Interdiffusion in Binary Systems during Rapid Heating: Thermoelastic Stress Influence

M.V. Yarmolenko
Cherkasy Engineering and Technological Institute, Cherkasy, Ukraine

Keywords: Interdiffusion, Thermoelastic Stress, Rapid Heating

If vacancies of a binary metallic system A-B have the potential energy $W_v$ depending on position, one can find the force, acting on a vacancy in such field

$$F_v = - \nabla W_v$$

(1)

If the system is under stress $\sigma$, and if a vacancy in the solid is modelled as the centre of negative dilatation, the potential energy of a vacancy is given by

$$W_v = - (\Delta \omega \text{ tr} \sigma)/3 \quad \Delta \omega = \omega_v - \omega_{\text{atom}}$$

(2)

Consequently, one can determine vacancy flux due to potential energy gradient:

$$j_v^\sigma = C_V D_{v} F_v/(kT) + (D_B^* - D_A^*) \nabla \delta C_B^\sigma$$

(3)

$$C_V D_{v} = C_A D_A^* + C_B D_B^*, \quad C_A + C_B = 1$$

This vacancy flux leads to appearance of atomic fluxes of atoms A and B in opposite direction (in the lattice reference system):

$$j_i^\sigma = - C_i D_{i} J_v^\sigma/(C_V D_{v}) - D_A D_B/(C_A D_A + C_B D_B) \nabla \delta C_B^\sigma$$

(4)

$$i = A, B$$

Besides, there are diffusion fluxes of atoms A and B (in the lattice reference system)

$$j_i = - D_i \nabla C_i \quad i = A, B$$

(5)

One can find resulting flux relatively to the Matano interface

$$J_B = - J_A = - (D \nabla \delta C_B + C_A C_B (D_B^* - D_A^*) F_v/(kT) + D \nabla \delta C_B^\sigma)$$

(6)

$$D = C_A D_B + C_B D_A$$
**Diffusion and Stresses**

For describing of a phase growth with the range of homogeneity $\Delta C$ one can apply the constant flux approximation [1,2]

$$J_B \approx \text{const} = - \left( D \frac{\Delta C}{\Delta X} - D^*(kT) \frac{\Delta W_v}{\Delta X} + D\delta C/\Delta X \right), \quad C=C_B$$  (7)

$$D = (1/\Delta C) \int c^{e+\delta c} D(C) dC; \quad D^* = (1/\Delta C) \int c^{e+\delta c} c_A c_B (D_B^* - D_A^*) dC$$

Taking into account that concentrations at the interfaces practically are not changed under stress, one can neglect the last term:

$$J_B = - D \frac{\Delta C}{\Delta X} + D^*(kT) \frac{\Delta W_v}{\Delta X} \approx \text{const}$$  (8)

We have two situations (if, for example, $D_B^* > D_A^*$):

1. $\Delta W_v > 0$. The phase grows more slowly, if

$$\Delta W_v < D \Delta C \frac{kT}{D^*}. \quad \text{And if }\Delta W_v/\Delta X = \text{const} = K,$n$$

one can find maximum width of phase

$$\Delta X_{\text{max}} = D\Delta C \frac{kT}{D^*k},$$

so stress gradient can stop the phase growth.

2. $\Delta W_v < 0$. The phase grows more rapidly.

If $\Delta W_v$ is small, the concentration profile tends to form a step ( $\sim$ -like shape ).

If $\Delta W_v$ has a great value, it is possible for atoms to diffuse up to the concentration gradient, if mutual solubility of substances A and B is limited.

The analogical concentration profile is determined after interdiffusion during rapid heating of Fe-Ti samples ( $\sim$ -like shape ) [3].

The force, acting on a vacancy, is directed from Ti to Fe and $D_{Fe}^* > D_{Ti}^*$.

The stress gradient arises during rapid heating due to difference between thermal expansion coefficient of Fe and Ti ( $\alpha_{Fe} \approx 2 \alpha_{Ti}$).