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Microprobe Analysis of Zigzag Diffusion Paths in Multiphase Interdiffusion Regions

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When materials are in contact at elevated temperatures they react and interdiffuse to form new microstructures in a region near the plane of contact. The composition variation across the region, known as the diffusion path, can be measured by microprobe analysis when the region is single phase. However to measure the average composition in a multiphase region, one must apply image analysis or other technique as well in order to obtain an accurate result.

A unique feature found when multiphase regions saddle the plane of contact is that the diffusion path takes a zigzag course. An example of an experimental zigzag path is given in Figure 1 [1]. The phase diagram in Figure 1 was taken from a series of diffusion couples made by several students over a span of six years. All microprobe work on the couples was performed at Sandia National Laboratories under the direction of Al Romig. The diagram was drawn by assuming that adjacent phases in the interdiffusion region were in local equilibrium.

The diffusion path was determined by using image analysis to obtain the local area fraction of each phase. The area fraction was assumed equal to the volume fraction, which, with the composition of each phase, was converted into the local average atomic percent. The fundamental reason why zigzag paths form was derived earlier by using an error function solution to the multiphase diffusion equation [2]. The analysis defined an effective diffusivity that was assumed to remain constant. The predicted path consisted of straight line segments as shown in Figure 1. However in 2001, Schwind et al [3] demonstrated that the paths should deviate from straight lines as shown in Figure 2 copied from their reference.

The formation of horns has been verified by one-dimensional, finite difference simulations using DICTRA [4] and by phase field simulations [5]. However experimental verification has yet to be reported and the physical reason why horns form has not been explained. The current understanding of why horns form and the significance of horns to alloy design will be given in this presentation.

References

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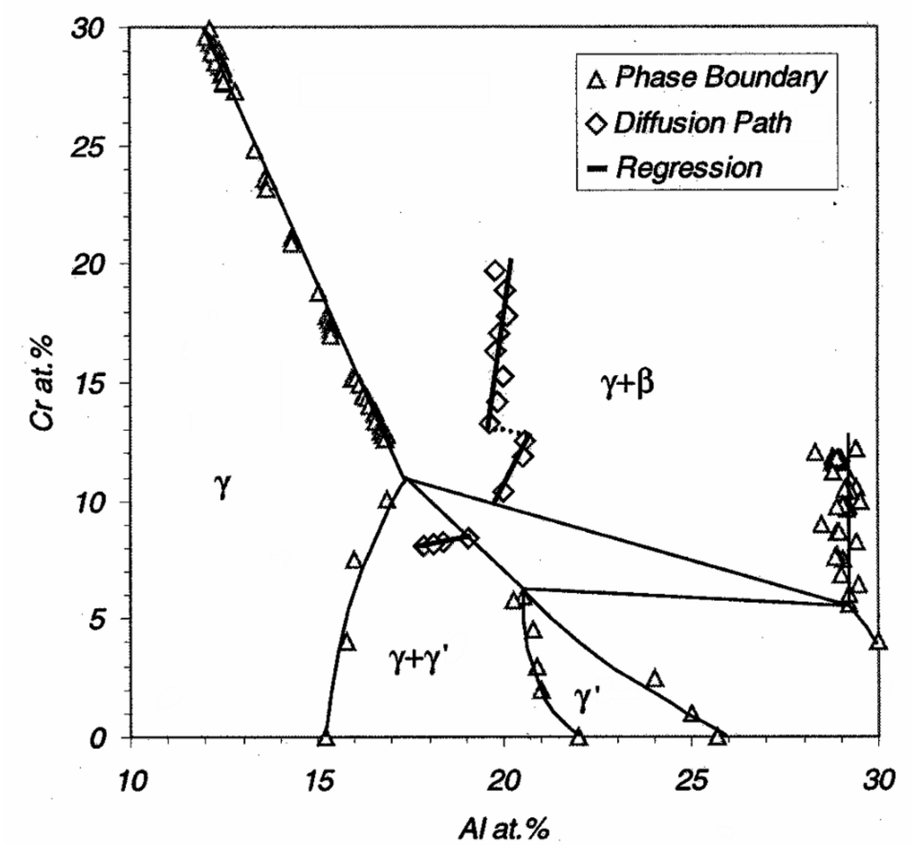

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Figure 1: Ni-Cr-Al isotherm at 1200°C determined from microprobe analysis of several multiphase diffusion couples. The diffusion path of one couple that has a zigzag path in the $\gamma + \beta$ region of the phase diagram is given as well.

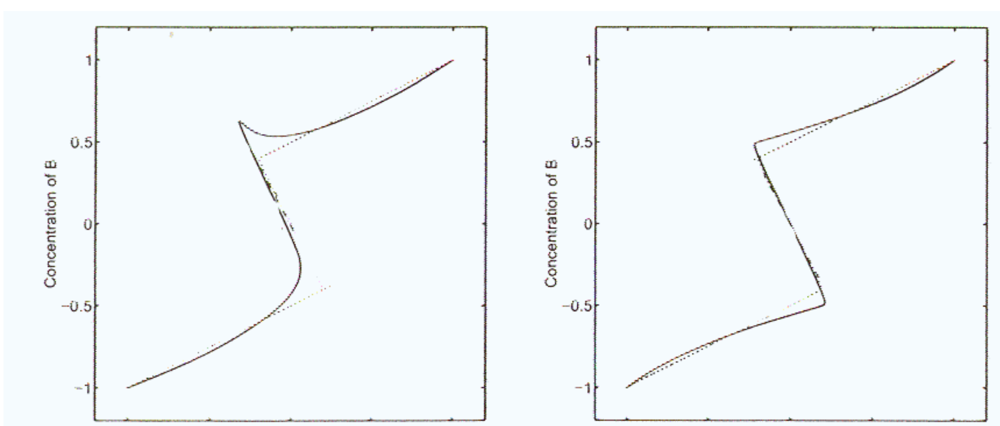

Figure 2: Deviations from linear zigzag paths calculated by Schwind et. al [3] when the effective diffusivity varies with composition. The extremities surrounding the jump in composition were called "horns."

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