

THE CARBON DIFFUSION THROUGH A CONTACT OF TWO SOLID SOLUTIONS

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Abstract

The diffusivity of carbon at 1273 K in solid solutions of Ni, Co, and Fe is determined by measuring the initial graphite precipitation temperature on the interface between regions of low and high carbon content during cooling. The onset of process of surface graphitization is noted on further cooling. The results show that diffusivity is independent of carbon concentration for the range of concentrations investigated. The numerical values of diffusional coefficient are in good agreement with literature data obtained by another authors.

Introduction

The composites formation can be stimulated by the molecular-kinetic processes in solid solutions. The surface segregation of one of alloy components at graphitization, cementation and nitrogenization may serve as an example of such process. The transport processes, as for instance, the thermally activated transport of atoms of alloy impurity component can essentially change its physical characteristics.

The main objective of present paper is investigation of diffusional process going on in contact zone of solid solutions of carbon in nickel, cobalt and iron, determination of concentrational curve of C component distribution in contact zone, calculation of diffusional coefficient and establishment of temperature dependence of diffusional coefficient.

When two solid solutions of carbon in Ni, Co or Fe with C_1 and C_2 concentrations come into contact, after diffusive annealing at the T temperature during the τ time the carbon redistribution is going into the contact zone: the carbon content in a solution with higher concentration decreases and in a solution with lower concentration it increases. The present study includes the results of experimental plotting of a carbon distribution curve at the contact and the calculation of carbon diffusivity.

Results and Discussion

Carbon Concentration Curves

The concentration curve of carbon distribution in a contact zone was obtained by recording the initial temperature of graphite precipitation on the surface at vacuum cooling [1].

The studies cover different diffusive pairs and concentrations:

Ni-C ($C_1 = 0.17$ and $C_2 = 0.09$ mass % of C),
Co-C ($C_1 = 0.22$ and $C_2 = 0.08$ mass % of C), (1)
Fe-C ($C_1 = 1.29$ and $C_2 = 1.09$ mass % of C).

To improve the contact one alloy in the form of a cylinder was placed into the hole of the other one. The diffusive annealing was carried out at 1273 K for one hour. After annealing the specimens were cooled at a rate of 20 K per minute and the initial temperature of carbon precipitation on the surface was determined with a microscope. The optics permitted the detection of graphite crystals

measuring $\sim 5 \cdot 10^{-4}$ centimeters. The measurements were made along the radial directions.

The carbon surface segregation in carbonic alloys is well known [2]. But not all of the matrix grains come out upon the observed surface by faces, favorable for graphite centers origin. Carbon does not form at some grains under the deepest supercooling, and it seems that these circumstances bring about the strong spread in determining the temperature at which solution decay begins. It does not take place because in the microscope field of view, it gets sufficient quantity of grains, and this provides reliable averaging of the observation results.

The initial temperature curves of graphite precipitation from solid solution for different points in the diffusion zone are shown in Fig. 1. These curves represent the carbon distribution near the contact, i.e. the concentration curve of carbon distribution, since between the initial temperature of solid solution decomposition and carbon content in alloy exists the definite relation, which for our experimental conditions may be presented by these equations [3, 4]

$$\begin{aligned} T &= -1024 \exp(-2.21 \cdot C) + 1879, \\ T &= -718 \exp(-2.54 \cdot C) + 1639, \\ T &= -1510 \exp(-0.54 \cdot C) + 1925, \end{aligned} \quad (2)$$

for Ni-C, Co-C alloys and hypereutectoid steels Fe-C; where T is the initial temperature of solid solution decomposition and C is the carbon concentration in alloy.

Carbon Diffusion Coefficient

The curves in Fig. 1 may be used for determination of the carbon diffusion coefficient.

The second Fick's law in finite differences may be given in the form [2, 5-15]

$$\frac{1}{\tau} \int_{x_1}^{x_2} \Delta C \cdot dx = \left[D \frac{\partial C}{\partial x} \right]_{x_2} - \left[D \frac{\partial C}{\partial x} \right]_{x_1}, \quad (3)$$

where x_1 and x_2 are coordinates of two randomly selected points with determination of $\frac{\partial C}{\partial x}$ concentration gradients for them; ΔC is the carbon concentration variation at these points due to diffusion during the τ time. Thus,

$$D = \frac{1}{\tau} \int_{x_1}^{x_2} \Delta C \cdot dx \left/ \left\{ \left[\frac{\partial C}{\partial x} \right]_{x_2} - \left[\frac{\partial C}{\partial x} \right]_{x_1} \right\} \right. \quad (4)$$

The last relationship holds true for the assumption that D does not depend on carbon concentration. This assumption will be applied to following analysis.

If the diffusion coefficient is a function of C concentration $D = D(C)$, then the interface of two solutions passes through the inflection point of the concentration curve in such a way that the amount of carbon leaving the solution with C_1 concentration will be equal to the amount of carbon entering the solution with C_2 concentration. The interface does not pass through $x = 0$ and its position is determined by specific conditions of concentration curve receipt. Conforming to the curves in Fig. 1, the interface is disposed at $x > 0$ region at a distance of 0.16 mm, 0.128 mm and 0.192 mm from contact for Ni-C, Co-C and Fe-C alloys, respectively.

