

Table 5. The potential constants and the calculated values of elastic constants for α phase Ag-Cd alloys

X_B	D (eV)	r_0 (Å)	α (1/Å)	C_{11} calculated	C_{12} calculated	C_{11} experimental	C_{12} experimental
0.00	0.3178	3.0887	1.4340	1.334	0.887	1.240	0.934
1.29	0.3155	3.0913	1.4321	1.321	0.878	1.228	0.925
1.84	0.3135	3.0951	1.4254	1.305	0.869	1.216	0.913

Elastic constants: 10^{12} dyn/cm² unit.Helmholtz free energy F is given by

$$F = E(a) + 3NkT \cdot \log(1 - e^{-\Theta_D/T}) - NkT \cdot D\left(\frac{\Theta_D}{T}\right), \quad (6)$$

where Θ_D is the Debye temperature and $D(x)$ is the well known Debye function. Using this expression, the equation of state, or P - V relation, and Grüneisen parameters were calculated and published in our previous paper[12]. The quasi-chemical approach assuming only constant nearest neighbor interactions cannot lead a P - V relation but our fairly simple method could do it. However, it should be noted that the phenomena associated with atomic rearrangement such as solute clustering can not be treated by the present method. The empirical Morse function is useful in applying some types of problems for metallic solid solutions but its validity is limited because of the lack of sound physical basis.

Acknowledgments—The authors are grateful to Prof. R. R. Hasiguti for his continuous interest and encouragements. This work is partially supported by the International Copper Research Corporation.

REFERENCES

1. Girifalco L. A. and Weizer V. G., *Phys. Rev.* **114**, 687 (1959).
2. Harrison W. A., *Pseudopotentials in the Theory of Metals*. Benjamin, New York (1966).
3. Johnson M. D., Hutchinson P. and March N. H., *Proc. R. Soc. A* **282**, 283 (1964).
4. Heine V. and Weaire D., *Solid State Physics*, Vol. 24. Academic Press, New York (1970).
5. Guggenheim E. A., *Mixtures*. Oxford University Press, London (1952).
6. Hillert M., *Metallic Solid Solutions*, Vol. XL VII-1. Benjamin, New York (1963).
7. Hultgren R., Orr R. L., Anderson P. D. and Kelly K. K., *Selected Values of Thermodynamic Properties of Metals and Alloys*. Wiley, New York (1963).
8. Cain L. S. and Thomas J. F., *Phys. Rev.* **B4**, 4245 (1971).
9. Obinata I. and Wasserman G., *Naturwiss* **21**, 382 (1933).
10. Peason W. B., *A Handbook of Lattice Spacings and Structures of Metals and Alloys*. Pergamon Press, Oxford (1958).
11. Born M., *Proc. Cambridge Phil. Soc.* **36**, 160 (1940).
12. Yamamoto R. and Doyama M., *Phys. Lett.* **40A**, 148 (1972).

ELASTIC CONSTANTS AND THEIR PRESSURE DERIVATIVES OF α -BRASS SINGLE CRYSTALS

R. A. CHIARODO, I. L. SPAIN and P. BOLSAITIS

Department of Chemical Engineering, University of Maryland, College Park, Md 20742, U.S.A.

(Received 21 March 1973; in revised form 26 September 1973)

Few elastic constant measurements on α -brass single crystals are reported in recent literature [1,2]. Although Subrahmanyam and Krishnamurthy [3] have conducted extensive measurements on polycrystalline alloys, their results, when converted to the equivalent single crystal parameters by the Kneer equations [4], show considerable scatter in the data.

The present note reports the values of ultrasonically measured elastic constants and their pressure derivatives for copper and two α -brass single crystals (19 at.% Zn and 29 at.% Zn). The elastic constants, expressed in terms of the Young's modulus (E), the adiabatic bulk modulus (B_s), and the shear constant C_{11} are in good agreement with the previous single crystal data, showing a nearly linear decrease of the three parameters with zinc concentration. The data obtained on polycrystalline samples by Subrahmanyam and Krishnamurthy [3] for the bulk modulus scatters around the values obtained from single crystal measurements, while the C_{11} and E values show, apart from the scatter, a more systematic deviation (see Figs. 1-3).

The crystals used for the measurements were purchased from Monocrystals Inc. of Cleveland, Ohio. Both crystals were homogenized by annealing for more than 100 h at temperatures up to 690°C and furnace cooled. The lattice parameters corresponding to these compositions are 3.658 Å (19% Zn) and 3.681 Å (29% Zn) [5]. The crystals were oriented by Laue X-ray back reflection and cut

to expose two parallel (110) faces to within 1° of this orientation and lapped flat and paralleled to within one part in 10⁵. The length of the crystals along the direction of sound wave propagation was 1.25 cm and 1.73 cm for the 19 and 29% Zn crystals respectively.

For each crystal the velocities of the longitudinal and the two transverse waves were measured by the well known McSkimin pulse superposition method [6] using 10 MHz X and Y cut quartz transducers.

The pressure derivatives of the elastic moduli were determined by measuring the ultrasonic wave velocities as a function of pressure up to 100,000 psi. The ultrasonic wave velocities were found to be linear functions of the pressure over this range. Further details of the experimental procedure are discussed in Ref. [7].

The results of the measurements are summarized in Table 1. As has been discussed previously [8] the errors implicit in the measurement of elastic constants in alloy single crystals are much smaller than the unresolvable uncertainties in the absolute composition values (assumed here as $\pm 1\%$). The irregular behaviour of the pressure derivatives of the elastic constants near the phase boundary (i.e. at 29% Zn) is similar to that observed for random Cu-Au alloys at the ordering composition [8].

The composition dependence of the elastic constants was also calculated, using some necessary simplifying assumptions, by means of the Electron Cell model, which has been used with fairly good success for representing

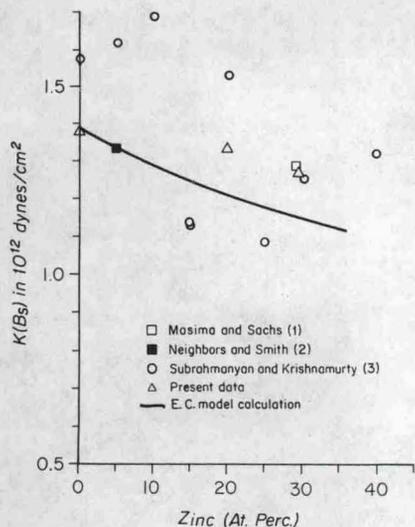


Fig. 1. Bulk modulus as function of composition.

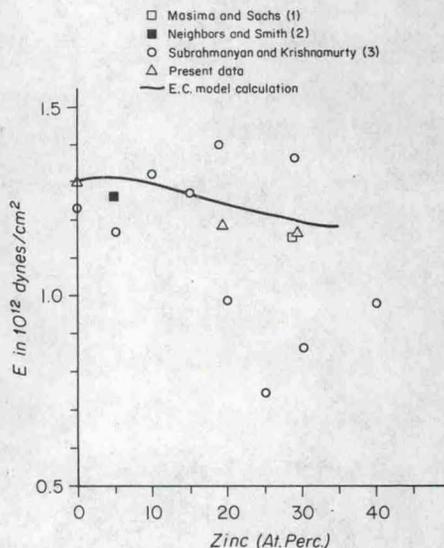


Fig. 2. Shear constant as function of composition.