J. Phys. Chem. Solids Vol. 49, No. 12, pp. 1465–1467, 1988
Printed in Great Britain.

0022-3697/88 $3.00 + 0.00

COMPRESSIBILITIES OF NIOBIUM ALLOYS

J. GRAMMATIKAKIS and C. A. LONDOS
Physics Department, Solid State Section, University of Athens, 104 Solonos Street, Athens 106 80, Greece

(*Received* 21 *March* 1988; *accepted in revised form* 20 *June* 1988)

Abstract—The compressibility κ of two niobium alloys (those of niobium–molybdenum and niobium–zirconium) has been studied as a function of the concentration of the added component. It is shown that the variation of κ could be interpreted in terms of a model formulated previously. The model allows the determination of κ at every concentration provided that at least two values of κ are known.

Keywords: Metals, alloys, niobium, compressibility.

1. INTRODUCTION

The variation of the elastic constants of the Nb–Mo and Nb–Zr alloys with temperature has been studied [1–4] intensively and extensively in the last 20 years. The object of the present work is to study the variation of the adiabatic compressibility κ of the above two alloys as a function of the concentrations of Mo and Zr added to Nb.

In a recent work [5] the variation of the compressibility of the binary alloys Pb–Th and Mg–Li has been interpreted in terms of a model previously formulated by Varotsos and Alexopoulos [6]. According to this model, when n foreign atoms are introduced in a crystal lattice which contains N atoms the following relations hold:

$$V = V_0 + \frac{n}{N}(Nv^d + V_0) \tag{1}$$

$$\kappa V = \kappa^0 V_0 + \frac{n}{N}(\kappa^d N_v^d + \kappa^0 V_0), \tag{2}$$

where V_0 and V are correspondingly the volume of the pure crystal ($V_0 = N\Omega_0, \Omega_0$ the mean atomic volume) and the volume of the alloy. v^d denotes the difference of the atomic volumes between the host and the impurity material, κ^0 is the adiabatic compressibility of the pure crystal, κ that of the alloy and κ^d is defined by

$$\kappa^d = \frac{1}{v^d}\frac{dv^d}{dp}.$$

Relation (2) for small concentrations is written approximately:

$$\kappa = \kappa^0 + \frac{n}{N}\frac{v^d}{\Omega_0}(\kappa^d - \kappa^0). \tag{3}$$

If the plot of $V = V(n/N)$ is a straight line, then taking into account eqn (1) we conclude that v^d is constant.

In this case, the linearity of the relation $\kappa V = \kappa V(n/N)$ from eqn (2) implies that κ^d is also constant, i.e. independent of the concentration of the alloy.

2. NIOBIUM–MOLYBDENIUM ALLOYS

Hubbell and Brotzen [2] have studied the adiabatic elastic constants of pure Nb and Nb–Mo alloys, at temperatures ranging from −190 to +100°C, with various concentrations of Mb from 16.8 to 92.1%. If x is the atomic concentration of Mo in Nb then from the relation $n/N = [x/(1-x)]$ $(x = n/n + N)$ we could calculate n/N. The relation

$$V = \frac{m_{\text{Nb}} + \frac{n}{N} m_{\text{Mo}}}{\rho},$$

where m_{Nb}, m_{Mo} are the atomic weights of Nb and Mo correspondingly and ρ the density of the alloy, gives the volume V. The density ρ is determined experimentally. Compressibility κ is calculated from the elastic constants [2], C_{11} and C_{12}, by employing the relation $\kappa = 3/(C_{11} + 2C_{12})$. From Fig. 1 we see that the plot of $V = V(n/N)$ is linear with a correlation factor c.f. = 0.999. From the slope of the above line we find

$$Nv^d = 1.38 \times 10^{-6}\,\text{m}^3.$$

From Fig. 2 we can also see that the plot of κV as a function of n/N is a straight line with c.f. = 0.99. We find that

$$\kappa^d = 20.0 \times 10^{-12}\,\text{m}^2\,\text{N}^{-1}$$

and

$$\frac{\kappa^d}{\kappa^0} = 3.45.$$

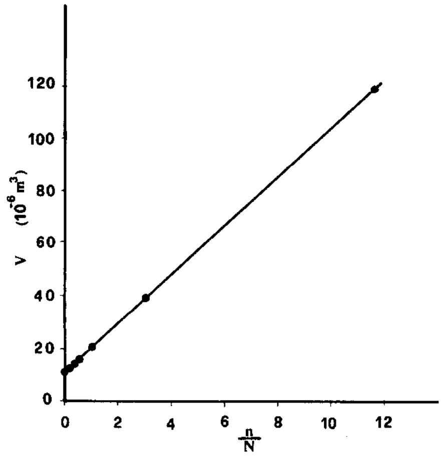

Fig. 1. The plot of V vs n/N for Nb–Mo alloys.

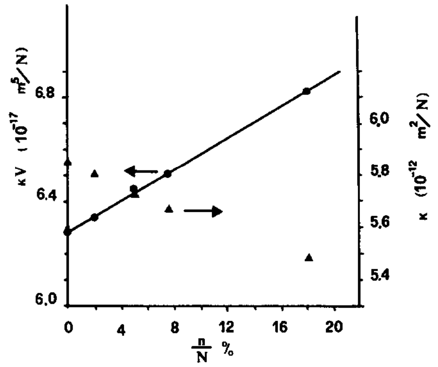

Fig. 3. The plots of κV vs n/N (●) and κ vs n/N (▲) for Nb–Mo alloys (data from Ref. 4).

