SOVIET PHYSICS – SOLID STATE VOL. 5, NO. 2 AUGUST, 1963

COMPRESSION OF BERYLLIUM SINGLE CRYSTALS ALONG THE HEXAGONAL AXIS IN THE TEMPERATURE RANGE 4.2-900°K

R. I. Garber, I. A. Gindin, and Yu. V. Shubin

Translated from Fizika Tverdogo Tela, Vol. 5, No. 2,
pp. 434-442, February, 1963
Original article submitted August 6, 1962

The present paper reports the results of an investigation of the mechanical properties of beryllium single crystals in which the basal plane is at right angles to the compression direction. In the temperature range 4.2-900°K beryllium single crystals of this orientation exhibited unusually high strength: at the temperature of liquid helium the maximum compressive strength reached a value of $\sigma_b = 532$ kg/mm^2. It was found that at high temperatures (500-900°K) beryllium single crystals possessed some plasticity due to slip along the second-order pyramidal planes; at low temperatures plastic deformation was not observed and practically all the deformation before fracture was elastic.

Introduction

Plastic deformation disrupts the continuity of a crystal, and even at the earliest stages of plastic flow a partial fracture occurs [1, 2]. Therefore, one would expect that crystals oriented so that the principal types of plastic deformation are avoided should exhibit higher strength. From this point of view hexagonal crystals are of special interest, since they have a limited number of crystallographic slip and twinning elements, particularly at low temperatures [3-5].

In the case of uniaxial compression of hcp metal single crystals at right angles to the basal plane (0001), the orientation and the stress state are such that all the usual types of plastic deformation are suppressed (Fig. 1). Twinning along the plane $\{10\bar{1}2\}$ cannot occur, because volume changes on formation of twins are related to an expansion along a direction at right angles to the basal plane (0001). Shear in the basal plane (0001) and first-order prismatic plane $\{10\bar{1}0\}$ cannot occur because the tangential stresses in these planes are zero. Thus the only possible states are elastic compression or slip along other crystallographic planes (for example, pyramidal planes).

Lee and Brick [6] investigated the plastic properties of beryllium single crystals (98.8% purity) of various orientations in the temperature range 20-500°C, and showed that single crystals in which the basal plane (0001) is at right angles to the compressive forces exhibited high compressive strengths. The strength σ_b varied from 199.5 kg/mm^2 at 20°C to 150.5-158.9 kg/mm^2 at 300-500°C. These authors showed that at room temperature the beryllium single crystals underwent almost pure elastic deformation; no traces of twins or slip lines were observed. Fracture occurred instantaneously on reaching the critical stress; the sample disintegrated into small particles. Lee and Brick were able to establish the indices of the planes along which fracture occurred by means of the Laue back-reflection method. These planes were the basal plane (0001) and three second-order prismatic planes $\{11\bar{2}0\}$. They noted also that asterism in the Laue diagrams developed only in two out of the three $[11\bar{2}0]$ zones. However, they gave no information on the nature of the deformation of beryllium single crystals of this orientation at the higher temperatures of 300 and 500°C.

Tuer and Kaufman [7] also carried out similar tests on beryllium single crystals of 98.89% purity. The compressive strength at room temperature was 140-168 kg/mm^2, which is approximately 25% lower than the value of σ_b given by Lee and Brick [6]. Tuer and Kaufman observed considerable plasticity at temperatures of 700-1000°C, but they did not describe the nature of the deformation at high temperatures.

In an earlier short note [8] the present authors described preliminary experiments on the low-temperature compression of 99.9% pure beryllium single crystals and of calcite single crystals in which the principal elements of plastic deformation were also suppressed by selecting a particular orientation.

These beryllium and calcite crystals exhibited exceptionally high values of the compressive strength: for example, fracture of a beryllium single crystal in liquid nitrogen occurred at a stress of 410 kg/mm^2, and for calcite at room temperature σ_b was 23 kg/mm^2. In beryllium single crystals of this orientation brittle fracture at low temperatures was replaced by some plas-