

# Influence of phase composition on diffusion in $Al_xCoCrFeNi$ -high entropy alloys

A thesis presented for the degree

**Master of Science**

Institute of Materials Physics

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submitted on Münster, February 26, 2018

## Abstract

Recently, high entropy alloys, i.e. multicomponent alloys with a large number of constituting elements in equiatomic or nearly equiatomic compositions, attract an increased attention as a potential structural material due to outstanding mechanical and physical properties. Because of its novelty, the influence of four anticipated ‘core’ effects on properties needs to be further investigated. In detail, these effects include the high entropy effect, the lattice distortion effect, the ‘cocktail’ effect and sluggish diffusion. With this thesis, we contribute to a debate about sluggish diffusion by investigating self-diffusion in  $\text{Al}_x\text{CoCrFeNi}$  alloys. Furthermore, the influence of the phase composition on diffusion in these alloys is examined.

Therefore, the microstructure in the system  $\text{Al}_x\text{CoCrFeNi}$  ( $x = 0.5, 1, 2$ ) is examined by XRD (X-ray diffraction), EBSD (electron backscatter diffraction) with coupled EDX (energy dispersive X-ray spectroscopy) analysis and SEM (scanning electron microscopy). This analysis was performed in the as-cast states as well as after annealing at 1273 K and 1373 K, respectively simulating the conditions of following diffusion annealing treatments. In the  $\text{Al}_x\text{CoCrFeNi}$ -HEA system, the phase composition is changed from pure fcc to a mixture of fcc + bcc (B2) phases ( $x = 0.5$  and 1) and finally to dominant bcc (A2+B2) phases ( $x = 2$ ) as the Al content is increased. The second phase precipitates in  $\text{Al}_{0.5}\text{CoCrFeNi}$  and  $\text{Al}_1\text{CoCrFeNi}$  alloys, i.e. bcc and fcc phases respectively, are found at grain boundaries forming a continuous network for long range diffusion through the whole material. Furthermore, average grain sizes larger than 100  $\mu\text{m}$  could be observed for the examined alloys.

In addition, this thesis provides the first radiotracer measurements of self-diffusion in Al-containing high entropy alloys. These measurements were executed with  $^{51}\text{Cr}$ ,  $^{57}\text{Co}$ ,  $^{59}\text{Fe}$  and  $^{63}\text{Ni}$  isotopes after annealing at 1273 K and 1373 K with different annealing times. Based on the microstructure, one may expect two parallel diffusion paths for long-range atom transport, one in the fcc and another in the bcc phase. Diffusion profiles were consequently analysed applying the Gaussian solution of the diffusion problem for two parallel and independent diffusion fluxes in a heterogeneous material. In comparison with other, already published values for diffusivities and activation energies, one may conclude that the concept of sluggish diffusion in HEAs has to be reconsidered, since the deceleration of diffusion with the addition of a fifth element to a four-component alloy is not apparent.

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