ti, calcium Ca, zirconium Zr, potassium K and phosphorus P (Figure 1).

Casting of technological samples: casting trials in industry-related standards with systematic addition of micro-alloying elements (Figure 2).

Determination of technological properties: flowability, hot crack susceptibility (Figure 3), shrinkage cavity formation.

Static and dynamic material testing: tensile test, hardness test, Woehler curve.

Determination of thermo-physical properties: specific heat capacity, thermal expansion, temperature conductivity, density, heat conductivity.

Metallographic examinations: SDAS, grain size.

SEM/EDXS/EBSD-measurements for the micro-characterization of the structure and the composition of the intermetallic phases are made on cross sections (Figures 4-6).

Out from phases of interest TEM-lamellas are prepared with the FIB-technique (Figure 4) and transferred to TEM for using STEM/EDXS/EELS/EFTEM and diffraction methods for the nano-characterization of these phases (Figures 7-8).

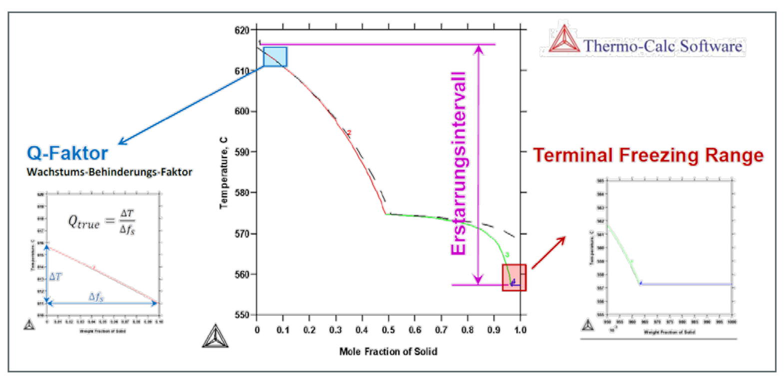

Figure 1 (left): thermodynamic calculations with ThermoCalc
Figure 2 (middle): casting spiral sample
Figure 3 (right): hot crack sample

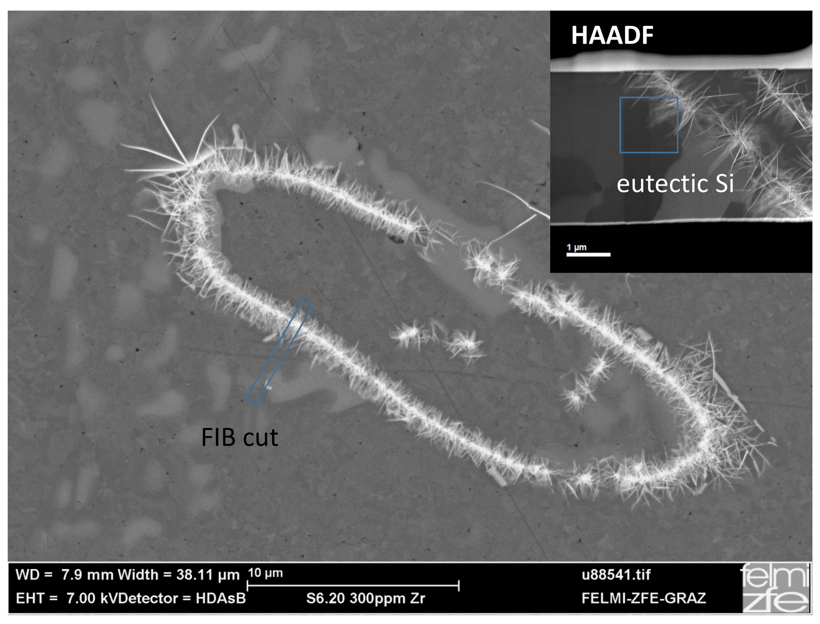

Figure 4 (left): Backscattered Electron (BSE) Image of AlSi7Mg0,3 doped with 300ppm zirconium. Fine needles form this coralliform shaped Al_3Zr-phases. The blue marker shows the area for the FIB-lamella – HAADF image in the upper right corner.

