THE INFLUENCE OF HYDROSTATIC COMPRESSION ON DIFFUSION CONSTANTS IN A TITANIUM-IRON ALLOY *

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(Received 17 March 1960)

The present investigation is a development of work carried earlier on the study of the influence of hydrostatic compression on diffusion constants [1,2].

It has been shown from the study of self-diffusion in zinc [1] and iron [2] that diffusion constants are substantially dependent on the degree of pressure from the inert gas in which diffusion annealing was carried out. It was established that even at relatively small pressures (up to 150 atm) the process of diffusion is characterized by higher speed and lower energy of activation.

The experimental determination of the dependence of diffusion constants on the degree of relatively low pressures acting continuously on a test specimen during diffusion annealing, provides information concerning the diffusion process in circumstances in which plastic microdeformations develop in the grain of a polycrystal as a result of the redistribution of stresses in the grains and the reorientation of the grains with regard to one another during the transition to a new equilibrium state brought about by the action of the pressure of the gaseous medium.

In the papers cited an investigation was made of the diffusion process of iron in polycrystals (average grain size 2 mm) of a titanium alloy with 4 at. % iron in the pressure range 1 to 170 atm. The titanium purity was 99.7 %.

Diffusion annealing was carried out at two temperatures, 950 and 1200°, which corresponded to the beta-modification of the alloy (body-centred cubic lattice), in an inert gas (argon) in a special apparatus by means of which it was possible to carry out annealing at pressures of up to 1000 atm. and temperatures up to 1500°. The inert gas in this apparatus had undergone additional cleaning, which practical ruled out the possibility of the test specimens being contamined by oxygen or nitrogen. The pressure of the gas remained constant during the course of the whole diffusion annealing. The temperature of the test specimens was maintained constant with a precision of ± 2°.

The rate of diffusion was determined by the autoradiographic method [3] using radioactive iron ^{55,59}Fe. The diffusion zone was about 1.5 mm in depth and the duration of diffusion annealing was about 0.5 to 1.2 hr. Calculation of the diffusion coefficients was carried out by the well-known formula

$$D = \frac{-0.1086}{t \times \tan \alpha},$$

where t is the duration of diffusion annealing, while $\tan \alpha$ is determined from the graph for the relationship

$$\log \frac{\partial I}{\partial x} = f(x^2).$$

The relevant figures for the diffusion coefficients are given in Table 1.

These data are presented graphically in Fig. 1 as $\log D = f(p)$ and in Fig. 2 as $\log D = f(1/T)$.

If follows from the table and graph that the maximum effect on the rate of diffusion at 950° is excercised by pressures at the beginning of the range investigated. Increase in pressure causes the curves $\log D = f(p)$ to incline more and more towards the axis p, i.e. the intensification of the process of diffusion is directed towards saturation. On the other hand, the relationship $\log D = f(p)$ at 1200° shows that there is a considerable reduction in the effect hydrostatic compression on the rate of diffusion with increased temperature. Thus if at 950° the ratio

$$\frac{D_{p=150}}{D_{p=1}} = 7.4,$$

then at 1200° this ratio will only be 1.63. Here the

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* *Fiz. metal. metalloved.*, 10, No. 2, 297-299, 1960

FIG. 1.

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TABLE 1. Diffusion coeffficient $D \times 10^7$ cm²/sec

№ sample	T, °C	Pressure, atm.					
		1	20	50	100	150	170
1 2 3 4	950	0.58 0.66 — —	1.25 1.34 1.09 1.49	1.56 1.59 2.22 1.92	3.54 2.61 3.06 2.78	4.26 3.98 5.25 4.76	— — — —
Sr		0.62	1.29	1.82	3.00	4.56	—
1 2 3	1200	5.05 5.60 —	— — —	6.44 5.38 7.39	6.63 7.60 7.13	— — —	8.38 9.17 8.83
Sr		5.33	—	6.40	7.12	—	8.76

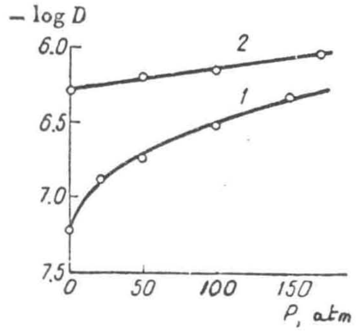

FIG. 1. Dependence of log D on pressure in a titanium alloy with 4 at.% iron at temperatures:
1 – 950°;
2 – 1200°.

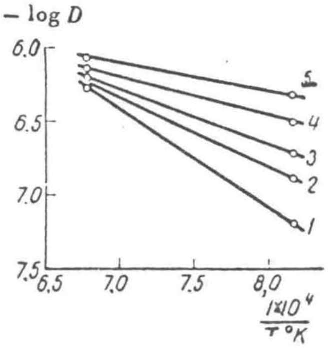

FIG. 2. Dependence of log D on $1/T$ for a titanium alloy with 4 at.% iron at pressures:
1 – 1 atm; 2 – 20; 3 – 50;
4 – 100; 5 – 150 atm.

orientation of the straight lines log $D = f\,(1/T)$ (although they are each plotted through two temperature points, because of the large interval between them (250°) and the considerable scatter of the values of D from the mean, they are good enough to provide a basis for qualitative conclusions) show that at a certain temperature T_0 the effect of pressure will be zero. It follows from this that increase in pressure will cause a regular reduction in the activation energy of diffusion. The permits the hypothesis, that the energy expended in the development of plastic microdeformation in a polycrystal is due to reduction in the potential barrier in the path of the diffusing atoms and that easier paths are then created for their diffusion movements.

The reduction in the effect of hydrostatic compression on the diffusion process at elevated temperature is apparently due to reduction in the number of crystal lattice defects arising in the course of plastic microdeformation, as a result of the more rapid healing of the defects.

The data presented here are in complete agreement with those obtained earlier [1, 2] and reveal a fully determinable dependence of the diffusion process on the magnitude of the pressure.

Translated by V. Alford

REFERENCES

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