It is noteworthy that the variation of κ vs n/N (Fig. 2) is not linear except for low concentrations in accordance with eqn (3).

Figure 3 exhibits the plot of $\kappa V = \kappa V(n/N)$ for Nb–Mo alloys for another set of data [4] reporting concentrations in range 0–15.33%. We find

$$\kappa^d = 24.0 \times 10^{-12}\, \mathrm{m}^2\, \mathrm{N}^{-1}$$

and

$$\frac{\kappa^d}{\kappa^0} = 4.12.$$

This value of κ^d differs from the previous calculated one by about 16%.

3. NIOBIUM–ZIRCONIUM ALLOYS

Zirconium, like Mo is completely soluble in Nb and provides solid solutions for every concentration of Zr. Walker and Peter[4] measured the adiabatic elastic constants of Nb–Zr alloys for concentrations of Zr ranging from 15 to 70% at temperatures from 4.2 to 300 K. From Figs 4 and 5 we see that the plots $V = V(n/N)$ and $\kappa V = \kappa V(n/N)$ are straight lines with c.f. = 0.999. We find

$$Nv^d = 3.18 \times 10^{-6}\, \mathrm{m}^3$$

$$\kappa^d = 3.11 \times 10^{-12}\, \mathrm{m}^2\, \mathrm{N}^{-1}$$

and

$$\kappa^d/\kappa^0 = 0.57.$$

We should notice that the linearity of $V = V(n/N)$ and $\kappa V = \kappa V(n/N)$ does not occur for all the alloys formed from various metals. It will be very interesting to know in which alloys and under what conditions eqns (1) and (2) give linear plots. The study of this question will be the subject of later work.

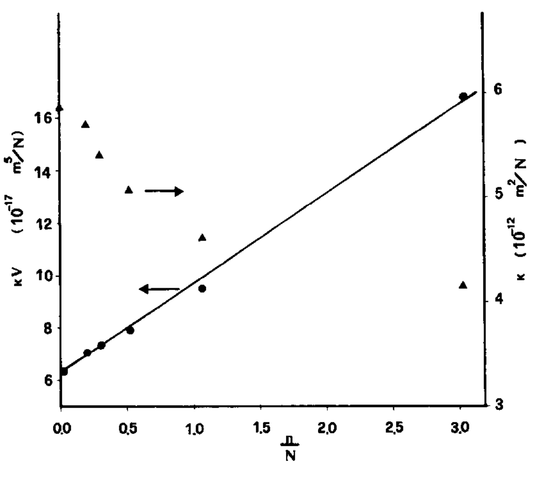

Fig. 2. The plots of κV vs n/N (●) and κ vs n/N (▲) for Nb–Mo alloys (data from Ref. 3).

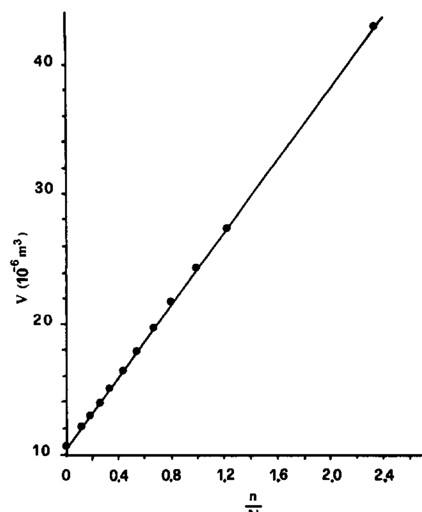

Fig. 4. The plot of V vs n/N for Nb–Zr alloys.

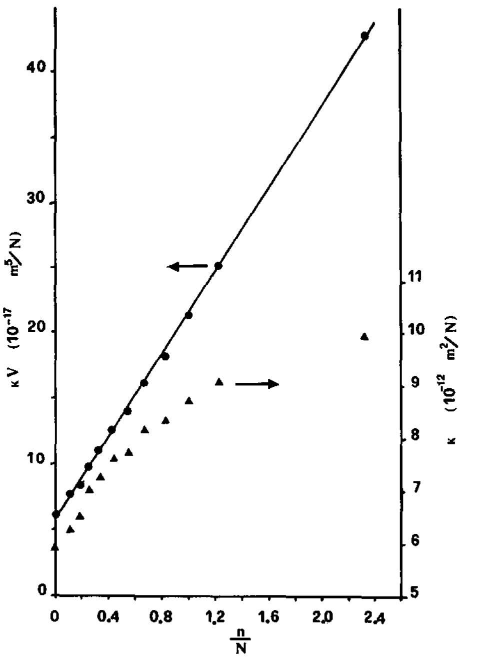

Fig. 5. The plots of κV vs n/N (●) and κ vs n/N (▲) for Nb–Zr alloys.

REFERENCES

1. Bujord P., Sanjines R., Walker E., Ashkenzazi J. and Peter M., *J. Phys. F: Metal Phys.* **11,** 775–86 (1981).
2. Hubbell W. C. and Brotzen F. R., *J. appl. Phys.* **43,** 3307 (1972).
3. Kataev K., *Akust. Zh.* **22,** 296 (1976).
4. Walker E. and Peter M., *J. appl. Phys.* **48,** 2820 (1977).
5. Grammatikakis J., Hadjekontis V., Eftaxias K. and Patapis S., *J. Phys. Chem. Solids* **49,** 965 (1988).
6. Varotsos P. and Alexopoulos K., in *Thermodynamics of Point Defects and their Relation with bulk Properties* (Edited by S. Amelinckx, R. Gevers and J. Nihoul). North-Holland, Amsterdam (1986).