Figure 5 (right): Backscattered Electron (BSE) Image of AlSi7Mg0,3 doped with 3000ppm zirconium and 3000pm calcium. Fine needles form this coralliform shaped Al_3Zr-phase beneath the diagonal crossed (St. Andrew´s cross shaped) Al_3SiZr-phase.

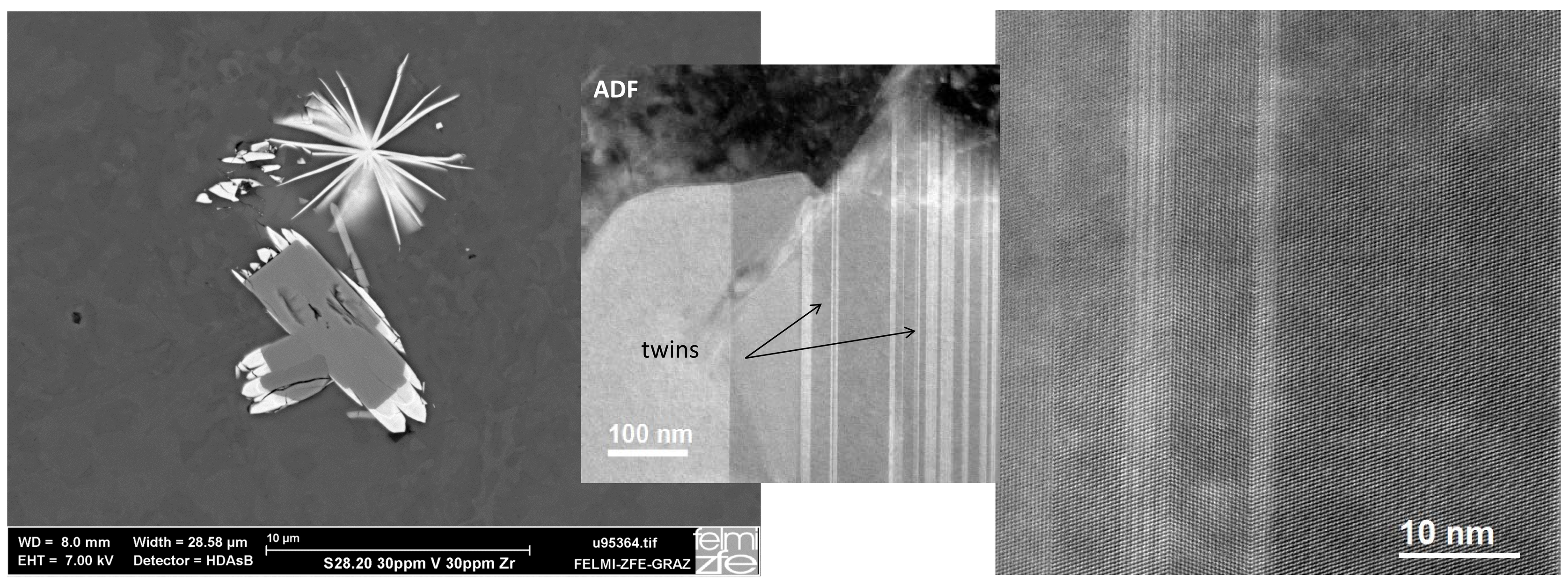

Figure 6 (left): Backscattered Electron (BSE) Image of AlSi7Mg0,3 doped with 30ppm zirconium and 30ppm vanadium. Fine needles form this coralliform shaped Al_3Zr-phase beneath the blocky VB_2 with the spiky Zr_2V-phase.

Figure 7 (middle): STEM ADF image of the eutectic Si-phase with twins

Figure 8 (right): STEM HAADF-image of the eutectic Si-phase with twins

Results

The examinations show a significant correlation between the thermodynamic calculations (ThermoCalc-Software) and the actual casting trials close to industrial conditions. Already minor traces of calcium lead to the formation of intermetallic Al_2Si_2Ca precipitations. Titanium, vanadium and zircon tend to precipitate the intermetallic Al_3M-phases when the solubility limit is exceeded. The casting characteristics worsen significantly with an increase of trace elements. The thermophysical properties, tensile strength and elongation at fracture decline with the increase of trace elements. Especially element combinations with calcium are problematic.

References/ Literature

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