X-Ray Studies on the Diffusion of Copper into Nickel

By

Chujiro Matano

(Received September 19, 1932)

Abstract

The coefficients of diffusion of copper into nickel have been determined from the changes of radii of Debye rings, as 3.5×10^{-7} cm^2./day at 650°C and 1.9×10^{-5} cm^2./day at 890°C.

Already in 1930 Elam[1] has applied the X-ray analysis in the form of Laue spots for the investigation of diffusion of zinc into copper crystals and in the same year Tanaka and the writer[2] have utilised the X-ray photographs in the form of Debye rings for the study of inter-diffusion of gold and copper. Recently Jost[3] has determined the coefficient of diffusion of copper into gold. Under the same principle, the writer independently has found that of copper into nickel at the temperatures of 650°C and 890°C. The detailed account of this is as follows:

The samples were made by the electroplating of nickel upon the copper plates (about 0.5 mm. thick), and they were heated *in vacuo* for some interval of time at the constant temperatures. The X-ray photographs of the samples were taken at the position shown in Fig. 1, by using the CuKα_1-line($\lambda = 1537$ x. u.). By means of Bragg's formula, the lattice constant of the solid-solution at the surface of the plate can be determined by taking the innermost radius of Debye ring corresponding for the plane (420). (It must be noticed that the difference of radii of the innermost and the outermost rings can not be

1. C. F. Elam: Jour. Inst. Metals, **43**, 73 (1930).
2. S. Tanaka and C. Matano: These Memoirs, **13**, 343 (1930).
3. W. Jost: Zeit. phys. Chem., B, **16**, 123 (1932).

taken for the purpose of the calculation of the lattice constant, for the outermost ring, in some cases, does not due to the pure copper.) And from the linear relation of the concentrations and the lattice constants, the concentration c of nickel at the surface of the plate can be found by using the lattice constant above determined. On the other hand, c is equal to[1] $\phi\left(\frac{h}{2\sqrt{Dt}}\right)$, where h the thickness of the nickel-deposition calculated from the difference of masses before and after the electrodeposition, D the coefficient of diffusion and t the time interval for which the sample has been heated, and lastly ϕ is the probability integral, if Fick's law may hold. So by using a table of ϕ-function and from the observed values of c, h and t, D can be determined as shown in Table I.

Fig. 1.

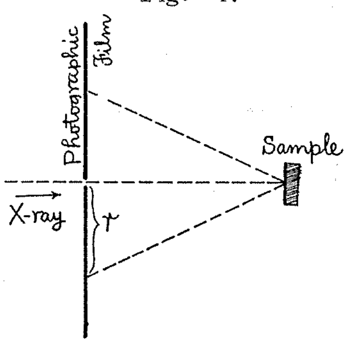

Table I

Thickness of layer h in cm.	Time of heating t in hr.	Radius of Debye ring r in cm.	Lattice constant d in x. u.	$\frac{h}{2\sqrt{Dt}}$	Coefficient of Diffusion D in cm².day	
3.93×10^{-4}	5.0	2.75	3548	0.744	3.4×10^{-7}	650°C
3.93×10^{-4}	7.5	2.90	3559	0.579	3.7×10^{-7}	
5.43×10^{-4}	7.5	2.67	3543	0.834	3.4×10^{-7}	
5.43×10^{-4}	0.5	3.03	3568	0.465	1.6×10^{-5}	890°C
1.21×10^{-3}	0.5	2.62	3539	0.806	2.1×10^{-5}	

For pure copper, $r=3.62$ cm., and $d=3613$ x. u., for pure nickel, $r=2.34$ cm., and $d=3521$ x. u., and the distance from film to sample $=5.0$ cm.

These results can be compatible with the writer's previous results[2] which were obtained from the change of electrical resistance. Experiments on the diffusion at the lower temperatures are now being

1. Riemann-Weber: Differentialgleichungen der Physik II, 189.
2. C. Matano: These Memoirs, **14**, 123 (1931).

carried on, in somewhat different manner, and will be shortly published. But as the writer supposes Owen and Pickup[1] carry on the experiments on the same principle, the data which have been obtained at present, will be here described.

In conclusion, the writer wants to express his sincere thanks to Profs. M. Ishino and U. Yoshida for their kind guidance.

Physical Laboratory,
The Osaka University of Engineering.

---

1. E. A. Owen and L. Pickup: Nature, **130**, 201 (1932).