In the case of D dependence on C the value of diffusion coefficient for "C" concentration may be determined by the expression [5, 8, 10]

$$D = - \frac{1}{2\tau} \frac{dx}{dC} \int_{C_1}^C x dC. \quad (5)$$

Thus, it is necessary to know dx/dC and $\int_{C_1}^C x dC$ (or $\int_C^{C_2} x dC$) for the determination of D value. The

magnitude of dx/dC is obtained (subject to formulae (2)) by drawing a tangent line to the

concentration curve at the “C” point. The $\int_{C_1}^C x dC$

value is determined as the area between the segment of the concentration curve in the interval $[C_1(T_1); C(T)]$ and the line corresponding to the interface.

In the present studies the diffusion coefficients have been determined by equation (5) for a diffusion zone within the range of -0.8 mm to $+0.8$ mm step. Their values for each point in these intervals are given in Table 1. As can be seen from Table 1, the diffusion coefficient of carbon for all alloys varies from point to point at random.

Conclusions

The results lead to the conclusion that for the investigated alloys the diffusion coefficient does not depend on the carbon concentration. For contacting alloys this may be explained by the slight difference in carbon content. The concentration dependence of the diffusion coefficient may be established by increasing the difference of carbon concentration in diffusive pairs.

When the greatest and the least values of diffusion coefficient are rejected at confidence probability $\alpha=0.9$ the true values may be obtained

$$\begin{aligned} & (2.7 \pm 0.3) \cdot 10^{-7} \text{ cm}^2/\text{s}, \\ & (1.66 \pm 0.19) \cdot 10^{-7} \text{ cm}^2/\text{s}, \\ & (3.26 \pm 0.13) \cdot 10^{-7} \text{ cm}^2/\text{s}, \end{aligned} \quad (6)$$

for Ni-C, Co-C and Fe-C alloys, respectively.

These results agree with the results described in the literature [2, 5, 6, 8, 14]. The comparison confirms the data represented in the work [1], when the diffusion coefficient was calculated by equation (4) with the assumption that $D \neq D(C)$. It should be noted that the use of the phenomenon of carbon precipitation on the solid solution surface allow for

the determination of the carbon distribution in a solution or metal contacting with graphite.

References

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Table 1. The diffusion coefficients D for different points of contact zone for Ni-C, Co-C and Fe-C alloys

X, mm	D·10 ⁷ , cm ² /s		
	Ni-C	Co-C	Fe-C
0.8	2.25	1.63	3.20
0.6	2.30	2.26	3.32
0.4	2.78	1.83	3.24
0.2	3.25	1.49	3.52
0	2.88	1.30	4.02
-0.2	1.79	1.92	3.36
-0.4	3.41	2.02	3.24
-0.6	3.30	1.42	2.92
-0.8	2.34	1.15	2.06

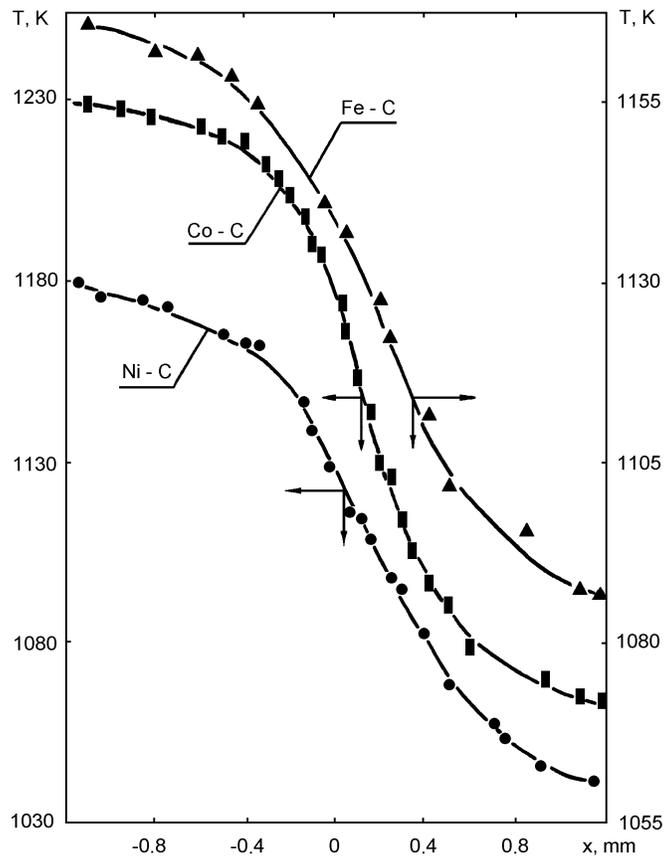


Fig. 1. Curves of the initial temperature of carbon precipitation from solid solution on different points of the contact zone.