

Effect of Pressure on Creep in Tin*

K. L. DEVRIES, G. S. BAKER, and P. GIBBS

University of Utah, Salt Lake City, Utah

(Received December 19, 1962)

Behavior of creep of tin is reported with an activation volume of approximately 8.5×10^{-23} cm³, essentially independent of temperature between 0° and 50° C. and pressure up to 8 kbar. The pressure dependence of the output of resistance-type strain gauges is given.

INTRODUCTION

HIGH-PRESSURE phenomena in solids have been discussed.¹ Christy² found the activation volume for creep in silicon to be $6.3 \pm 0.5 \times 10^{-23}$ cm³, slightly less than the $7-7.6 \times 10^{-23}$ cm³ for diffusion as determined by Janhauser.³ Butcher and Ruoff⁴ and DeVries, Baker, and Gibbs⁵ found the activation volume for creep in lead (fcc) to be approximately the atomic volume. This is nearly equal to the self-diffusion in lead as determined by Nachtrieb, Resing, and Rice.⁶ Tin has a tetragonal structure

SAMPLE PREPARATION AND EXPERIMENTAL PROCEDURE

Samples were prepared from three grades of tin. The first was of unknown origin, but marked 99.99+%. The second was 99.9+% tin purchased from Morris P. Kirk & Sons, Inc. 99.999% tin was purchased from the Chemical Corporation. An ingot of the tin was rolled to approximately 0.35-cm thickness, after which samples were cut and filed to finished size: 2.4 cm long, 0.275 cm wide, and 0.25 to 0.35 cm thick. Specimens spontaneously recrystallized completely between preparation and use, with final average grain size of approximately 0.1 mm.

The tin samples were loaded under 3000 psi loading as described for lead.⁷ The distance between end supports was 2.1 cm and the central load of approximately 1 kg was applied by a spring.

Two methods were employed to measure sample deformation. A differential transformer and resistance-type strain gauges. The differential transformer was

basically the same as that described for use on lead. It had a linear region of approximately 1-cm length and an output of approximately 5 V/cm.

The resistance strain gauges (BLH AB-7 and ABF-32) were bonded directly to the sample with Eastman 910, and measured directly the strain at the tension surface of the sample. The effect of pressure on strain-gauge output was determined by attaching the strain gauge to a spring-steel beam which was bent about a form of known radius of curvature. The beam was secured in this position by a fine wire which was broken at various pressures allowing the beam to straighten out. Noting the strain indication at various pressures gave an indication of the effect of pressure on strain-gauge output. The results of these tests are shown in Fig. 1.

A large transient output of the gauge upon any pressure change was encountered with resistance type gauges. Upon initial application of pressure, the gauges indicated an apparent shortening of the samples, the rate of which decreased approximately exponentially with time. Soft metals such as tin, showed very large effects (apparent transient strains of up to 0.2% at 10 kbar). The effect was considerably less on brass and very small on steel. The time required for the transient to disappear was often as long as 12 hr for tin at 10 kbar, and only a few minutes when the gauge was attached to steel under the same conditions. These transients made pressure changes and subsequent rapid strain readings difficult. As an alternative method,

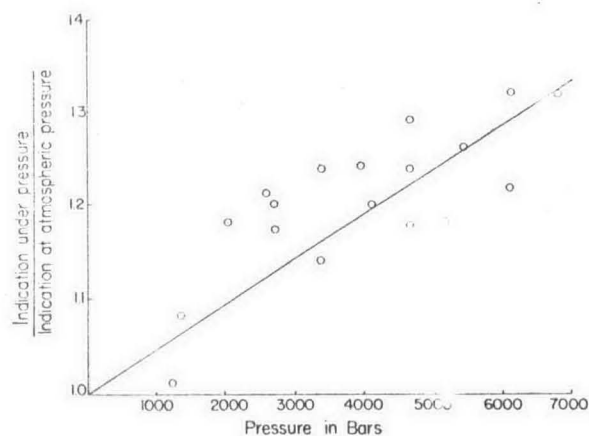


FIG. 1. Pressure dependence of the output of resistance strain gauges (BLH type AB-7 and type ABF-32).

* This work was supported by the U. S. Air Force Office of Scientific Research.

† Present address: Aerojet General, Sacramento, California.

‡ Address for 1963: Depto. De Fisica, Escola de Engenharia de Sao Carlos, Sao Carlos, Est. Sao Paulo, Brazil.

¹ P. W. Bridgman, *The Physics of High Pressure* (G. Bell and Sons, London, 1949).

² Christy, in *Solid State Physics*, edited by F. Seitz and D. Tabor (Academic Press Inc., New York, 1960), Vol. 13, p. 257.

³ DeVries, G. S. Baker, and P. Gibbs, "A Survey of High Pressure Effects on Solids," WADC Tech. Rept. 59-341 (1960).

⁴ Christy, *Acta Met.* 2, 284 (1954).

⁵ Janhauser, *Phys. Chem. Solids* 5, 224 (1958).

⁶ Butcher and A. L. Ruoff, *J. Appl. Phys.* 32, 2036 (1961).

⁷ K. L. DeVries, G. S. Baker, and P. Gibbs, *J. Appl. Phys.* 34, 2254 (1963), preceding paper.

⁸ N. H. Nachtrieb, H. A. Resing, and S. A. Rice, *J. Chem. Phys.* 31, 135 (1959).