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3.21 Kinetics of Materials—Spring 2006

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Lecture 4: Interdiffusion. Effects of electical potential, capillarity, and stress on diffusion potential.

References

1. Balluffi, Allen, and Carter, *Kinetics of Materials*, Sections 3.2–3.5.

Key Concepts

- Interdiffusion may be conveniently described in a crystal frame (*C-frame*) attached to an inert marker placed inside the diffusion zone, or in a volume-fixed frame (*V-frame*, also known as a laboratory frame).
- In the C-frame description of interdiffusion in a two-component system, Fick's law is expressed for each component and each component has its own *intrinsic diffusivity*. In general the fluxes of each component are not equal in the C-frame.
- The intrinsic diffusivity of a component diffusing in a concentration gradient is related to that component's self-diffusivity by an appropriate thermodynamic factor (see *KoM* Eq. 3.13).
- In the V-frame description of interdiffusion in a two-component system Fick's law is expressed in terms of a single diffusivity known as the *interdiffusivity*.
- When two interdiffusing species have the same atomic volumes, the interdiffusivity and the intrinsic diffusivities are related by $\widetilde{D} = X_1 D_2 + X_2 D_1$ (*KoM* Eq. 3.26).
- In general, the intrinsic diffusivities and the interdiffusivity are all functions of concentration.
- The *Kirkendall effect* refers to a set of phenomena that arise when interdiffusing species move at different rates. In a substitutional alloy this requires vacancy creation and destruction. These processes can take place quite efficiently provided the material contains sufficient numbers of vacancy sources and sinks. However, it is not unusual to find *Kirkendall porosity* on one side of the interdiffusion zone.
- The mobility M_i that relates the diffusive flux of i to its chemical potential gradient is always positive. Diffusivities are usually positive also, but not always. For instance, inside the spinodal where $\partial^2 G/\partial c^2 < 0$, $\widetilde{D} < 0$.
- The diffusion potential Φ_i for species i can have terms arising from concentration gradients (interdiffusion), gradients in electrical potential (e.g., ionic conduction and electromigration), thermal gradients, capillarity (e.g., surface smoothing), and stress (e.g., diffusional creep). *KoM* Section 3.5.4 summarizes the various diffusion potentials that we'll encounter in 3.21.

Related Exercises in *Kinetics of Materials*

Review Exercises 3.1–3.8 and 3.10, pp. 68–75.