growth method, and as we have seen, is characteristic of short-circuit-enhanced rather than pure lattice diffusion. In fact, the tracer coefficients found in our work with ZrC and elsewhere for SiC,[25] indicate that the D_0's used by Tobin *et al.*[24] are too low by a factor of 10^2–10^3 and correspondingly, the activation energies are too low by a factor of 1.5 to 2. Furthermore, apart from the seemingly anomolous results of the creep and carburization experiments already mentioned, the rather high (>110 kcal) activation enrgies observed for the tracer work with ZrC and SiC indicates that the mechanism for diffusion may be more complex than that envisioned by Tobin *et al.*[24] At any rate, a mechanism based on the cooperative motion of both species should not be completely rejected at this time.

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V. CONCLUSIONS

The lattice diffusion coefficient of carbon in zirconium carbide is $1.62\times10^2 \exp(-113\,200/RT)$ cm^2/sec. The kinetics of carbide layer growth is controlled by carbon diffusion and the enhancement of material transport along grain boundaries is appreciable. High-temperature creep in zirconium carbide may be controlled by the motion of point defects, but the mechanism is probably not of the Nabarro–Herring type. These conclusions must be altered if the diffusion process involves the cooperative motion of both species.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to Dr. R. W. Kebler who supplied the specimens which made this study possible, and to Professor R. Smoluchowski and Dr. W. S. Williams for their helpful discussions of the results.

JOURNAL OF APPLIED PHYSICS VOLUME 38, NUMBER 4 15 MARCH 1967

Optical Lever Observation of Hypervelocity Impact Shock Waves

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(Received 18 August 1966; in final form 11 November 1966)

An optical lever system was used to observe the impact shock wave arrival and free-surface motion at the rear surface of a 2.54-cm-thick 2024-T4 aluminum target plate. The projectile was a 0.636-cm-diam. steel ball and struck the target at a velocity of 5.28 ± 0.11 mm/μsec. The shock-wave data, in the range 30–1 kbar, extend data by Fowles to lower pressures. The measured elastic shock velocity of $6.23\pm3\%$ agrees with ultrasonic values and with elastic shock values by other investigators.

Elastic shock amplitudes do not maintain a constant value as in one-dimensional experiments, but decay at a rate faster than predicted for spherical elastic waves.

I. INTRODUCTION

THE adaptation of the optical lever technique to hypervelocity impact experiments creates a new tool for investigations in this area. Optical lever observations from one experiment demonstrate agreement with data obtained by explosive experiments and extends shock-wave data to lower values in 2024-T4 aluminum.

The optical lever technique was first used by Allen[1] and by Allen and McCrary[2] to observe spherical shock waves in steel. They used an explosive to generate spherical shock waves, and a streak camera with flash lamp to record shock wave arrivals. Since that time, the technique has been used to observe explosively-produced shock waves in experiments having a plane or two-dimensional steady-state geometry.[3–5] The optical lever technique adapted to record shock waves produced by hypervelocity impact is generally similar to the technique by Allen and McCrary. However, improved experimentation and improved data interpretation permits a more accurate and detailed analysis of experiments than was available to Allen and McCrary.

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II. EXPERIMENT

Figure 1 illustrates a top view of the experiment, showing the equipment and its placement. Light from a flash lamp is turned into the polished target and out again to a streak camera by two 45-deg mirrors. This arrangement insures major pieces of equipment from damage by target perforation.

A continuous-writing streak camera built by Avco is used. The continuous-writing camera is necessary because there may be several milliseconds variation in projectile firing time, as well as a long projectile flight. After the projectile is fired, it passes several viewing ports used to measure projectile velocity.

A UV detector at one port with an appropriate delay time triggers the flash lamp. The flash lamp is