Kinetics of solidification of B2 intermetallic phase in the Ni–Al system

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Abstract

Solidification from the undercooled melt is dominated by nucleation and subsequent crystal growth. For chemically ordered intermetallics, the kinetics of crystal growth can be markedly different from that of disordered solid solutions, manifested as substantial interfacial undercoolings or anomalous partitioning behaviour. In the present work the electromagnetic levitation technique is applied, as a containerless processing route, to melt and deeply undercool Ni–Al alloy melts of various compositions – mostly within the homogeneity range of the B2 (β) phase. The ensuing rapid solidification of the undercooled specimen is directly observed by time-resolved temperature measurements and monitored by a high-speed video camera. This allows for direct investigations of crystal growth velocities as a function of composition and undercooling. The experimental results show that the growth of stoichiometric B2 phase (NiAl) is – contrary to common expectations – more sluggish as compared to that of Ni-rich alloys, despite the hindering effect of solute rejection on the growth rate which seems to occur only in the latter. These findings are interpreted within current models of crystal growth taking into account non-equilibrium effects due to partial 'disorder trapping' at the solid–liquid interface.
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1. Introduction

A significant number of binary alloy systems [1] include one or more chemically ordered intermetallic phases, which are stable up to their melting temperature. This implies that the study of solidification microstructure in many alloys calls for an understanding of the solidification behaviour of intermetallic phases, in addition to that of random solid solutions. Ensuring a correct understanding of solidification behaviour is crucial, particularly when solidification microstructures are to be predicted through quantitative models of crystal nucleation and growth.

Early theoretical models for the prediction of solidification microstructures have dealt mostly with the limiting case of dilute random solutions, where both the equilibrium partition coefficient, k, and the slope of liquidus, m,

are generally assumed to be constant, i.e., independent of composition or temperature. This assumption has also served as a basis for the analysis of kinetic effects, such as solute trapping [2], which arise due to high rates of crystal growth. For concentrated alloys and intermetallic phases, however, k and m may vary significantly with temperature. These variations can have a marked effect on the predictions of theoretical models, e.g., those dealing with dendritic solidification. Trivedi and Kurz [3] have treated the problem of variable partition coefficient in concentrated alloys and intermetallics. Their treatment, however, is limited to the equilibrium phase diagram information, i.e., to the cases of solidification with negligible kinetic effects. At high growth rates or undercoolings, the kinetic effects can play a decisive role in the overall solidification scenario, especially when the solid phase is an intermetallic compound. As shown by Boettinger and Aziz [4], the solidification kinetics of intermetallics can be influenced additionally by 'disorder trapping', and thus can be

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