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Diffusion-Induced Instabilities at Internal Interfaces in Solids

E. Rabkin[1], V. Semenov[1,2], W. Gust[1] and L.S. Shvindlerman[2]

[1] Institut für Metallkunde, Seestr. 75, D-70174 Stuttgart, Germany

[2] Institute of Solid State Physics, Chernogolovka, Moscow District, 142432 Russia

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Abstract—Recent experimental results of studies on diffusion-induced grain boundary migration and liquid film migration are reviewed and the nature of the driving force for the migration of interfaces is discussed. It is shown that in many cases the coherency strain in the bulk diffusion zone ahead of the moving interface can be the reason for interface migration, but not the only one. The experimental results of the study on Fe–10 at.% Si alloy interaction with molten Sn are presented. The unusual penetration patterns are interpreted in terms of a coherency strain assisted dissolution of the solid alloy in the liquid phase along the dislocation lines. It is shown that a threshold value of the excess Gibbs energy of the solid/liquid interface exists, below which an instability develops. Besides, there are experimental situations in which the coherency strain does not play any role in the migration of interfaces during diffusion along them. One of such situations is considered: the grain boundary migration induced by the selective change of grain boundary energy and by the departure from equilibrium in the triple junctions during the diffusion process.

Introduction

It is well established now that the interfaces in solids can migrate during diffusion along them or during the diffusion across them into the bulk of the material [1]. The former phenomenon is known as a chemically-induced or diffusion-induced grain boundary migration (**DIGM**). During DIGM an alloyed zone (**AZ**) is formed in the regions swept by the migrating grain boundary (**GB**). The solute atoms are supplied to the alloyed zone by GB diffusion. Another phenomenon closely connected with DIGM is the liquid film migration (**LFM**). An AZ is also formed during LFM in the regions swept by the film, but the solute atoms are provided in this case by the liquid film itself. DIGM and LFM represent the way of approaching an equilibrium in the case in which volume diffusion is very slow. For example, if the temperature of the equilibrated two-phase system with liquid films is increased rapidly, then liquid films will migrate leaving behind them a solid solution of the new equilibrium concentration. In spite of the fact that DIGM and LFM have been observed in more than 70 binary and multicomponent systems, the fundamental question about the origin of the driving force for these reactions is not completely clarified. On the first glance, the decrease of the Gibbs energy of an alloy in the AZ with respect of the Gibbs energy of the pure components creates an energetic asymmetry across the interface and provides the driving force for its migration. However, there is a fundamental problem with this thermodynamic driving force. In the cases in which a noticeable volume diffusion ahead of the migrating interface occurs, a large part of this thermodynamic driving force dissipates during the formation of a thin alloyed layer in the consumed grain. Brechet and Purdy [2] suggested the way to avoid this problem, introducing a phenomenological parameter l, which has the meaning of the thickness of the layer of material on both sides of the GB which influences its motion. Due to the asymmetry in the solute distribution across the moving GB the decrease of the Gibbs energy due to the alloy formation will be always higher in the growing grain than in the consumed one, which restores at least partially the thermodynamic driving force. However, taking into account the short-range character of interatomic interactions in metals, the physical meaning of this parameter l is unclear. There is a group of